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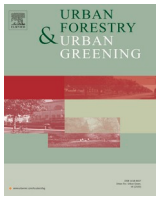

Original article

Social inequalities, residential greenness and common mental disorders in women: evidence from the Born in Bradford family cohort study

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ABSTRACT

Background: Green space may promote mental health in vulnerable groups but evidence is mixed. We explored prevalence of Common Mental Disorders (CMD) and associations with green space in a deprived urban multi-ethnic population.

Methods: We included 4737 women from the Born in Bradford cohort (64% South Asian origin, 49% most deprived population decile). Green space was measured using the normalised difference vegetation index (NDVI) around home addresses and availabiltiy of major green spaces within 300 m. CMD were identified from health records (diagnosis and prescriptions) and self-reported anxiety and depression symptoms. Area deprivation, ethnicity, education, physical activity, use, and satisfaction with green spaces were collected. Linear and logistic regression models explored the distribution of CMD and residential greenness for different socio-economic groups and associations between greenness metrics and CMD. Mediators (physical activity) and moderators (green space use and satisfaction) were explored.

Findings: Thirty percent of participants showed at least one CMD indicator. White British and the least and most educated groups had higher CMD rates. South Asian and Black ethnic groups had less surrounding greenness and greater availability of major green spaces; however used them less frequently. No relationships between green space and CMD were apparent. For those unsatisfied with their local park, living within 300 m of a major green space increased risk of anxiety symptoms, but not other CMD indicators.

Interpretation: Availability of quality green spaces alone may not be enough to confer health benefits for populations experiencing high rates of CMD and multiple environmental and social stressors.

1. Introduction

Common mental disorders (CMD) such as anxiety and depression affect up to 580 million people across the globe. They are the leading cause of years spent living with disability and generate huge societal costs from care costs to lost economic productivity (World Health Organization, 2022). Socio-economically vulnerable populations, such as people living with poverty, unemployment or low education, along with ethnic minority groups, and those living in deprived areas, are at higher risk of developing CMD (Chlapecka et al., 2020; Henking, 2022; Prady et al., 2021). This might be caused by cumulative burden of chronic stress from financial insecurity, stigma, poorer work conditions and lower access to social and health care support (Prady et al., 2021).

Increasing evidence points to the importance of environmental

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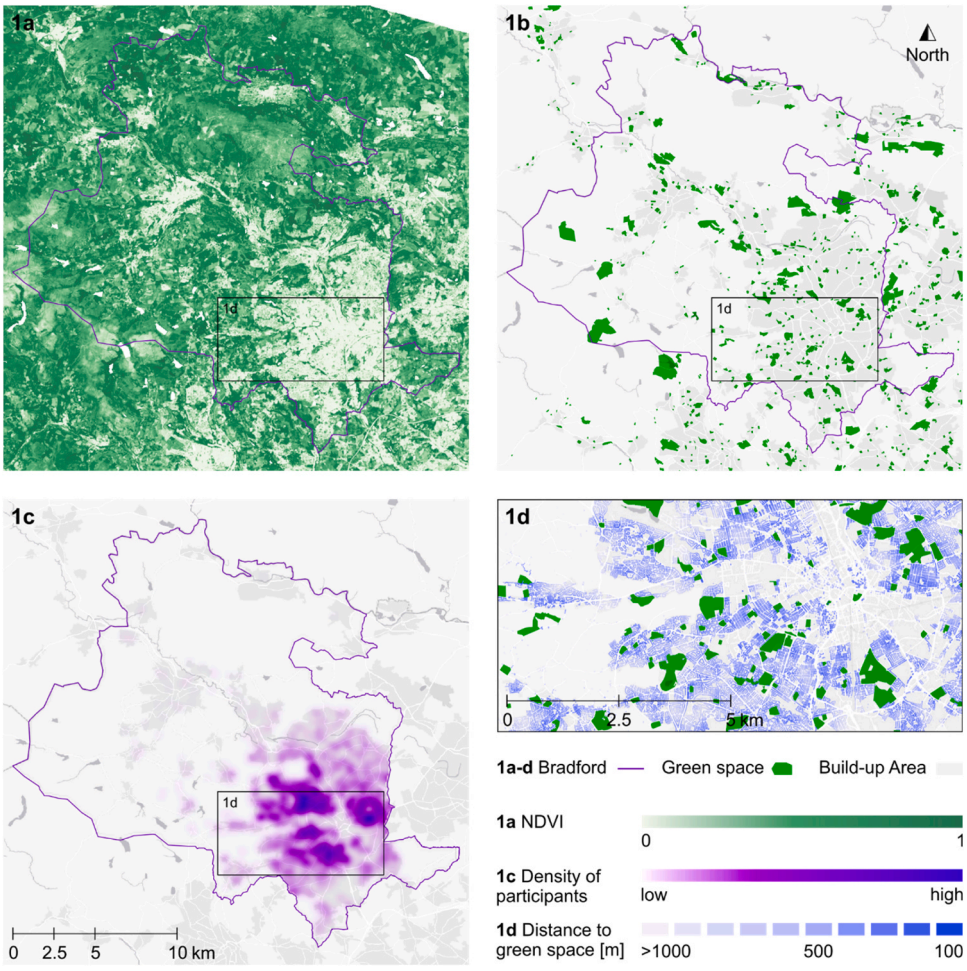

Fig. 1. **1a:** NDVI scores, **1b**: availability of major green spaces, **1c:** hot spot map of study participants, and, **1d:** zoom-in to the southeast area of Bradford, where most of the participants live. The blue lines in Fig. 1**a** and **b** delineate municipal boundaries. Green polygons in Fig. 1**b** and **d** correspond to major green spaces >5000 m^2. Map background layer based on data from Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS User Community through QuickMapServices plugin on QGIS (version 3.16). Data accessed on 05.12.2023." Source of participants' street address data: NHS Personal Demographics Service.

factors in promoting mental health (Generaal et al., 2019). However, not all groups have equal access to beneficial environments. Environmental injustice denotes the unequal distribution of environmental exposures that disproportionately affect certain population groups, increasing their exposure to harmful factors while limiting their access to beneficial environmental features (Murray et al., 2022). This inequity might heighten the risk of already vulnerable groups and may exacerbate social inequalities in mental health (Mitchell et al., 2015). Current literature shows that people living in lower SES areas are exposed to lower residential greenness levels (Klompmaker et al., 2023) and lower availability of green spaces (Aamodt et al., 2023; Astell-Burt et al., 2014). However, this pattern is not always consistent and a study conducted in six European cities revealed that in some cases, the trend is opposite (Robinson et al., 2018).

Much research has explored the impact of green-space on mental health with mixed findings (Dzhambov et al., 2020; Zhang et al., 2021). Said impact is thought to occur through several complementary pathways such as the promotion of physical activity and social cohesion, the reduction of exposure to air pollution or attention restoration (Markevych et al., 2017). The review by Zhang et al. (2021) compiled 16 studies with a mental health variable as outcome and 10 analysing the effects of greenness on well-being. A protective and statistically significant direct effect was found in 10/16 (62.5%) and 6/10 (60%) studies respectively and the physical activity pathway could be statistically confirmed only in 4/10 (40%) and 4/6 (66.67%) studies within said groups. In addition to this literature, there are authors suggesting that physical activity may indeed play a moderating (i.e., modifies the strength of the association), instead of a mediating (i.e., explains the association), role in the relationship between greenness and mental health. This is the case of the study by McEachan et al. (2016), in which the authors found that the protective link between residential greenness (in the form of the Normalized Difference Vegetation Index) and depression was stronger for those participants that were more physically active. Despite the fact that the mediation and moderation narratives here have different consequences, both could be integrated in order to develop a better understanding of the mental health benefits of urban green infrastructures.

