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Greenspace Exposure and Obsessive-Compulsive Behaviors in Schoolchildren

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Abstract

Green environments are associated with improved child brain development and mental health. We study cross-sectionally the association of the availability of greenspace at home and school with obsessive-compulsive behaviors (OCB) in primary schoolchildren. Greenspace and tree cover surrounding home and school of 378 children aged 9 to 10 in Barcelona (Spain) were characterized using satellite-based indices [Normalized Difference Vegetation Index (NDVI), Modified Soil Adjusted Vegetation Index (MSAVI), Vegetation Continuous Field (VCF)] across buffers of 100, 300, and 500 m, and distance to the nearest green space. OCB was assessed with the Spence Children's Anxiety Scale-Parent version. Linear and mixed effects models showed that greenspace at school, but not at home, was significantly related to a reduction in OCB across buffers, with benefits for girls and also children with graduate parents. Higher greenspace around the school might be associated with less obsessive-compulsive behavior in primary schoolchildren, especially in girls and those with higher socioeconomic status.

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The ongoing urbanization worldwide has substantially reduced the contact of the individuals with nature. A growing body of evidence has associated contact with nature, including greenspace, with health benefits such as improving mental health (J. Zhang, Yu, et al., 2020). In adults, exposure to greenspace has been associated with significant benefits for psychological wellbeing and mental health (Bratman et al., 2019; Dadvand et al., 2016). Similarly, in children, a number of studies have reported that exposure to residential and school greenspace is associated with improved neurodevelopmental outcomes such as higher IQ levels (Bijnens et al., 2020; Lee et al., 2021), improvement in academic performance (Donovan et al., 2020), more prosocial behavior (Amoly et al., 2014; Putra et al., 2021), improved early psychomotor development (Kabisch et al., 2019; Liao et al., 2019), enhanced cognitive development (Dadvand et al., 2015, 2017), improved self-satisfaction and well-being (Dadvand et al., 2019; Feng & Astell-Burt, 2017; McCormick, 2017; McEachan et al., 2018), and is also associated with beneficial anatomical changes in developing brain (Dadvand et al., 2018). Specifically, exposure to greenspace has been related with lower risk of behavioral and emotional problems such as externalizing behavior problems (Bijnens et al., 2020; Lee et al., 2019), anxiety and depression (Larson et al., 2018; Liao et al., 2020), attention deficit/hyperactivity disorder (Amoly et al., 2014; Lee et al., 2019; Liao et al., 2020; Markevych et al., 2014; Vanaken & Danckaerts, 2018; Yang et al., 2019), schizophrenia (Engemann et al., 2018, 2020), and poorer general mental health (Andrusaityte et al., 2020).

Obsessive-compulsive disorder (OCD) refers to the presence of unwanted recurrent thoughts, urges, or images (obsessions) and/or unnecessary repetitive behaviors or mental acts performed in response to obsession (compulsions) (American Psychiatric Association, 2013). OCD thoughts and rituals are identified as nonsensical. In about half of the cases the disorder starts in childhood, with prevalence until adolescence ranging from 0.1% to 4% (Heyman et al., 2001; Rapoport et al., 2000). The severe form of this disorder could be associated with serious distress and impairment in the daily life of not only the affected child, but also the family, which is usually involved in the rituals (Monzani et al., 2020). According to a recent systematic review and meta-analysis of the available evidence, persistence rates for full pediatric OCD diagnosis are about 40% at least 1 year later, with shorter duration being a predictor of remission and hence a better prognosis (Liu, Cui et al., 2021). These findings highlight the need for identifying the measures that may help to early hinder the progression and continuity of symptoms to full OCD.

The proposed mechanisms through which greenspace could be beneficial on health include: (a) reducing harm such as mitigating exposure to noise, heat or air pollution, (b) restoring capacities, mainly through reducing physiological stress and recovering attention, and (c) building capacities such as improving physical fitness or promoting social contact and cohesion (Markevych et al., 2017). Although through some of these mechanisms, greenspace could also have an impact on OCD, the available evidence on such an impact is still very scarce. Therefore, the aim of our study was to evaluate the association of exposure to greenspace at home and school with obsessive-compulsive behaviors (OCB) in primary schoolchildren.

Materials and Methods

Study Setting

The study was conducted in the Barcelona metropolitan area (636 km^2) located in the northeast coast of Spain with a population of 5.6 million inhabitants, which is the second most populated province in Spain (Instituto Nacional de Estadística, 2020). The area has a Mediterranean climate, with hot and dry summers and mild winters (average annual temperature is 21.2°C during the day and 15.1°C at night) and much of the precipitation occurring during spring and autumn months (on average 78 rainy days a year).

