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Original article

The Association Between Natural Environments and Depressive Symptoms in Adolescents Living in the United States

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A B S T R A C T

Purpose: Exposure to nature and natural environments may be beneficial for mental health; however, most population-based studies have been conducted among adults whereas few have focused on adolescents. We aimed to investigate the relationship between both greenness (vegetation) and blue space (water), and depressive symptoms among teenagers in the United States.
Methods: The study population included 9,385 participants ages 12–18 in the 1999 wave of the Growing Up Today Study. We characterized greenness exposure using the Normalized Difference Vegetation Index at a 250-m and 1,250-m radius around a subject's residence using data from the moderate-resolution imaging spectroradiometer onboard the National Aeronautics and Space Administration's Terra satellite. Exposure to blue space was defined as the presence of blue space within a 250-m and 1,250-m radius and distance to the nearest blue space. We used logistic regression models to examine associations with high depressive symptoms, measured using self-reported responses to the McKnight Risk Factor Survey.
Results: An interquartile range higher peak greenness in the 1,250-m buffer was associated with 11% lower odds of high depressive symptoms (95% confidence interval .79–.99). Although not statistically significant, this association was stronger in middle school students than in high school students. No such association was seen for blue spaces.
Conclusions: Surrounding greenness, but not blue space, was associated with lower odds of high depressive symptoms in this population of more than 9,000 U.S. adolescents. This association was stronger in middle school students than in high school students. Incorporating vegetation into residential areas may be beneficial for mental health.

IMPLICATIONS AND CONTRIBUTION

Nature, including both green spaces (vegetation) and blue features (water), can foster mental health. In this study adolescents living in greener areas had lower depressive symptoms. Greater residential exposure to greenness or green spaces may be beneficial for mental health.

There is emerging evidence that exposure to nature, particularly in the residential environment, may confer mental and physical health benefits [1,2]. Nature may directly influence mental health by improving people's affective states [3,4] and

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activating restorative processes related to cognition and attention [5]. Natural environments can also provide opportunities to engage in physical activity and social interactions, which may in turn benefit both physical and mental health [1,2,6,7].

Studies across many countries, mostly cross-sectional, have observed associations between surrounding greenness or green space and lower stress, psychological distress, and depressive symptoms [1,2,6], primarily in adults. Greenness has been associated with reduced risk of clinically relevant disorders, including anxiety and major depressive disorder [1,2]. Many of the pathways connecting greenness and health, including stress reduction, increased physical activity, and social interaction and cohesion, are particularly relevant for the outcome of depression or depressive symptoms [1], a major contributor to morbidity in the U.S. and around the world [8]. Findings from studies of greenness and depression in adults have been mixed but suggest an association [9–12].

Evidence for a relationship between greenness and mental health, including depression, in children and adolescents is more limited [2]. Some studies have shown associations between both objectively and subjectively measured green spaces and outcomes such as behavioral problems [13] or attention deficit and hyperactivity disorder symptoms among children and adolescents ages 5–18 [14]. Two population-based studies found higher objectively assessed greenness was associated with lower emotional distress among children between ages 3 and 10 [15,16], but did not assess this association in adolescence. Adolescence, often defined as the period between ages 11 and 24, is an important period for many aspects of development, including behavioral and mental health [17].

In a given year depression impacts one in nine adolescents in the United States [18], and experiencing depression in adolescence is associated with subsequent episodes in adulthood [19]. We are aware of only one study that considered the association between nature and depressive symptoms in adolescence [11], and it found no associations between changes in self-reported greenery and changes in depressive symptoms. Objective characterizations of exposure can strengthen our understanding of this association [2].

Much of the existing research has focused on exposure to greenness or green spaces, but recent studies have begun to consider whether exposure to blue space (surface water) may also benefit health [2,20]. Blue space may provide similar benefits for cognitive restoration and stress reduction [7]; however, population-based evidence is limited and mixed, and most studies have been conducted in adults [2,20–25]. The mixed findings may be attributed in part to heterogeneous exposure definitions, including linear distance to coast and presence of any blue space within various buffers, and in part to variable outcomes, including self-reported general health and various mental health measures.

The present study investigated the relationship between residential exposure to natural environments and depressive symptoms in a large cohort of teenagers living in the United States. We hypothesized that residential exposure to greenness and blue space would be associated with lower depressive symptoms. Given the relatively limited evidence for the association between nature, particularly blue space, and health and the lack of consistent exposure definitions, we focused on a cross-sectional analysis in this paper. We consider potential confounding by important neighborhood and environmental attributes that co-vary with greenness, including air pollution and socioeconomic conditions, and possible effect modification by grade level, gender, and region.

Methods

Study participants were from the Growing Up Today Study (GUTS). GUTS was founded in 1996 by inviting mothers from the ongoing Nurses' Health Study II (NHS II) to enroll their children ages 9–14. Once parental consent was obtained, participants who returned completed questionnaires at baseline were considered enrolled (n = 16,875). The study was approved by the Brigham and Women's Hospital Institutional Review Board.

For this analysis, eligible participants were 12–18-year-olds who completed the 1999 wave of GUTS (n = 12,413, 74% of the original sample) because that was the first wave at which depressive symptoms were assessed. We excluded participants who did not report on depressive symptoms in 1999 (n = 1,599), who lived outside the contiguous United States (n = 27), or who were younger than 12 when they completed the 1999 questionnaire (n = 2). Study participants were assigned addresses based on the addresses of their mothers participating in NHS II. Addresses of all NHS II participants had been previously geocoded, and we assigned each eligible GUTS participant the latitude and longitude values corresponding to their mother's address in 1999. Since address assignment was based on the mother's reported residence, we excluded subjects who reported not living with their mothers on the previous questionnaire (n = 1,149), attending military or boarding school (n = 61), or attending college (n = 190), leaving 9,385 participants. Socioeconomic and environmental characteristics of the neighborhoods where the mothers of included subjects lived did not differ substantially from those who were excluded.

Outcome

The primary outcome of interest was high depressive symptoms in 1999, assessed using the McKnight Risk Factor Survey (MRFS). The depressive symptom questions on the MRFS consist of six items each scored on a five-point Likert scale [26]. Each item was scored zero (never) to four (always) and the mean was taken. Scores on the MRFS were strongly correlated with the more commonly used Centers for Epidemiologic Studies of Depression [26]. Subjects missing one item were included, with their mean score calculated from available responses; subjects missing two or more items were excluded. Our final sample of 9,385 individuals included 122 subjects who responded to five of six items and 9,263 subjects who responded to all six. An age-specific *z*-score was calculated for each age at the time of questionnaire return using all available MRFS questionnaires completed by GUTS participants. The MRFS does not have an established clinical cutoff for high depressive symptoms. The prevalence of depression in this age range is estimated at 11.5% [18], so we considered those subjects with the highest 11.5% of scores to be cases of "high depressive symptoms." In sensitivity analyses we also separately considered the highest 5% and highest 15% of scores as cases.

Exposures

Greenness was characterized using the Normalized Difference Vegetation Index (NDVI), an index of vegetative density commonly used in studies of health outcomes [1,27–29]. NDVI leverages the fact that chlorophyll in plants absorbs visible light