Additionally, despite the evidence that disadvantaged communities may benefit the most from green spaces (Mitchell et al., 2015), low-income families face a range of barriers to using local green spaces including fears about safety, lack of amenities and anti-social behaviour effectively making these 'no-go' areas (Chenyang et al., 2022; Cronin-de-Chavez et al., 2019). Adding to those barriers, international literature suggests that disadvantaged communities tend to have access to lower acreage and worse quality green spaces than their more affluent counterparts (Rigolon, 2017, 2016). McEachan et al. (McEachan et al., 2018) found that satisfaction with green spaces (a proxy of quality) was a more important predictor of children's mental health than availability. The perceived 'quality' of green spaces and their use may therefore be important moderators of relationships between green space and mental health.

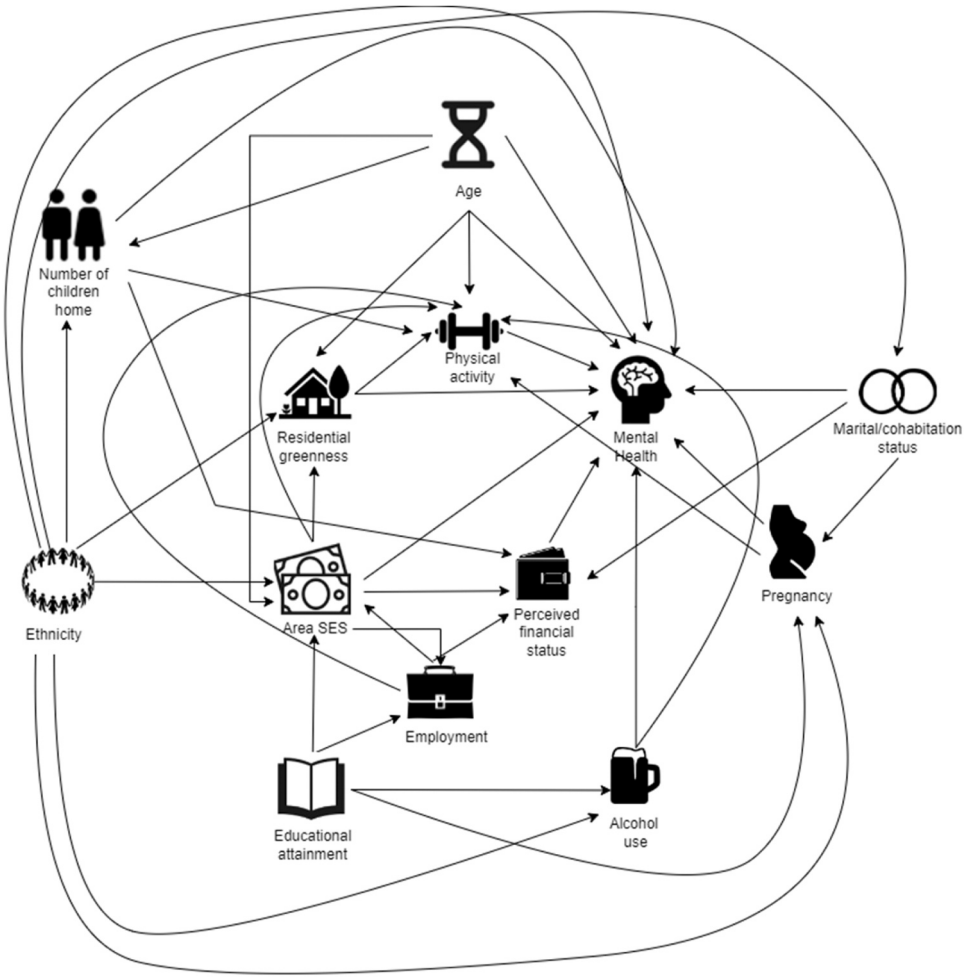

Fig. 2. DAG explaining the relationship between study variables. The arrows indicate causal paths.

1.1. Research questions

The objective of this study was to explore the socio-economic distribution of residential greenness, the potential social inequalities on mental health and the effects of greenness on mental health in a multi-ethnic sample of women living in deprived urban areas. Our research questions were:

1. Are socio-economically vulnerable participants more affected by mental health problems?
2. Are residential greenness metrics equally distributed among different ethnic and socio-economic participants?
3. Does residential greenness have a protective effect on mental health?
4. Does physical activity mediate or moderate the effects of greenness on mental health?
5. Do use of, and satisfaction with parks moderate the effects of greenness on mental health?

2. Methods

2.1. Study setting

Bradford is home to 546,000 people in West Yorkshire, northern England and hosts a young, diverse and multi-ethnic community; 43% identify as an ethnicity that is not White British. It is the 13th most deprived local authority in England with 32% of the population among the most deprived decile in the country (https://ubd.bradford.gov.uk/about-us/poverty-in-bradford-district/; https://ubd.bradford.gov.uk/about-us/ethnicity-and-religion/). Deprivation is clustered in Bradford central districts, which also have higher air and noise pollution levels and had lower availability of green spaces than non-deprived areas (Mueller et al., 2018).

2.2. Sample of participants and recruitment procedure

Participants consisted of mothers recruited to the Born in Bradford (BiB hereafter) family birth cohort between 2007 and 2011. We used data from the most recent follow-up, conducted 7–10 years after recruitment (n= 4737). Both studies are extensively described elsewhere (Bird et al., 2019; Wright et al., 2013; McEachan et al., in press). Women gave informed consent and completed a questionnaire with the assistance of a researcher either at home or at a community venue. Data were collected between 2017 and 2021 and the ethical approval was obtained from the Humber (Bradford Leeds) Research Ethics Committee (reference: 16/YH/0320).

2.3. Residential greenness

We operationalized participants' residential greenness via two complementary variables: the Normalized Difference Vegetation Index (NDVI) and distance to major green spaces (>5,000 m^2) (Krenz et al., 2023). NDVI is a pixel-based metric that estimates the density of green vegetation within satellite imagery and which ranges from −1 to +1, being 1 the maximum greenness level possible. Satellite images were obtained from the USGS Landsat 8 product (U.S. Geological Survey 2022) for each of the years when the data collection took place

Table 1
Description of study variables in the sample. Scores within parentheses indicate the proportion of participants in the corresponding categories or the standard deviation in continuous variables.

Variable	N (%)		Variable	N (%)
Ethnicity	Asian - 3031 (63.99%) Black - 68 (1.44%) Mixed - 77 (1.63%) Other - 32 (0.68%) White British - 1377 (29.17%)		Managing financially	Living comfortably - 1233 (26.03%) Doing alright - 1951 (41.19%) Just about getting by - 1105 (23.33%) Finding it quite difficult - 245 (5.17%) Finding it very difficult - 100 (2.11%) Do not wish to answer −83 (1.75%)
			Alcohol consumption	No - 3614 (76.29%) Yes - 1045 (22.06%) Don't want to answer - 31 (0.65%)
Educational level	<5 GCSE equivalent - 866 (18.28%) 5 GCSE equivalent - 1188 (25.08%) A-level equivalent - 575 (12.14%) Higher than A-level - 1054 (22.25%) Other - 220 (4.64%) Don't know - 41 (0.87%) Foreign Unknown - 40 (0.84%)		Availability of green spaces > 5.000 m^2 within 300 m	No – 2293 (62.18%) Yes – 1744 (36.82%)
			CMD diagnosis	No – 3970 (83.81%) Yes – 767 (16.19%)
			Prescriptions	No – 3815 (80.53%) Yes – 922 (19.47%)
	National version	**Bradford version**	PHQ-8 score > 10 p.	No - 4163 (87.88%) Yes - 547 (11.55%) NA 27 (0.57%)
IMD 2019 decile	1–2321 (49%)	1–670 (14.14%)		
	2–787 (16.61%)	2–633 (13.36%)	GAD-7 score > 10 p.	No - 4234 (89.38%) Yes - 485 (11.24%) NA – 18 (0.38%)
	3–841 (17.75%)	3–862 (18.20%)		
	4–242 (5.11%)	4–557 (11.76%)	CMD composite measure	No – 3249 (65.59%) Yes – 1458 (30.79%) NA – 30 (0.63%)
	5–148 (3.12%)	5–579 (12.22%)		
	6–164 (3.46%)	6–600 (12.66%)		
	7–93 (1.93%)	7–300 (6.33%)	**Variable**	***M(SD)***
	8–74 (1.58%)	8–248 (5.24%)	Age	37.83 (5.57)
	9–43 (0.91%)	9–155 (3.27%)		
	10–12 (0.25%)	10–57 (1.20%)		
Relation status	Married & living with partner - 3681 (77.71%) Not married & living with partner - 365 (7.71%) Not living with partner - 677 (14.29%)		Number of children in the household	2.64 (1.25)
Pregnant	No - 4572 (96.51%) Yes - 114 (2.41%) Don't know - 14 (0.30%)		NDVI 100 m	0.19 (0.06)
			NDVI 300 m	0.20 (0.06)
			NDVI 500 m	0.21 (0.06)
Work status	Unemployed - 2568 (54.21%) Employed - 2155 (45.49%)		Index of Total Physical Activity [3–21]	11.60 (5.10)