Study Population

This study was part of a well-established ongoing cohort that aims to identify the risk factors of psychological problems in children (Ezpeleta et al., 2014). Following a two-phase sample design an initial sample of 2,283 children from 54 schools (25.9% semi-public and 74.1% public) were randomly selected from the census of kindergarten schools across our study area in 2009 to 2010 (Figure 1). A total of 1,341 families (58.7%) agreed to participate. In the second stage, children were screened for psychological problems using the parent-administered Strengths and Difficulties Questionnaire (SDQ) (Goodman, 1997). All the children who screened positively for behavioral problems and an additional 30% of the children with scores below the cut-off screening scores were enrolled in the longitudinal study. Of those included, 622 children (89.4 %) and their parents agreed to participate in the longitudinal study, with no statistically significant differences in sex ($p = .82$)

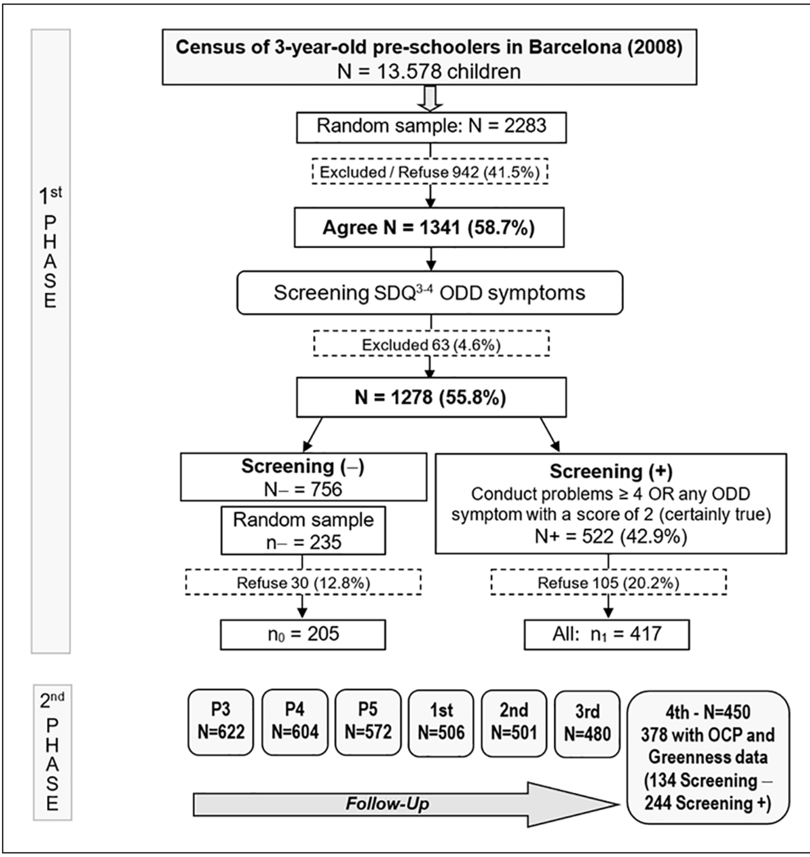

Figure 1. Study sample and follow-ups.

or type of school ($p = .85$) found between participants and drop-outs; however, children who did agree to participate were of higher socioeconomic status (SES) (86.2% of high SES for participants vs. 73.6% of high SES for drop-outs; $p = .01$). Children were followed annually (i.e., six follow-ups until the assessment of OCB) for the evaluation of their neurodevelopment and mental health status and the corresponding risk factors. Further details regarding this cohort has been published previously (Ezpeleta et al., 2014). The final sample for the present study included 378 children at age 9 years (i.e., sixth follow-up – cross-sectional analysis) when the evaluation of the OCB was conducted (Figure 1), 244 children (64.6%) from the screening positive initial group. There was no bias in sex ($p = .62$) neither in type of school ($p = .18$) due to attrition. Nevertheless, children who remained in the study at age 9 had a higher SES ($p < .01$) than those at the first follow-up.

The project was approved by the Ethics Committee on Animal and Human Experimentation of the Universitat Autònoma de Barcelona (Ethics approval CEEAH 4324). Families were recruited at the schools and gave written consent for the assessment. The families who agreed were contacted by telephone and interviewed at the school for each annual assessment.

Exposure Assessment

Assessment of greenspace exposure included two different aspects: namely surrounding greenspace and access to greenspace, and was conducted, separately, for home as well as school.

Surrounding greenspace. We applied the following three satellite-based indices to identify greenspace, separately for all vegetation types together as well as trees, surrounding home and school for each participant.

(1) The Normalized Difference Vegetation Index (NDVI) which is an indicator of photosynthetically active landcover, calculated based on the land surface reflectance of red and near infrared parts of the spectrum. Its values range from −1 to 1 with higher values indicating the higher greenspace (NCLB, 2000). To englove the study population there were used two images from 2015 (Landsat 8 OLI/TIRS) from the greenest season, April and May (Landsat images for 2015 U.S. Geological Survey, 2015).