Note: IMD = Index of Multiple Deprivation, CMD = Common Mental Disorder, PHQ-8 = Patient Health Questionnaire – 8 items, GAD-7 = General Anxiety Disorder (GAD-7), NDVI = Normalized Difference Vegetation Index.

(2017–2021) and individual NDVI values were calculated and expressed for 100 m, 300 m and 500 m straight-line buffer radii around the participants' residential address location information (Ordnance Survey, 2022a). These buffer sizes are standard in the field (Nordbø et al., 2018) and were selected following previous studies (e.g., Binter et al., 2022; Nieuwenhuijsen et al., 2019) . We also used the Ordnance Survey[1] Open Greenspace dataset (Ordnance Survey, 2022b) to calculate the distance between participants' houses and the following greenspace classifications with an area of at least 5,000 m^2: public parks or gardens, allotments or community growing spaces, cemeteries, play spaces, religious grounds, bowling greens, golf courses, other sports facilities, playing fields, and tennis courts through the OS street and urban path network (Ordnance Survey, 2022c). Following World Health Organization's recommendation (WHO Regional Office for Europe, 2016), we created a binary variable indicating whether participants had green spaces available within 300 m of their residence using street network distance to provide a more realistic representation of individual's availability than the common approach of using a straight-line buffer 'as the crow flies'. Fig. 1 shows these greenness metrics and the distribution of participants across the city.

Participants were asked to indicate how often they visited parks during winter and summer months using the following answer options (>5 times a week, 2–4 times a week, once a week, 1–3 times a month and < once a month). These variables were used to classify participants as sporadic, seasonal and frequent users of parks. Sporadic users were those visiting parks and green spaces no more than 1–3 times per month in both time points, seasonal users were defined as participants using parks no more than 1–3 times per month in one of the time points (e.g. Winter) and at least once a week in the other one. Frequent users were those who consistently visited more than once a week across the year. Satisfaction with local parks was measured via a single 5-point Likert item ranging from 1 (*very dissatisfied*) to 5 (*very satisfied*). Using their answers to these questions participants were divided in two groups; satisfied (response options 4–5) and dissatisfied (1−3).

2.4. Physical activity

Physical activity was measured using the International Physical Activity Questionnaire (IPAQ) Short Form (Craig et al., 2003). We built a comprehensive physical activity variable by adding the number of times in the last week in which participants either did moderate, vigorous physical activity or walked for at least 10 minutes. This way, we obtained a variable ranging from 3 to 21 points with increasing physical activity levels denoted by higher values.

2.5. Mental health variables

Mental health outcomes were obtained from primary care records and from validated questionnaires. Drawing on prior studies (Prady et al., 2016a), we compiled a list of 189 Read Codes relevant to the identification of CMD in General Practice[2] records (see Supplementary Table 1), of which 104 belonged to depressive conditions and the rest to anxiety-related problems. We also identified the prescription of

[1] The Ordnance Survey is the national mapping agency for Great Britain.
[2] General Practice refers to the Primary Care system in the UK, which is composed by a network of health centres and other infrastructures in which the general population can access doctors, nurses and other health professionals.

Table 2
Models showing the differences in mental health variables by deprivation, educational attainment and ethnicity.

Predictor	Adjustment variables	Outcome	Level	Estimate (OR)	95%CI	t	p
IMD_tertile (ref. Q1 - highest deprivation level)	Age, education, ethnicity, employment	Total_CMD	Q2	0.99	(0.83, 1.17)	-0.17	0.864
			Q3	0.81	(0.64, 1.02)	-1.79	0.073
		CMD_diag	Q2	0.9	(0.73, 1.10)	-1.03	0.304
			Q3	0.84	(0.63, 1.12)	-1.17	0.244
		Prescriptions	Q2	1.04	(0.85, 1.27)	0.37	0.715
			Q3	0.96	(0.74, 1.25)	-0.27	0.784
		PHQ-8	**Q2**	**0.7**	**(0.54, 0.89)**	**-2.93**	**<0.001**
			Q3	**0.51**	**(0.35, 0.73)**	**-3.66**	**<0.001**
		GAD-7	Q2	0.94	(0.73, 1.20)	-0.53	0.6
			Q3	0.73	(0.50, 1.04)	-1.72	0.085
Education (ref. primary ed.)	None	Total_CMD	**Secondary**	**0.64**	**(0.55, 0.74)**	**-5.99**	**<0.001**
			College	**0.79**	**(0.68, 0.92)**	**-3.01**	**0.003**
			Higher	1.07	(0.92, 1.26)	0.88	0.382
		CMD_diag	**Secondary**	**0.64**	**(0.53, 0.77)**	**-4.81**	**<0.001**
			College	0.87	(0.72, 1.06)	1.39	0.165
			Higher	1.08	(0.88, 1.32)	0.07	0.487
Predictor	**Adjustment variables**	**Outcome**	**Level**	**Estimate**	**95%CI**	**t**	**p**
		Prescriptions	**Secondary**	**0.67**	**(0.56, 0.79)**	**-4.57**	**<0.001**
			College	**0.7**	**(0.58, 0.84)**	**-3.92**	**<0.001**
			Higher	1.01	(0.84, 1.22)	0.12	0.904
		PHQ-8	**Secondary**	**0.59**	**(0.47, 0.73)**	**-4.7**	**<0.001**
			College	**0.75**	**(0.60, 0.95)**	**-2.45**	**0.014**
			Higher	0.87	(0.69, 1.10)	-1.17	0.24
		GAD-7	**Secondary**	**0.63**	**(0.50, 0.79)**	**-3.92**	**<0.001**
			College	**0.69**	**(0.55, 0.87)**	**-3.1**	**0.002**
			Higher	1.02	(0.80, 1.30)	0.18	0.859
Ethnicity (ref. White British)	None	Total_CMD	**SA + B**	**0.53**	**(0.46, 0.62)**	**-8**	**<0.001**
		CMD_diag	**SA + B**	**0.62**	**(0.51, 0.75)**	**-4.93**	**<0.001**
		Prescriptions	**SA + B**	**0.32**	**(0.27, 0.38)**	**-12.88**	**<0.001**
		PHQ-8	**SA + B**	**0.68**	**(0.55, 0.85)**	**-3.41**	**<0.001**
		GAD-7	**SA + B**	**0.73**	**(0.58, 0.92)**	**-2.67**	**<0.001**

Note: Participants in the third tertile (Q3) of IMD Q3 are those living in the least deprived areas. IMD = Index of Multiple Deprivation, CMD = Common Mental Disorder, PHQ-8 = Patient Health Questionnaire – 8 items, GAD-7 = General Anxiety Disorder (GAD-7).

antidepressants and anxiolytics (medications used to treat anxiety) included in the British National Formulary.[3] We extracted diagnosis and prescription information in the years immediately before and after the participants filled in their questionnaire. Two binary (yes/no) variables were obtained this way; CMD diagnosis and prescriptions.