(2) The Vegetation Continuous Field (VCF) is an indicator of tree canopy cover, and displays the percentage of land covered by the woody vegetation with a height greater than 5 m (Sexton et al., 2013). The higher VCF values indicate the higher percentage of tree cover. VCF is derived from Landsat images and at periods of 5 years from 2000. Here were used 2015, and also were used two images to spatially cover the study population (Land Cover Land Use Change (NASA) (2015). The address of residence for each participant were obtained at baseline and during each follow-up. We defined home surrounding greenspace as the average of NDVI, VCF, and MSAVI across buffers of 100, 300, and 500 m in a circular buffer area (representing immediate, intermediate, and neighborhood areas, respectively) around all the home addresses where children had lived between age 3 years (baseline visit) and 9 years (assessment of OCD), weighted by the time that the child had resided in each address. Similarly, we defined

school surrounding greenspace as average of NDVI, VCF, and MSAVI across the aforementioned buffer sizes around all the schools where children had attended between age 3 and 9 years, weighted by the time that the child had spent at each school.

Access to green spaces. The distance to the closest green space (DCG) was applied as an indicator of access to green spaces We applied the Urban Atlas of the Copernicus Land Monitoring Service for 2012 (European Union, 2020) to identify green spaces in our study area. We then calculated the Euclidean distance separately from home and school to their nearest green space. As such higher values corresponded to less exposure to greenspace.

Assessment of Obsessive-Compulsive Behaviors

Pediatric OCD has a typical onset in later childhood or adolescence (Geller, 2006). Accordingly we chose age 9 to 10 to characterize this condition in our cohort, using the *Spence Children's Anxiety Scale-Parent version* (SCAS-P) (Spence, 1998) questionnaire. SCAS-P assesses the severity of anxiety symptoms following the anxiety disorder categories proposed by the DSM-IV (American Psychiatric Association, 2000). It contains 38 items (0: *never* to 3: *always*) organized in six domains of anxiety one of which being OCD. The obsessive-compulsive scale includes six items about checking, repeating behaviors, ritualistic behavior, intrusive recurrent thoughts, special thoughts, and bad thoughts.

Whiteside et al. (2012) studied the convergent validity through examining correlations of the subscale with ratings from standardized clinical diagnostic interviews, such as the Children's Yale-Brown Obsessive Compulsive Scale (CY-BOCS) (Scahill et al., 1997) and Anxiety Disorders Interview Schedule for DSM-IV: Child Version (ADIS-C) (Silverman et al., 1994). SCAS obsessive-compulsive scale parent-reports were positively correlated with the total score and subscale scores on the CY-BOCS and the number of obsessions and compulsions and distress associated with OCD symptoms as reported on the ADIS:C. SCAS obsessive-compulsive scale scores also showed criterion validity given that mean scores differed significantly between patients with an OCD diagnosis, patients without an OCD diagnosis, and children from the community, and the mean from the OCD group was significantly greater, with large effect sizes, than the means of the other two groups. In the clinical sample pre-treatment scores of SCAS obsessive-compulsive scale were significantly greater than post-treatment scores for parent report with large effect sizes ($d = 1.28$).

The raw data was transformed to T-scores according to the test manual (Spence, n.d.), which were used as the indicator of OCB. Ordinal alpha for SCAS-P obsessive-compulsive scale was .91 in our study sample.

Covariates

Data on sex, ethnicity, and parental education were obtained through interview as a part of the routine demographic data collection in our cohort. Neighborhood sociodemographic status characteristics such as the percentage of unemployed people, and the percentage of people with no or primary education at the census tract where home and school were located were also abstracted. The *Life Events Checklist* (Johnson & McCutcheon, 1980) was also applied to obtain data on child's stressful life events during the year previous to the assessment (moving home, change school, parent's divorce, etc.) from the mother or caregiver.

Statistical Analysis

Main analyses. Given the multistage sampling process, the analyses were weighted by the inverse probability of the selection in the second phase of sampling (Lohr, 2019), as we did in our previous studies based on the data from this cohort (Ezpeleta et al., 2014). For evaluating the association between the indicators of exposure to greenspace at home and OCB, we developed linear mixed models including OCB as the outcome, each measure of greenspace exposure at each buffer (one at a time) as predictor, and school as the random effect. In the analysis of greenspace at school all the children going to the same school had the same greenspace value, with no within-school variability. Therefore, the random effect of school was not included in analysis of the association of school greenspace with OCB. Accordingly, for estimating the association of greenspace exposure at school with OCB, we applied linear regression models. All models were adjusted for a priori selected set of covariates including (i) sex, (ii) parental education (with vs. without university education), (iii) ethnicity (White vs. other), (iv) two indicators of neighborhood sociodemographic status (both for the home address and the school's address), and (v) number of stressful life events the child has lived during the year preceding the assessment of the OCD. Exposures were scaled by their interquartile range (IQR) in order to provide comparable results for different exposure indicators. Because the low percentage of missing, data pairwise analysis was done using for each model all the available data. All the statistical analyses were carried out using Stata 16 (StataCorp, 2019). The type I error was set at 0.05 value.

Table 1. Description of the Sociodemographic Characteristics and Obsessive-Compulsive Symptoms in Study Participants ($N = 378$).

Characteristics	Description
Age (years)[a]	9.7 (0.5)
Sex; % Female	49.2
Parent's education: university studies; % Yes	68.8
Ethnicity; % White	93.1
Number of stressful life events	1.0 (2.0)
% of unemployment at neighborhood	18.7 (10.6)
% of Primary or no education at neighborhood	7.2 (7.3)
SCAS-P Obsessive-Compulsive	47.0 (2.0)

Note. SCAS-P OC: Spence Children's Anxiety Scale-Parent version.
[a]Continuous variables described by their median (IQR).

Sensitivity and stratified analyses. As a first sensitivity analysis, we used Modified Soil-Adjusted Vegetation Index (MSAVI) to assess home and school surrounding greenspace and repeated the analyses for this alternative set of exposure. The MSAVI improves NDVI measures by minimizing the effect of the soil background and as such could provide a more precise estimation of the vegetation where there are areas with few chlorophyll or high proportions of bare soil (Qi et al., 1994). Similar to NDVI, MSAVI values range from −1 to 1 with higher values indicating more greenspace (NCLB, 2000). Additionally, as a second sensitivity analysis and to explore influence of ethnicity on our main results, we repeated the analyses by limiting the participants to White children. Given the small percentage of non-white children (6.9%), it was not possible to conduct a separate analysis for this sub-group. Finally, as a third sensitivity analysis we re-estimated models by further adjusting for the best job occupation from both parents (unemployed, manual/unskilled worker, non-manual/skilled worker).

To explore the potential variation of our evaluated associations across strata of sex, SES, and presence of behavior problems, we stratified our analyses at home and school surrounding greenspace (at 300 m buffer) and DCG, by sex, by parental education (with or without university education), and by having or not behavior problems at recruitment at age 3.

Results

The sociodemographic characteristics of study participants are described in Table 1. Of 378 participants included in our study, 49.2% were girls, 68.8% had at least one parent with university studies, 93.1% where white and had a

Table 2. Spearman's Correlation Coefficients Between Indicators of Exposure to Greenspace at Home (Above Diagonal) and School (Below Diagonal).

	1	2	3	4	5	6	7
1. NDVI 100 m.	—	*.86*	*.80*	*.85*	*.81*	*.78*	*−.54*
2. NDVI 300 m.	.90	—	*.96*	*.70*	*.91*	*.92*	*−.65*
3. NDVI 500 m.	.88	.98	—	*.61*	*.84*	*.94*	*−.62*
4. VCF 100 m.	.91	.81	.79	—	*.77*	*.65*	*−.46*
5. VCF 300 m.	.90	.97	.93	.81	—	*.91*	*−.61*
6. VCF 500 m.	.87	.96	.97	.79	.96	—	*−.60*
7. DCG m.	−.69	−.76	−.75	−.60	−.76	−.78	—

Note. NDVI = normalized difference vegetation index; VCF = vegetation continuous field (% of tree covering); DCG = distance to closest green space; italic: above diagonal correlation values at home.

median of 1 stressful life event during the year preceding the OCD evaluation.

Table 2 shows the Spearman's correlation matrix between the different greenspace measures and buffer sizes both at residence and at school. The pattern of relationships was similar in both locations, with slightly higher values at home than at school. There were strong correlations between NDVI and VCF measures when compared with each other and moderate to strong correlations when they were compared with the DCG. As expected, the strongest correlations between NDVI and VCF were found for the same buffer size.

Table 3 presents the description of greenspace measures and its association with OCB, separately for home and school greenspace measures. Significant associations were found for school NDVI and VCF, with negative coefficients reflecting that a greater exposure to greenspace was associated with lower OCB (i.e., less OCD symptoms). The magnitude of the association was greater for smaller buffers (100 m.) than for the largest (300 and 500 m). An increment of one IQR in NDVI measured within 100 and 500 m buffer was associated with a significant decrease of between −1.24 (95% confidence intervals (CIs: −2.36, −0.13) and −1.70 (95% CIs: −3.35, −0.04) points in OCB scale. Similarly, an increment of one IQR in VCF was associated with a significant decrease of between −0.57 (95% CIs: −0.92, −0.22) and −1.22 (95% CIs: −2.25, −0.19) points in OCB. For the school DCG, and also for the home surrounding greenspace and DCG, although we observed beneficial associations with OCB, none of these associations attained statistical significance.