We assessed self-reported depression and anxiety during the study visit using two validated mental health scales; the Patient Health Questionnaire depression scale (Kroenke et al., 2009) and the Generalized Anxiety Disorder scale (GAD-7, (Spitzer et al., 2006). Participants indicated the degree they had experienced each of the described symptoms during the last 2 weeks (1-not at all, 4 –everyday). Both scales showed very good internal consistency (Cronbach's $\alpha = 0.89$ and 0.92 respectively). PHQ-8 and GAD-7 scores were dichotomized using the established cut-points of >=10; where scores above this is indicative of the presence of depression or generalized anxiety disorder.

Primary care and questionnaire-based mental health variables were combined in a single binary (yes/no) variable indicating whether each participant had at least one indicator of CMD.

2.6. Covariates

The following variables were used as individual-level covariates: age, ethnicity, educational attainment, employment status, perceived financial status, marital status, alcohol use, number of children in the household. We extracted the 2019 Index of Multiple Deprivation (IMD; https://opendatacommunities.org/resource?uri=http%3 A%2 F% 2Fopendatacommunities.org%2Fdat%2Fsocietal-wellbeing% 2Fimd2019%2Findices) score for each participant's census area from the UK Ministry of Housing, Communities and Local Government. This index includes area-level information on income deprivation, employment deprivation, education, skills and training deprivation, health deprivation and disability, crime, barriers to housing and services and living environment deprivation. Given that 83% of study participants lived in areas within the three highest national deprivation deciles, we re-calculated and used deciles based on the observed scores within Bradford.

2.7. Data analysis plan

The dataset was analysed using R software v.4.0.3 (R Core Team, 2022). Descriptive statistics (mean/median/n; standard deviation/ [IQR]/%) were calculated for all variables. A Direct Acyclic Graph (DAG) was developed (Fig. 2.) to represent literature-based assumptions and select for covariate adjustment (Pearl, 2009). The validity of the DAG was examined using the R packages *dagitty* (Textor, 2020) and *lavaan* (Rosseel, 2012) to carry out the testable implications. Testable implications are pairwise marginal and conditional independencies implied by a given DAG (Elwert, 2013): if these properties of the joint distribution are not satisfied by the data, we find reason to reject, or possibly modify, the model (Chen et al., 2014). Thus, since our dataset is a combination of categorical and continuous data, we computed the polychoric correlation matrix of the dataset (Ankan et al., 2021) through the lavaan function lavCor(), and then applied the test itself of the aforementioned conditional independencies against the correlation matrix using the dagitty function localTests() (Textor, 2020). Testable implications were considered unmet when p-value<0.05 and r-scores>0.20; unmet implications were taken as indication of missing

[3] The British National Formulary is a reference book that compiles information and advice on prescribing and pharmacology about the medicines available on the UK National Health Service (NHS).

Table 3
Residential greenness metrics, park use and satisfaction by area deprivation, education level and ethnicity.

Greenspace metric	Deprivation level			Education				Ethnicity	
	Q1	Q2	Q3	Primary	Secondary	College	Higher	WB	SA+B
NDVI 100	0.16 (0.06)	0.20 (0.06)	0.22 (0.05)	0.17 (0.06)	0.18 (0.06)	0.19 (0.06)	0.20 (0.06)	0.22 (0.05)	0.17 (0.06)
NDVI 300	0.18 (0.05)	0.22 (0.05)	0.24 (0.05)	0.19 (0.05)	0.20 (0.05)	0.21 (0.05)	0.22 (0.06)	0.23 (0.05)	0.19 (0.05)
NDVI 500	0.19 (0.05)	0.22 (0.05)	0.26 (0.05)	0.20 (0.05)	0.21 (0.05)	0.22 (0.05)	0.23 (0.06)	0.24 (0.05)	0.20 (0.05)
Green space availability	No - 1399 (62.43%) Yes - 842 (37.57%)	No - 1035(59.62%) Yes - 701 (41.38%)	No - 559 (73.55%) Yes - 201 (26.45%)	No - 513 (59.24%) Yes - 353 (40.76%)	No - 734 (61.79%) Yes - 454 (38.21%)	No - 376 (65.39%) Yes - 199 (34.61%)	No - 686 (65.09%) Yes - 368 (34.91%)	No - 977 (70.95%) Yes - 400 (29.05%)	No - 1904 (59.35%) Yes - 1304 (40.65%)
Park use	Sporadic - 419 (18.70%) Seasonal - 1282 (57.21%) Frequent- 540 (24.10%)	Sporadic - 359 (20.68%) Seasonal - 973 (56.05%) Frequent- 404 (23.27%)	Sporadic - 297 (39.08%) Seasonal - 334 (43.95%) Frequent- 129 (16.97%)	Sporadic - 146 (16.86%) Seasonal - 495 (57.16%) Frequent - 225 (25.98%)	Sporadic - 254 (21.38%) Seasonal - 654 (55.05%) Frequent - 280 (23.57%)	Sporadic - 151 (26.26%) Seasonal - 306 (53.22%) Frequent - 118 (20.52%)	Sporadic - 286 (27.13%) Seasonal - 546 (51.80%) Frequent - 222 (21.06%)	Sporadic - 242 (17.54%) Seasonal - 624 (45.32%) Frequent - 511 (37.11%)	Sporadic - 798 (24.86%) Seasonal - 1892 (58.98%) Frequent - 518 (16.15%)
Park satisfaction	Dissatisfied - 616 (27.49%) Satisfied - 1625 (72.51%)	Dissatisfied - 384 (22.12%) Satisfied - 1352 (77.88%)	Dissatisfied - 129 (16.97%) Satisfied - 631 (83.03%)	Dissatisfied - 232 (26.79%) Satisfied - 634 (73.21%)	Dissatisfied - 292 (24.58%) Satisfied - 896 (74.42%)	Dissatisfied - 129 (22.43%) Satisfied - 446 (77.57%)	Dissatisfied - 226 (21.44%) Satisfied - 828 (78.56%)	Dissatisfied - 330 (23.97%) Satisfied - 1047 (76.03%)	Dissatisfied - 762 (23.75%) Satisfied - 2446 (76.25%)

Note: Area deprivation Q1 group includes participants living in the most deprived areas. WB = White British, SA + B = South Asian and Black.

relationships and subsequently included in the DAG via the addition of new arrows.[4] We then estimated 1) the total effects models of socio-demographic variables (i.e. area deprivation, educational attainment and ethnicity) on residential greenness variables and mental health indicators to answer research questions 1 and 2, and, 2) the total and direct effects (effects other than the ones explained by the promotion of physical activity) of greenness metrics on mental health, to answer research questions 3 and 4. We also stratified the total effects models of greenness on mental health by park use and park satisfaction profiles, to test whether such variables moderated the effects of greenness on mental health (research question 5). For each model, we used the covariate adjustment set resulting from the updated DAG. Logistic regression models were used for mental health variables. Odds Ratios (OR) in models with NDVI as the predictor variable reflect changes in the likelihood of having CMD by NDVI increases of 1 IQR. To ease interpretation, localised deprivation was used in tertiles when used as exposure variable.

3. Results

The sample comprised 4737 participants with a mean age of 37 years. Two-thirds of the participants were of South Asian origin, and slightly less than one-third were of White British origin. Educational attainment was well distributed. Most of the participants, either married or not, resided with their partners and only a minimal proportion of the participants were pregnant at the time of data collection. Half of the sample was unemployed and only a fifth drank alcohol. A third had major green spaces within 300 m of their houses and the average NDVI value within 300 m radius was 0.20 ($SD = 0.06$). With regard to mental health, 17% had a CMD diagnosis from health care records, 19% were prescribed medication for CMD and 11% had PHQ-8 or GAD-7 scores above the cut-off values. Thirty percent of participants had at least one indicator of CMD. See Table 1.