Table 3. Adjusted[a] Regression Coefficients for One Interquartile (IQR) Increase in Each Indicator of Greenspace Exposure in Association with Obsessive-Compulsive Score.

	Home[b]		School[c]	
	Greenspace	Association	Greenspace	Association
	Median (IQR)	*B*[a] (CI 95%)	*Median (IQR)*	*B*[a] (CI 95%)
NDVI				
100 m buffer	0.176 (0.095)	−0.51 (−1.48, 0.46)	0.180 (0.156)	−1.70 (−3.35, −0.04)**
300 m buffer	0.194 (0.116)	−0.59 (−1.95, 0.77)	0.238 (0.167)	−1.24 (−2.36, −0.13)**
500 m buffer	0.197 (0.128)	−0.49 (−1.99, 1.02)	0.236 (0.170)	−1.27 (−2.51, −0.03)**
VCF				
100 m buffer	2.498 (2.062)	−0.14 (−0.48, 0.20)	2.811 (3.002)	−1.22 (−2.25, −0.19)**
300 m buffer	2.904 (2.095)	−0.11 (−0.38, 0.17)	3.635 (3.148)	−0.57 (−0.92, −0.22)**
500 m buffer	3.043 (2.329)	−0.13 (−0.43, 0.17)	3.571 (4.278)	−0.85 (−1.41, −0.30)**
DCG (m)	185.3 (244.3)	1.09 (−0.24, 2.42)	206.6 (288.0)	0.73 (−0.76,2.22)

Note. NDVI = Normalized Difference Vegetation Index; VCF = Vegetation Continuous Field (% of tree covering); DCG = Distance to closest green space.
[a]Models were adjusted for sex, ethnicity, parent's education level (university vs. other), percentage of unemployment, percentage of illiterate and total number of stressful events. CI: Confidence interval. IQR: Interquartile range.
[b]Based on mixed effects models with school as the random effect.
[c]Based on linear regression models.
***$p < .05$.

Sensitivity and Stratified Analyses

Supplemental Table S1 presents the results of the analyses using MSAVI to assess home and school surrounding greenspace. The associations for both locations were non-significant but showed the same direction than those observed for NDVI and VCF in main analyses, with coefficients of greater magnitude for school than for home. Otherwise, after limiting analyses to only white children, the observed associations were in line with those of main analyses with regards to the direction and statistical significance (Supplemental Table S2). Also, when adding parents' occupation as adjusting term, regression coefficients were similar to those without, although statistical significance for NDVI at 100 and 500 m was lost (Supplemental Table S3).

Figure 2 presents the association between greenspace exposure at home/school and OCB stratified by sex. For home surrounding greenspace confidence intervals included the zero-value reflecting non-significant associations. At school, a protective association of greenspace exposure for girls when measured with NDVI or VCF was obtained.

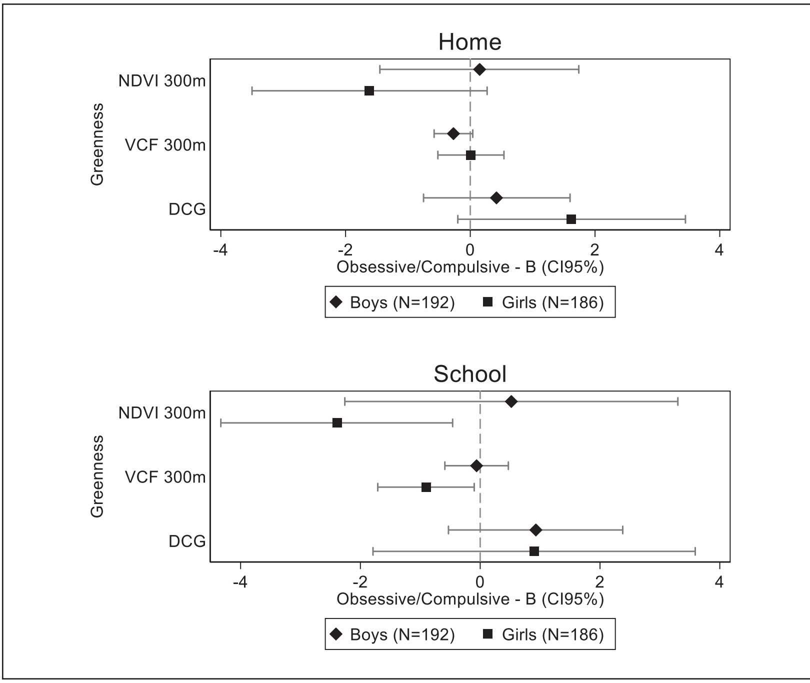

Figure 2. Adjusted[a] Associations (95% Confidence Intervals) Between One Interquartile Increase in Greenspace Exposure at Home/School and Obsessive-Compulsive Score Stratified by Sex.
[a]Models were adjusted for ethnicity, parent's education level (university vs. other), percentage of unemployment, percentage of illiterate, and total number of stressful events.

Figure 3 shows the association between greenspace exposure at home/school and OCB stratified by parental education (at least one parent with university education versus both parents without university education). For NDVI and VCF, we did not find a notable difference between the two strata in terms of the direction of the associations: in both strata we observed a protective association between these greenspace exposure indicators and OCB, which was statistically significant only for those with at least one parent having university education when greenspace exposure was obtained at school. For the DCG, the association varied between locations for those children with parents without any university education, showing statistically significant protective association against OCB at home but null at school.

Figure 4 presents the association between greenspace exposure at home/school and OCB stratified by having or not behavior problems at age 3.

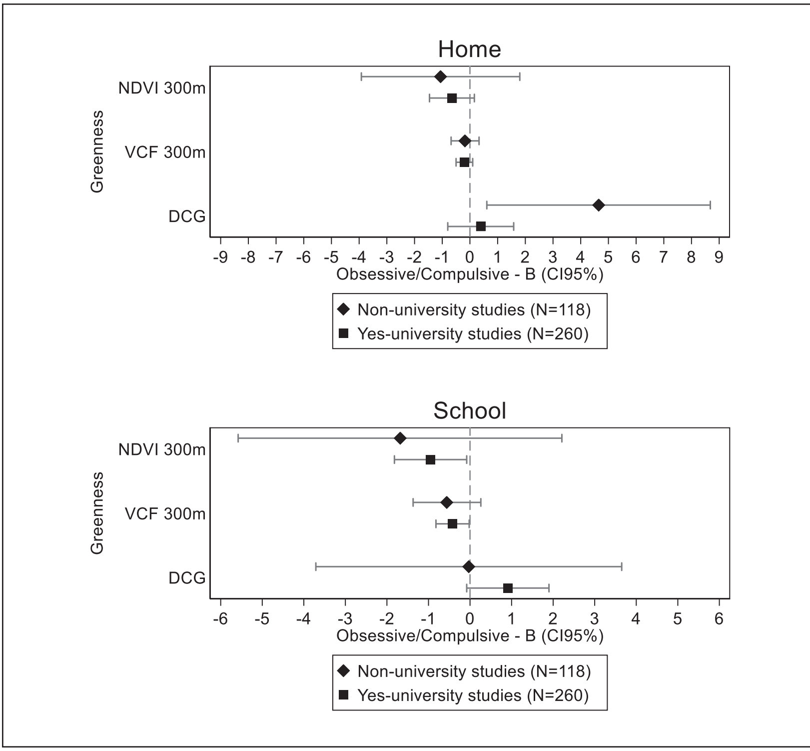

Figure 3. Adjusted[a] Associations (95% Confidence Intervals) Between One Interquartile Increase in Greenspace Exposure at Home/School and Obsessive-Compulsive Score Stratified by Parental Education (Without University Studies/With University Studies).
[a]Models were adjusted for sex, ethnicity, percentage of unemployment, percentage of illiterate, and total number of stressful events.

Results exhibited a very similar pattern for both groups with two exceptions: DCG measured at home, showing a protective significant association with OCB only for children without behavior problems, and NDVI measured at school, which associated with a reduction of OCB in the group with behavior problems.

Discussion

To our knowledge this is the first study that evaluated the association between greenspace at both home and school and OCB in community children. Our