3.1. DAG validation

All but three of the 59 testable implications from the DAG were met (Supplementary Table 2 and Supplementary Figure 1). To avoid redundancy, results of testable implications checks for the rest of the models are not included in the manuscript. The unmet testable implications were: “employment status ⊥ number of children home”, “alcohol ⊥ employment status | education level”, and, “ethnicity ⊥ employment status”. “⊥” indicates independence between the terms at each side of the symbol whereas “|” indicates that the statement to the left is true when controlling for the variable(s) to the right of the symbol. Therefore, the testable implications shown above should be read as follows: “employment status is independent from the number of children home”, “alcohol consumption is independent from employment status when controlling for education level”, and, “ethnicity is independent from employment status”. We updated the DAG (see Supplementary Figure 2) with these relations and extracted the minimal set of adjustment variables for each of the models which are described below.

3.2. Research question 1: social inequalities in mental health

The models shown in Table 2 show differences in mental health status by deprivation tertiles. We found negligible association between area-level deprivation and CMD. The only exception was that those in the most deprived tertile were more likely to report clinically significant symptoms of depression compared with those in less deprived tertiles. The relationship between educational attainment and mental health was complex. For all the mental health variables except CMD diagnosis, we

[4] For more works following this procedure, please see Subiza-Pérez et al. (2023a, 2023b).

Table 4
Models showing the differences in green exposures metrics by deprivation, educational attainment and ethnicity.

Predictor	Adjustment variables	Outcome	Level	Estimate (B/OR)	95%CI	t	p
IMD_tertile	Ethnicity	NDVI 100	**Q2**	**0.03**	**(0.02, 0.03)**	**13.95**	**<0.001**
(ref. Q1 - highest deprivation level)			**Q3**	**0.04**	**(0.04, 0.05)**	**15.03**	**<0.001**
		NDVI 300	**Q2**	**0.03**	**(0.03, 0.04)**	**18.46**	**<0.001**
			Q3	**0.05**	**(0.05, 0.06)**	**21.01**	**<0.001**
		NDVI 500	**Q2**	**0.03**	**(0.03, 0.04)**	**19.2**	**<0.001**
			Q3	**0.06**	**(0.05, 0.06)**	**24.34**	**<0.001**
		Green space avail.	Q2	1.1	(0.94, 1.29)	1.29	0.198
			Q3	**0.63**	**(0.50, 0.78)**	**-4.09**	**<0.001**
Maternal education	None	NDVI100	**Secondary**	**0.02**	**(0.01, 0.02)**	**8.61**	**<0.001**
(ref. primary ed.)			College	0	(>−0.01, 0.01)	1.25	0.211
			Higher	0	(>−0.01, <0.01)	-0.12	0.908
		NDVI300	**Secondary**	**0.02**	**(0.01, 0.02)**	**9.56**	**<0.001**
			College	0	(> −0.01, 0.01)	1.22	0.221
			Higher	0	(>−0.01, <0.01)	-0.08	0.933
		NDVI500	**Secondary**	**0.02**	**(0.01, 0.02)**	**10.13**	**<0.001**
			College	0	(>−0.01, <0.01)	0.89	0.373
			Higher	0	(−0.01, <0.01)	-0.88	0.378
		Green space avail.	**Secondary**	**0.87**	**(0.76, 0.99)**	**-2.03**	**0.042**
			College	1	(0.87, 1.16)	0.06	0.953
			Higher	1.11	(0.95, 1.30)	1.31	0.189
Ethnicity	None	**NDVI100**	**SA + B**	**-0.04**	**(−0.05, −0.04)**	**-20.18**	**<0.001**
(ref. White British)		**NDVI300**	**SA + B**	**-0.04**	**(−0.05, −0.04)**	**-22.38**	**<0.001**
		NDVI500	**SA + B**	**-0.05**	**(−0.05, −0.04)**	**-24.01**	**<0.001**
		Green space avail.	**SA + B**	**1.63**	**(1.39, 1.91)**	**6.14**	**<0.001**

Note: IMD = Index of Multiple Deprivation, SA + B = South Asian and Black, NDVI = Normalized Difference Vegetation Index. All the coefficients shown in the table are B values but for the models in which green space availability is the outcome, where the coefficients are ORs.

found that both the least and most educated participants were more likely to have worse mental health than those in an intermediate educational level. With regard to CMD diagnosis, the least educated were less likely to be diagnosed than those with secondary education. Finally, South Asian and Black participants showed better mental health across all the indicators considered in this study.

3.3. Research question 2: environmental justice analyses

Table 3 displays the residential greenness metrics, park use and satisfaction with parks variables by deprivation level, education attainment and ethnicity. Table 4 shows the results of the models we fitted to analyse the distribution of greenness metrics among these socio-economic and ethnicity variables with the aim of answering research question 2. Participants in the most deprived tertile, and those of South Asian or Black origin had lower NDVI scores but were more likely to live near a major green space. In the case of education, these differences were not as consistent and straightforward because we found that the least educated (primary education) lived in less green areas than those of secondary education but we found no differences in participants of higher education levels. Descriptive analysis showed satisfaction with green spaces were similar across all groups, however, despite being closer to major green spaces, South Asian and Black origin groups were less like to report being frequent users (Table 3).

3.4. Research questions 3–5: effects of residential greenness on mental health

We did not find any statistically significant relationships between any measure of residential greenness and any mental health outcome and ORs were greater than 1 in most instances (Table 5). Supplementary Table 3 shows the direct effects of greenness on mental health (after controlling for physical activity) which were similar to the total effects estimates in most cases. However, we did find a positive link [OR = 1.17, CI95% = (0.99, 1.39)] between NDVI in 100 m radius and the risk of depression as defined by PHQ-8 scores, indicating that higher the NDVI scores were associated with a higher risk of depression. Overall, these results did not support mediation through increased physical activity.

We re-fitted total effects models of green space availability, stratifying by park use[5] and park satisfaction (see Supplementary Table 4 and Table 6). We did not find any interaction by levels of park use and only found a significant effect when stratifying by park satisfaction. For those unsatisfied with their local parks, living within 300 m of a park increased the likelihood of being at risk of anxiety [OR = 1.7, CI95% = (1.11, 2.58)] as compared to those that did not live close.

4. Discussion

In our multi-ethnic deprived sample we found 30% of participants had an indicator of common mental disorder. This figure is higher than the estimated 17% national prevalence identified by others (McManus et al., 2016). This difference may reflect the factor that ethnic minority populations are less likely to be correctly diagnosed and treated (Prady et al., 2016b, 2016a). However, we found little variation in prevalence by deprivation, with the exception of depressive symptoms, which were more prevalent in the most deprived groups. Our sample was very highly deprived in relation to national averages which may have caused a floor effect in our dataset masking differences by deprivation. We found a U-shape relationship between education attainment and mental health, with those in the lowest and highest extremes of the continuum showing higher levels of CMD across all indicators. In contrast with previous research (Prady et al., 2021, 2016b, 2016a), participants of South Asian origin and Black origin reported better mental health. This could be explained by stronger social, cultural and family connections and support (Uphoff et al., 2016) characteristics of these groups compared with deprived White British groups.

Second, we did not find a clear pattern of environmental inequality

[5] By request of one of the reviewers, we analysed the bivariate associations between green space use and mental health status. The results of these analyses can be found in Supplementary Table 5. We found that frequent users distributed evenly among the categories within the mental health variables and that seasonal users were less likely to fall into the categories showing worse mental health. The opposite was found for sporadic users. However, not all the coefficients reached statistical significance and if they did, the effect sizes were small to negligible.

Table 5
Total effects models of residential greenness on mental health.