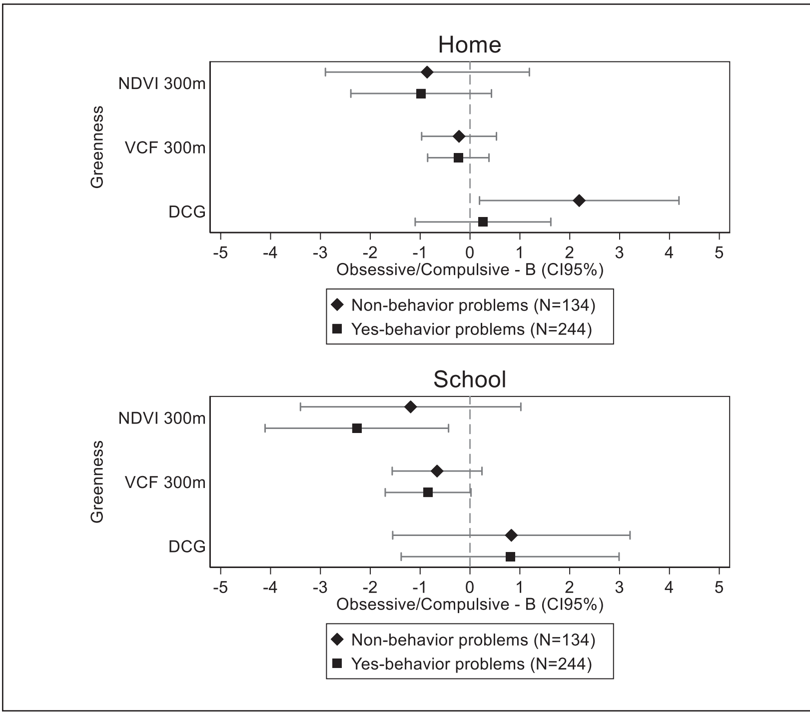

Figure 4. Adjusted[a] Associations (95% Confidence Intervals) Between One Interquartile Increase in Greenspace Exposure at Home/School and Obsessive-Compulsive Score Stratified by Behavior Problems at age 3 (Without/With).
[a]Models were adjusted for sex, ethnicity, parent's education level (university vs. other), percentage of unemployment, percentage of illiterate, and total number of stressful events.

study benefited from data from a well-established cohort of children with prospectively collected data on important covariates (e.g., sociodemographic factors and stressful life events) and characterization of OCB using a widely-used tool together with a comprehensive characterization of greenspace exposure at both home and school. We found that greenspace surrounding the school had a potentially beneficial association with obsessive-compulsive behavior, reflected as lower OCB scores. For the greenspace surrounding home, and also home and school DCG, we also observed suggestions for a possible protective association; however, they were not statistically significant. Furthermore, we observed some suggestions for a potentially stronger association for girls, and perhaps those children with higher SES.

We are aware of only one previous study reporting on the association of greenspace exposure and OCD. This study conducted in Denmark reported higher greenspace surrounding home (measured as NDVI average) was associated with lower risk of OCD (Engemann et al., 2019). This finding was in line with our observed association between home surrounding greenspace and OCB; however, our observed associations were not statistically significant. In contrast with this previous study, our study also characterized greenspace at school, for which we observed stronger associations with OCB compared to those for greenspace at home. Our observed stronger association for greenspace at school is in line with other studies that also found that school but not home surrounding greenspace indicators were significantly associated with cognitive function such as working memory and inattentiveness (Dadvand et al., 2015), attention deficit/hyperactivity disorder (Yang et al., 2019), and biological markers such as blood pressure or cholesterol (Ribeiro et al., 2019). Children spend large amounts of time at the school, and it is at the schoolyards where they carry out most of the outside activities such as sports, socializing with other peers, and other recreational leisure activities during the week. Greenspace at school may be restorative (Kelz et al., 2015; Y. Zhang, Mavoa, et al., 2020) and can promote reduction of stress, relaxation, and distraction from repetitive thoughts and behaviors. The associations found at school are especially important for public health because: (a) focused interventions at schools are more feasible and affect more children compared to interventions at neighborhoods and across cities; (b) children are individuals in development with great plasticity to environmental influences such as greenspace at school and their associated benefits; (c) increasing greenspace at school in some way is feasible in most cases; and (d) increasing greenspace at school could contribute to improve children's mental health.

We observed stronger associations with OCB for the indicator of general greenspace (NDVI) compared to the indicator of the tree cover (VCF) at school. These results are in line with findings of an Australian study in adults, which also showed a slightly stronger association of their indicator of general greenspace with psychological distress, depression or anxiety, and general health compared with their indicator of tree cover (Astell-Burt & Feng, 2019). Similarly, another study showed that higher home surrounding greenspace, measured as NDVI average, was associated with lower cortisol levels (an indicator of stress) in the cord blood, while for tree cover surrounding the home address, measured using VCF, no association was found (Boll et al., 2020).

The same mechanisms by which greenspace could affect mental health and wellbeing, which are yet to be fully established, could also help to explain the associations found with OCD. Genetic and environmental factors could influence biological and psychological characteristics that ultimately lead to OCD (Rapoport & Shaw, 2015). Heritability rates of OCD in childhood range between 45% and 65% (van Grootheest et al., 2005). Nonetheless, environmental influences, such as perinatal injury, childhood infection, or life stressful events have also been suggested to be relevant (Grisham et al., 2008). These environmental influences may result in diverse types of stress that, in turn, may alter different biological systems, such as the immune system (Bottaccioli et al., 2019). OCD is a neuropsychiatric disorder that involves the cortico-striato-thalamo-cortical (CSTC) loop, implicated in action regulation, whose abnormal hyperactivation could lead to repetitive thoughts and actions (obsessions and compulsions) (Dougherty et al., 2018). A controlled experiment in adults has shown that being exposed to nature could reduce rumination and the activity in the brain area related with ruminations (subgenual prefrontal cortex) (Bratman et al., 2015), which is connected to the CSTC brain loop. Rumination is a cognitive process which consists of repetitive and unproductive thoughts that are frequent in OCD. Therefore, contact with nature, through distracting from the ruminations, could reduce OCD-related behaviors and levels.

Since early childhood the exposure to greenspace seems to favor neurodevelopment, as shown by cognitive and psychomotor execution (Dadvand et al., 2015; Liao et al., 2019). Children with OCD show greater executive dysfunction in flexibility (shift), working memory, planning, and inhibition (Garcia-Delgar et al., 2018; Negreiros et al., 2020; Ornstein et al., 2010). As such, the ability of greenspace exposure to enhance the development of cognitive and executive functions could reduce the risk of OCD. In line with these findings, our previous study in a sample of schoolchildren in Barcelona (Dadvand et al., 2018) identified enhancements in some brain regions (prefrontal cortex, premotor cortex, and cerebellar hemispheres) in urban children raised in greener neighborhoods. These brain regions were also associated with OCD (Apergis-Schoute et al., 2018) and with better scores in working memory and attention, suggesting the potential contribution of exposure to greenspace to brain development (Dadvand et al., 2018). Finally, another alternative path from lack of greenspaces to OCB might be through the stress produced by the environmental influences (i.e., air pollution, noise, and heat), which may affect the immune system (Bottaccioli et al., 2019) and in turn the basal ganglia involved in the control of voluntary movements (Boileau, 2011). Along this line, proximity of the school to greenspaces is an environmental factor that has been associated with a lower allostatic load in children (Ribeiro et al., 2019). The allostatic load refers to how chronic environmental stress favors the dysregulation of multiple biological systems (hormones, metabolism, immune system, cardiovascular, etc.) of the individuals, making them more vulnerable to disease (McEwen & Stellar, 1993). The mechanism by which allostatic load improves might be through the enhancement of cardiovascular, metabolic and other biologic systems because activity increases when greenspace is available, the ameliorative effects of greenspace on quality of air, or the relaxation effects associated with exposure to greenspace (Ribeiro et al., 2019).

We found suggestions for a potentially stronger association of surrounding greenspace with OCB in girls; however, for the DCG, we did not observe any notable difference between girls and boys. In which sex the influence of greenspace is greater is a matter of debate and, until now the available evidence is heterogeneous. Studies in adults have suggested that psychological and physiological characteristics might influence how each sex is affected by greenspace. For instance, whereas in men the objective amount of greenspace could better associate with health, in women the associations could be stronger with more subjective indicators such as quality of greenspaces or their restorative value (Bolte et al., 2019). However, our findings suggest that greenspace might be contributing to the slight preponderance of OCD in prepubertal boys versus girls (Rapoport & Shaw, 2015). With regards to SES, while for surrounding greenspace we did not observe a considerable difference across the strata of parental education, for DCG, we observed some suggestions for a potentially stronger association for those children from lower SES. Although there is not full agreement about the direction of SES in the association with greenspace, a recent systematic review has reported that the benefits for physical health of greenspace might be more in low SES than in high SES groups (Rigolon et al., 2021).

The results of our study should be interpreted in light of some limitations. First, our study, given its cross-sectional design had a limited capacity to establish a causal relationship. Moreover, given our modest sample size, our stratified analyses, particularly based on parental education, could have been under-powered. Also, because children in the age when we assessed their OCB (i.e., 9 years) could have questionable reliability and validity in answering questionnaires (Schniering et al., 2000), only parents reported on OCB, which could have resulted in the misclassification of our outcome variable. Additionally, our results should be generalized with caution to families of low SES given that these families were under-represented in the analyzed sample. Furthermore, our assessment of exposure to greenspace did not include quality aspects such as safety, esthetic, biodiversity, facilities, amenities, and organized activities, which could have influenced our evaluated associations.

The ongoing urbanization worldwide is leading an increasing number of children to live in urban areas, where residents might be at higher risk of increasing obsessive-compulsive behaviors (Rigolon et al., 2021) and often have less access to greenspace. Obsessive-compulsive behaviors often have an early onset and a large proportion of cases progress to full OCD. Therefore, childhood could be a window of opportunity for primary and secondary prevention of this condition. We observed that higher greenspace at school might reduce OCB in primary schoolchildren. Our findings, if confirmed by future studies, could provide an evidence base for policymakers to implement interventions (e.g., greening the schools and its surroundings) to reduce the incidence of this condition and its accompanying burden on the family and society in our rapidly urbanizing world. Further longitudinal studies based on large sample sizes with repeated characterization of OCB are required to confirm our findings in other settings with different climates and cultures.

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Ethical Approval

The project was approved by the Ethics Committee on Animal and Human Experimentation of the Universitat Autònoma de Barcelona. Families gave written consent for the assessment.

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Supplemental Material

Supplemental material for this article is available online.

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