Exposure	Outcome	Estimate (OR)	95% CI	z	p
NDVI 100	TOTAL CMD	1.06	(0.94, 1.19)	0.91	0.362
NDVI 300	TOTAL CMD	1.07	(0.94, 1.21)	1.01	0.311
NDVI 500	TOTAL CMD	1.06	(0.92, 1.21)	0.83	0.408
Green availability	TOTAL CMD	0.99	(0.85, 1.16)	-0.11	0.909
NDVI 100	CMD diagnosis	1	(0.86, 1.15)	-0.05	0.963
NDVI 300	CMD diagnosis	1.01	(0.86, 1.18)	0.1	0.924
NDVI 500	CMD diagnosis	1.01	(0.85, 1.19)	0.07	0.943
Green availability	CMD diagnosis	1.03	(0.85, 1.24)	0.28	0.777
NDVI 100	Prescriptions	1.03	(0.89, 1.18)	0.37	0.710
NDVI 300	Prescriptions	1.07	(0.92, 1.25)	0.89	0.371
NDVI 500	Prescriptions	1.09	(0.93, 1.28)	1.11	0.266
Green availability	Prescriptions	1.07	(0.89, 1.28)	0.69	0.491
NDVI 100	PHQ-8	1.17	(0.99, 1.39)	1.86	0.064
NDVI 300	PHQ-8	1.17	(0.97, 1.16)	1.61	0.108
NDVI 500	PHQ-8	1.12	(0.92, 1.36)	1.12	0.263
Green availability	PHQ-8	1.07	(0.86, 1.34)	0.62	0.539
NDVI 100	GAD-7	1.13	(0.95, 1.34)	1.34	0.179
NDVI 300	GAD-7	1.12	(0.92, 1.35)	1.12	0.263
NDVI 500	GAD-7	1.1	(0.89, 1.34)	0.88	0.377
Green availability	GAD-7	1.11	(0.88, 1.39)	0.89	0.373

Covariate adjustment set: IMD, ethnicity. IMD = Index of Multiple Deprivation, SA + B = South Asian and Black, CMD = Common Mental Disorder, PHQ-8 = Patient Health Questionnaire – 8 items, GAD-7 = General Anxiety Disorder (GAD-7), NDVI = Normalized Difference Vegetation Index.

Table 6
Total effects models of greenspace availability stratified by park satisfaction.

Outcome	Model	Estimate (OR)	95% CI	z	p
TOTAL_CMD	Unsatisfied	1.33	(0.98, 1.79)	1.57	0.064
	Satisfied	0.89	(0.74, 1.07)	-1.2	0.232
CMD diagnosis	Unsatisfied	1.25	(0.88, 1.77)	1.27	0.204
	Satisfied	0.95	(0.76, 1.20)	-0.4	0.689
Prescriptions	Unsatisfied	1.1	(0.83, 1.64)	0.88	0.380
	Satisfied	1.04	(0.84, 1.29)	0.65	0.729
PHQ-8	Unsatisfied	1.24	(0.84, 1.87)	1.05	0.292
	Satisfied	1.02	(0.78, 1.33)	0.15	0.88
GAD-7	**Unsatisfied**	**1.7**	**(1.11, 2.58)**	**2.46**	**0.014**
	Satisfied	0.93	(0.70, 1.22)	-0.51	0.610

Covariate adjustment set: IMD, ethnicity. IMD = Index of Multiple Deprivation, CMD = Common Mental Disorder, PHQ-8 = Patient Health Questionnaire – 8 items, GAD-7 = General Anxiety Disorder (GAD-7).

in our data. Participants living in more deprived areas, those of lower education levels and those belonging to ethnic minorities did live in less green areas but conversely had increased availability of green spaces. This may be explained by the historical development of the city of Bradford. During the 18th and 19th centuries, the central districts of Bradford were inhabited by affluent citizens who funded the development of parks and green spaces. Later, in the second half of the 19th century and across the 20th these neighbourhoods were occupied by great numbers of migrant workers coming to work in the textile mills. This provides a plausible historical explanation as to why people living in these areas now enjoy increased availability to green spaces even though the overall NDVI values are lower. This could also be explained by a decrease in other vegetation elements (e.g. street trees or domestic gardens) as the area has declined in prosperity.

Finally, we investigated the potential mental health benefits related to residential greenness. In contrast to previous research (Dzhambov et al., 2020), our results did not provide support for a positive association between greenness and mental health, adding to the uncertainty about it that have been found elsewhere (Gascon et al., 2015; Geneshka et al., 2021; Zhang et al., 2021). This could be explained by several reasons. The lack of green space in central Bradford is associated with higher air pollution and noise levels than in other areas of the city (Mueller et al., 2018), and therefore the effects of such exposures could mask the positive effects of greenness. A limitation of our study is that we are unable to account for the actual quality and design features of the green spaces in the city which might moderate the beneficial effects of greenness. Parks can be also a focus of antisocial behaviour and therefore a source of insecurity and distress for nearby communities (Chenyang et al., 2022), which has been already described in Bradford (Cronin-de-Chavez et al., 2019). This latter fact can indeed help to understand why living in the proximity of a green space was increasing anxiety symptoms for those participants who were unsatisfied with the quality of their local parks. It can be hypothesized that if insecurity is a problem in green spaces in a given area and one of the factors explaining dissatisfaction, living close to one of those could indeed have a negative impact on mental health due to increased stress or fear of crime.

4.1. Study strengths and limitations

This study addresses the lack of research in deprived and multiethnic urban communities that contrasts with previous studies developed in more affluent and less diverse Western settings. Second, we developed a comprehensive mental health indicator coming not only from self-report but also extracting CMD diagnosis and drug prescription data from health care records. Third, we were able to include measures of park use and satisfaction, not often measured in studies in this area. Finally, we made a double test of the role of physical activity in the greenness-mental health relation by exploring its potential mediating and moderating properties.

However, this study has limitations. Due to the COVID pandemic, recruitment stopped after having reached only a portion of the participants originally involved in cohort, and the final sample included a higher proportion of more deprived urban communities than the full cohort. The reduced variation in deprivation may have limited our ability to meaningfully compare results between more or less deprived groups. Also, we did not collect the length of residence at the address where participants lived when data collection took place. This may have implications for our results given that some participants might had recently moved to the area and therefore had lower chances of using surrounding green spaces. The use of a sample composed solely by women also affects our ability to generalize our findings to men residing in Bradford, which remains open for future studies. Finally, as in many other environmental epidemiology studies, we assumed that the residential environment is the main exposure environment to analyse the impact of green infrastructure on mental health and it may be that participants used more distant green destinations than the ones we measured (Kwan, 2009).

5. Conclusion

We explored relationships between green space and mental health in a highly deprived urban multi-ethnic sample. Overall, we found a high prevalence of common mental disorders with White British participants experiencing higher levels than participants of South Asian or Black origin. We found no evidence that green space had a protective effect on mental ill-health. Our findings suggest that for highly deprived populations, green space may be insufficient on its own as a tool to improve population health. A holistic approach to improving environments and reducing social stressors to improve the health of deprived communities is needed. Future research in deprived areas should aim to understand how local environments are perceived by communities and how these perceptions interact with structural features to impact health.

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CRediT authorship contribution statement

Subiza-Pérez Mikel: Conceptualization, Formal analysis, Writing – original draft, Methodology. **Krenz Kimon:** Resources, Software, Visualization, Writing – review & editing, Conceptualization. **Watmuff Aidan:** Data curation, Writing – review & editing. **Yang Tiffany:** Conceptualization, Writing – review & editing. **Gilbody Simon:** Conceptualization, Writing – review & editing. **Vaughan Laura:** Conceptualization, Writing – review & editing. **Wright John:** Conceptualization, Writing – review & editing. **McEachan Rosemary R.C.:** Conceptualization, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2024.128241.

References

Aamodt, G., Nordh, H., Nordbø, E.C.A., 2023. Relationships between socio-demographic / socio-economic characteristics and neighborhood green space in four Nordic municipalities – results from NORDGREEN. Urban For. Urban Green. 82, 127894 https://doi.org/10.1016/j.ufug.2023.127894.

Ankan, A., Wortel, I.M.N., Textor, J., 2021. Testing graphical causal models using the R package "dagitty". Curr. Protoc. 1, 1–22. https://doi.org/10.1002/cpz1.45.

Astell-Burt, T., Feng, X., Mavoa, S., Badland, H.M., Giles-Corti, B., 2014. Do low-income neighbourhoods have the least green space? A cross-sectional study of Australia's most populous cities. BMC Public Health 14, 19–21. https://doi.org/10.1186/1471-2458-14-292.

Binter, A., Bernard, J.Y., Mon-williams, M., Andiarena, A., González-Safont, L., Vafeiadi, M., Lepeule, J., Soler-Blasco, R., Kampouri, M., Alonso, L., Mceachan, R., Santa-Marina, L., Wright, J., Chatzi, L., Sunyer, J., Philippat, C., Nieuwenhuijsen, M., Vrijheid, M., Guxens, M., 2022. Urban environment and cognitive and motor function in children from four European birth cohorts. Environment International journal 158. https://doi.org/10.1016/j.envint.2021.106933.

Bird, P.K., McEachan, R.R.C., Mon-Williams, M., Small, N., West, J., Whincup, P., Wright, J., Andrews, E., Barber, S.E., Hill, L.J.B., Lennon, L., Mason, D., Shire, K.A., Waiblinger, D., Waterman, A.H., Lawlor, D.A., Pickett, K.E., 2019. Growing up in Bradford: Protocol for the age 7-11 follow up of the Born in Bradford birth cohort. BMC Public Health 19. https://doi.org/10.1186/s12889-019-7222-2.

Chen, B., Tian, J., Pearl, J., 2014. Testable implications of linear structural equation models. Proc. Natl. Conf. Artif. Intell. 4, 2424–2430. https://doi.org/10.1609/aaai.v28i1.9065.

Chenyang, D., Maruthaveeran, S., Shahidan, M.F., 2022. The usage, constraints and preferences of green space at disadvantage neighborhood: A review of empirical evidence. Urban For. Urban Green. 75, 127696 https://doi.org/10.1016/j.ufug.2022.127696.

Chlapecka, A., Kagstrom, A., Cermakova, P., 2020. Educational attainment inequalities in depressive symptoms in more than 100,000 individuals in Europe. Eur. Psychiatry 63. https://doi.org/10.1192/j.eurpsy.2020.100.

Craig, C.L., Marshall, A.L., Sjöström, M., Bauman, A.E., Booth, M.L., Ainsworth, B.E., Pratt, M., Ekelund, U., Yngve, A., Sallis, J.F., Oja, P., 2003. International physical activity questionnaire: 12-Country reliability and validity. Med. Sci. Sports Exerc. 35, 1381–1395. https://doi.org/10.1249/01.MSS.0000078924.61453.FB.

Cronin-de-Chavez, A., Islam, S., McEachan, R.R.C., 2019. Not a level playing field: A qualitative study exploring structural, community and individual determinants of greenspace use amongst low-income multi-ethnic families. Health Place 56, 118–126. https://doi.org/10.1016/j.healthplace.2019.01.018.

Dzhambov, A.M., Browning, M.H.E.M., Markevych, I., Hartig, T., Lercher, P., 2020. Analytical approaches to testing pathways linking greenspace to health: a scoping review of the empirical literature. Environ. Res. 186, 109613 https://doi.org/10.1017/CBO9781107415324.004.

Elwert, F., 2013. In: Graphical Causal Models. Handbook OfCausal Analysis for Social Research, pp. 245–273. https://doi.org/10.1007/978-1-4471-6699-3_13.

Gascon, M., Mas, M.T., Martínez, D., Dadvand, P., Forns, J., Plasència, A., Nieuwenhuijsen, M.J., 2015. Mental health benefits of long-term exposure to residential green and blue spaces: A systematic review. Int. J. Environ. Res. Public Health 12, 4354–4379. https://doi.org/10.3390/ijerph120404354.

Generaal, E., Hoogendijk, E.O., Stam, M., Henke, C.E., Rutters, F., Oosterman, M., Huisman, M., Kramer, S.E., Elders, P.J.M., Timmermans, E.J., Lakerveld, J., Koomen, E., Ten Have, M., De Graaf, R., Snijder, M.B., Stronks, K., Willemsen, G., Boomsma, D.I., Smit, J.H., Penninx, B.W.J.H., 2019. Neighbourhood characteristics and prevalence and severity of depression: Pooled analysis of eight Dutch cohort studies. Br. J. Psychiatry 215, 468–475. https://doi.org/10.1192/bjp.2019.100.

Geneshka, M., Coventry, P., Cruz, J., Gilbody, S., 2021. Relationship between green and blue spaces with mental and physical health: a systematic review of longitudinal observational studies. Int. J. Environ. Res. Public Health 18. https://doi.org/10.3390/ijerph18179010.

Henking, C., 2022. Inequalities in common mental health disorders: understanding the predictors of lifetime prevalence, treatment utilisation, and helpfulness across 113 countries. Lancet 400, 45. https://doi.org/10.1016/S0140-6736(22)02255-3.

Klompmaker, J.O., Hart, J.E., Bailey, C.R., Browning, M.H.E.M., Casey, J.A., Hanley, J. R., Minson, C.T., Scott Ogletree, S., Rigolon, A., Laden, F., James, P., 2023. Racial, ethnic, and socioeconomic disparities in multiple measures of blue and green spaces in the United States. Environ. Health Perspect. 131, 1–9. https://doi.org/10.1289/EHP11164.

Krenz, K., Dhanani, A., McEachan, R.R.C., Sohal, K., Wright, J., Vaughan, L., 2023. Linking the urban environment and health: an innovative methodology for measuring individual-level environmental exposures. Int. J. Environ. Res. Public Health 20, 1953. https://doi.org/10.3390/ijerph20031953.

Kroenke, K., Strine, T.W., Spitzer, R.L., Williams, J.B.W., Berry, J.T., Mokdad, A.H., 2009. The PHQ-8 as a measure of current depression in the general population. J. Affect. Disord. 114, 163–173. https://doi.org/10.1016/j.jad.2008.06.026.

Kwan, M.P., 2009. From place-based to people-based exposure measures. Soc. Sci. Med. 69, 1311–1313. https://doi.org/10.1016/j.socscimed.2009.07.013.

Markevych, I., Schoierer, J., Hartig, T., Chudnovsky, A., Hystad, P., Dzhambov, A.M., de Vries, S., Triguero-Mas, M., Brauer, M., Nieuwenhuijsen, M.J., Lupp, G., Richardson, E.A., Astell-Burt, T., Dimitrova, D., Feng, X., Sadeh, M., Standl, M., Heinrich, J., Fuertes, E., 2017. Exploring pathways linking greenspace to health: Theoretical and methodological guidance. Environmental Research 158, 301–317. https://doi.org/10.1016/j.envres.2017.06.028.

McEachan, R.R.C., Prady, S.L., Smith, G., Fairley, L., Cabieses, B., Gidlow, C., Wright, J., Dadvand, P., van Gent, D., Nieuwenhuijsen, M.J., 2016. The association between green space and depressive symptoms in pregnant women: moderating roles of socioeconomic status and physical activity. J. Epidemiol. Community Health 70, 253–259. https://doi.org/10.1136/jech-2015-205954.

R.R.C. McEachan G. Santorelli A. Watmuff D. Mason S.E. Barber D.D. Bingham P.K. Bird L. Lennon D. Lewer M. Mon-Williams K.A. Shire D. Waiblinger J. West T.C. Yang D. A. Lawlor K.E. Pickett J. Wright on behalf of the BiB New Wave co-applicant group. Cohort Profile Update: Born in Bradford Press; International Journal of Epidemiology.

McEachan, R.R.C., Yang, T.C., Roberts, H., Pickett, K.E., Arseneau-Powell, D., Gidlow, C. J., Wright, J., Nieuwenhuijsen, M., 2018. Availability, use of, and satisfaction with green space, and children's mental wellbeing at age 4 years in a multicultural, deprived, urban area: results from the Born in Bradford cohort study. Lancet Planet. Health 2, e244–e254. https://doi.org/10.1016/S2542-5196(18)30119-0.

McManus, S., Bebbington, P., Jenkins, R., Brugha, T., 2016. Mental Health and Wellbeing in England Adult Psychiatric Morbidity Survey 2014. NHS Digital, Leeds.

Mitchell, R.J., Richardson, E.A., Shortt, N.K., Pearce, J.R., 2015. Neighborhood environments and socioeconomic inequalities in mental well-being. Am. J. Prev. Med. 49, 80–84. https://doi.org/10.1016/j.amepre.2015.01.017.

Mueller, N., Rojas-Rueda, D., Khreis, H., Cirach, M., Milà, C., Espinosa, A., Foraster, M., McEachan, R.R.C., Kelly, B., Wright, J., Nieuwenhuijsen, M., 2018. Socioeconomic inequalities in urban and transport planning related exposures and mortality: a health impact assessment study for Bradford, UK. Environ. Int. 121, 931–941. https://doi.org/10.1016/j.envint.2018.10.017.

Murray, M.H., Buckley, J., Byers, K.A., Fake, K., Lehrer, E.W., Magle, S.B., Stone, C., Tuten, H., Schell, C.J., 2022. One health for all: advancing human and ecosystem health in cities by integrating an environmental justice lens. Annu. Rev. Ecol., Ecolution, Syst. 53, 403–423. https://doi.org/10.1146/annurev-ecolsys-102220.

Nieuwenhuijsen, M.J., Agier, L., Basagaña, X., Urquiza, J., Tamayo-Uria, I., Giorgis-Allemand, L., Robinson, O., Siroux, V., Maitre, L., Castro, M.de., Valentin, A., Donaire, D., Dadvand, P., Aasvang, G.M., Krog, N.H., Schwarze, P.E., Chatzi, L., Grazuleviciene, R., Andrusaityte, S., Dedele, A., McEachan, R., Wright, J., West, J., Ibarluzea, J., Ballester, F., Vrijheid, M., Slama, R., 2019. Influence of the Urban Exposome on Birth Weight. EHP 127 (4).

Nordbø, E.C.A., Nordh, H., Raanaas, R.K., Aamodt, G., 2018. GIS-derived measures of the built environment determinants of mental health and activity participation in childhood and adolescence: A systematic review. Landscape and Urban Planning 177, 19–37. https://doi.org/10.1016/j.landurbplan.2018.04.009.

Ordnance Survey. (2022a). OS Address Base Premium. [Online]. Available at: https://www.ordnancesurvey.co.uk/products/addressbase-premium (Licensed on: 11 February 2022).

Ordnance Survey. (2022b). OS Open Greenspace. [Online]. Available at: https://www.ordnancesurvey.co.uk/products/os-open-greenspace (Accessed: 8 February 2022).

Ordnance Survey. (2022c). OS MasterMap Highways Network and OS MasterMap Highways Network - Paths [GeoPackage geospatial data]. Using: EDINA Digimap Ordnance Survey Service, https://digimap.edina.ac.uk (Accessed: 9 January 2022).

Pearl, J., 2009. Causality. Cambridge University Press, Cambridge. https://doi.org/10.1017/CBO9780511803161.

Prady, S.L., Endacott, C., Dickerson, J., Bywater, T.J., Blower, S.L., 2021. Inequalities in the identification and management of common mental disorders in the perinatal period: an equity focused reanalysis of a systematic review. PLoS ONE 16, 1–21. https://doi.org/10.1371/journal.pone.0248631.

Prady, S.L., Pickett, K.E., Gilbody, S., Petherick, E.S., Mason, D., Sheldon, T.A., Wright, J., 2016a. Variation and ethnic inequalities in treatment of common mental disorders before, during and after pregnancy: combined analysis of routine and research data in the Born in Bradford cohort. BMC Psychiatry 16, 1–13. https://doi.org/10.1186/s12888-016-0805-x.

Prady, S.L., Pickett, K.E., Petherick, E.S., Gilbody, S., Croudace, T., Mason, D., Sheldon, T.A., Wright, J., 2016b. Evaluation of ethnic disparities in detection of depression and anxiety in primary care during the maternal period: combined analysis of routine and cohort data. Br. J. Psychiatry 208, 453–461. https://doi.org/10.1192/bjp.bp.114.158832.

Rigolon, A., 2017. Parks and young people: An environmental justice study of park proximity, acreage, and quality in Denver, Colorado. Landsc. Urban Plan. 165, 73–83. https://doi.org/10.1016/j.landurbplan.2017.05.007.

Rigolon, A., 2016. A complex landscape of inequity in access to urban parks: a literature review. Landsc. Urban Plan. 153, 160–169. https://doi.org/10.1016/j.landurbplan.2016.05.017.

Robinson, O., Tamayo, I., de Castro, M., Valentin, A., Giorgis-Allemand, L., Krog, N.H., Aasvang, G.M., Ambros, A., Ballester, F., Bird, P., Chatzi, L., Cirach, M., Dėdelė, A., Donaire-Gonzalez, D., Gražuleviciene, R., Iakovidis, M., Ibarluzea, J., Kampouri, M., Lepeule, J., Maitre, L., McEachan, R., Oftedal, B., Siroux, V., Slama, R., Stephanou, E. G., Sunyer, J., Urquiza, J., Weyde, K.V., Wright, J., Vrijheid, M., Nieuwenhuijsen, M., Basagaña, X., 2018. The urban exposome during pregnancy and its socioeconomic determinants. Environ. Health Perspect. 126 https://doi.org/10.1289/EHP2862.

Rosseel, Y., 2012. lavaan: an R package for structural equation modeling. J. Stat. Softw. 48, 1–36.

Spitzer, R.L., Kroenke, K., Williams, J.B.W., Löwe, B., 2006. A brief measure for assessing generalized anxiety disorder: the GAD-7. Arch. Intern. Med. 166, 1092–1097. https://doi.org/10.1001/archinte.166.10.1092.

Subiza-Pérez, M., García-Baquero, G., Fernández-Somoano, A., Guxens, M., González, L., Tardón, A., Dadvand, P., Estarlich, M., De Castro, M., McEachan, R.R.C., Ibarluzea, J., Lertxundi, N., 2023a. Residential green and blue spaces and working memory in children aged 6–12 years old. Results from the INMA cohort. Health Place 84, 103136. https://doi.org/10.1016/j.healthplace.2023.103136.

Subiza-Pérez, M., García-Baquero, G., Fernández-Somoano, A., Riaño, I., González, L., Delgado-Saborit, J.M., Guxens, M., Fossati, S., Vrijheid, M., Fernandes, A., Ibarluzea, J., Lertxundi, N., 2023b. Social inequalities, green and blue spaces and mental health in 6–12 years old children participating in the INMA cohort. Health Place 83, 103104. https://doi.org/10.1016/j.healthplace.2023.103104.

Textor, J., 2020. Dagitty Manual.

Uphoff, E.P., Pickett, K.E., Crouch, S., Small, N., Wright, J., 2016. Is ethnic density associated with health in a context of social disadvantage? Findings from the Born in Bradford cohort. Ethn. Health 21, 196–213. https://doi.org/10.1080/13557858.2015.1047742.

WHO Regional Office for Europe, 2016. Urban green spaces and health 92.

World Health Organization, 2022. World mental health report. Transforming mental health for all. Geneva. https://doi.org/10.1136/bmj.o1593.

Wright, J., Small, N., Raynor, P., Tuffnell, D., Bhopal, R., Cameron, N., Fairley, L., A Lawlor, D., Parslow, R., Petherick, E.S., Pickett, K.E., Waiblinger, D., West, J., 2013. Cohort profile: the born in bradford multi-ethnic family cohort study. Int. J. Epidemiol. 42, 978–991. https://doi.org/10.1093/ije/dys112.

Zhang, R., Zhang, C., Rhodes, R.E., 2021. The pathways linking objectively-measured greenspace exposure and mental health: a systematic review of observational studies. Environ. Res. 198, 111233 https://doi.org/10.1016/j.envres.2021.111233.