Neighborhood Blight, Stress, and Health: A Walking Trial of Urban Greening and Ambulatory Heart Rate

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We measured dynamic stress responses using ambulatory heart rate monitoring as participants in Philadelphia, Pennsylvania walked past vacant lots before and after a greening remediation treatment of randomly selected lots. Being in view of a greened vacant lot decreased heart rate significantly more than did being in view of a nongreened vacant lot or not in view of any vacant lot. Remediating neighborhood blight may reduce stress and improve health. (*Am J Public Health.* 2015;105:909–913. doi:10.2105/AJPH.2014.302526)

Vacant lots are abandoned parcels of urban land that signal blight, with overgrown vegetation, trash dumping, and other illegal activities. Exposure to these lots is associated with negative health outcomes.[1–7] Although complex social and economic factors broadly explain the relationship between neighborhood blight and health, limited experimentation with biological outcomes has been conducted in real-world settings.[8]

The body's stress response is a reasonable biological pathway for understanding the impact of neighborhood blight on health.[9,10] Although this response is protective in acute situations, permanent downstream inflammatory changes and dysregulation of cardiovascular, neurological, and endocrine systems accumulate over a lifetime for persons repeatedly exposed to stressors in their neighborhood surroundings.[11–16] Basic structural improvements to blighted neighborhood environments, such as "greening" vacant lots, offers a promising and sustainable, yet underused, solution to such stressors.[5,17]

We examined the microspatial impact of neighborhood physical conditions during short neighborhood walks by experimentally testing a specific condition (the remediation of blighted vacant land) to a dynamic biological marker (heart rate).[18–21] Using georeferenced heart rate monitoring in an experimental study of an individual's native environment is a unique approach to field studies of neighborhood blight on acute stress.[22]

METHODS

We randomly selected 2 clusters of vacant lots in Philadelphia, Pennsylvania, to receive either a standard greening treatment (greening site) or no greening treatment (control site). The greening treatment, performed in May 2011 by the Philadelphia Horticulture Society, is a reproducible, low-cost, environmental intervention that includes cleaning and removing debris, planting grass and trees, and installing a low wooden post-and-rail fence.[23] All people living within approximately 2 blocks of the study vacant lots were eligible to participate in the study. This protocol was described in detail in a previous study.[17]

The Walk

We took 12 study participants on a self-paced, prescribed walk in their neighborhood (the greening or control site) past the study's randomly selected vacant lots, both before (pre) and 3 months after (post) the greening treatment. Investigators determined the walking route after vacant lot randomization but before the start of study recruitment.

The walks also took participants past vacant lots that did not receive the greening treatment, as they were not randomly selected to be in the study. The first walk took place in early spring, and the second walk took place during summer. Walks ranged from approximately 2100 feet in length and between 7 and 15 minutes at the treatment site and 1520 feet in length and between 6 and 10 minutes at the control site.

Heart Rate

We used heart rate as a dynamic physiological marker of stress response. In response to an acute stressor the body activates the sympathetic-adrenomedullary system, with downstream release of epinephrine, which increases heart rate.[21] Heart rate change has been used in a few previous studies to evaluate acute stress response, although this was done primarily in indoor laboratory settings, which are devoid of real-world stressors.[24,25]

Heart rate has a direct link to acute stress and dynamic change in response to stressors, and it is easy to measure in the field. During each walk, we collected a continuous measure of participants' heart rate using a Garmin Forerunner 205/305 GPS-enabled heart rate monitor (Garmin International, Inc., Olathe, KS).

Spatial and Statistical Analyses

We processed geocoded heart rate data using ESRI Spatial Analyst viewshed algorithms in a geographic information systems software package, version 10.2 (ESRI, Redlands, CA). We divided the walk into 8-foot slices perpendicular to the coordinates of the prescribed walk, and each slice contained at least 1 heart rate measurement per participant. If more than 1 heart rate measurement was present, we calculated an average. We analyzed geocoded heart rate data points that fell outside the coordinates of the walk (because of slight spatial errors inherent in GPS data) on the basis of the slice they occupied.

We then analyzed changes in heart rate averages across each walk on the basis of 3 exposure conditions: (1) being in view of study vacant lots, (2) being in view of nonstudy vacant lots, and (3) not being in view of any vacant lots. Being in view of vacant lots was thought to be a stronger influence on moment-to-moment physiological response than was being out of view.[26] We determined visible areas, or viewsheds, on the basis of altitude angle between the lot and local horizon in addition to building elevations.

Study participants served as their own controls over time in pre–post comparisons. We calculated simple linear regression models to obtain difference-in-differences (DD) estimates and SEs. The DD approach allowed us to compare the change in heart rate over time within and between those living near the

TABLE 1—Changes in Mean Heart Rates at the Intervention and Control Sites Before and After Greening Intervention Grounded on View of Vacant Lots: Philadelphia, PA, 2011

View	Preintervention		Postintervention		
	No. of HR Measurements	HR, bpm, Mean (SD)	No. of HR Measurements	HR, bpm, Mean (SD)	Difference, bpm (95% CI)
Intervention site					
In view of study vacant lots	519	103.3 (12.8)	439	107.2 (8.3)	3.9*** (2.5, 5.2)
Not in view of any vacant lot	1008	101.2 (16.4)	958	107.2 (9.3)	6.0*** (4.8, 7.1)
In view of nonstudy vacant lots	2452	99.6 (17.6)	1986	109.1 (9.5)	9.5*** (8.6, 10.3)
Difference-in-differences (study vs nonstudy vacant lots)					−5.6
Control site					
In view of study vacant lots	480	106.4 (10.8)	496	103.0 (8.3)	−3.4*** (−4.6, −2.2)
Not in view of any vacant lot	1472	109.5 (10.4)	1330	105.5 (8.2)	−4.0*** (−4.7, −3.3)
In view of nonstudy vacant lots	239	110.2 (9.9)	200	106.3 (9.3)	−3.9*** (−5.6, −2.0)
Difference-in-differences (study vs nonstudy vacant lots)					0.5

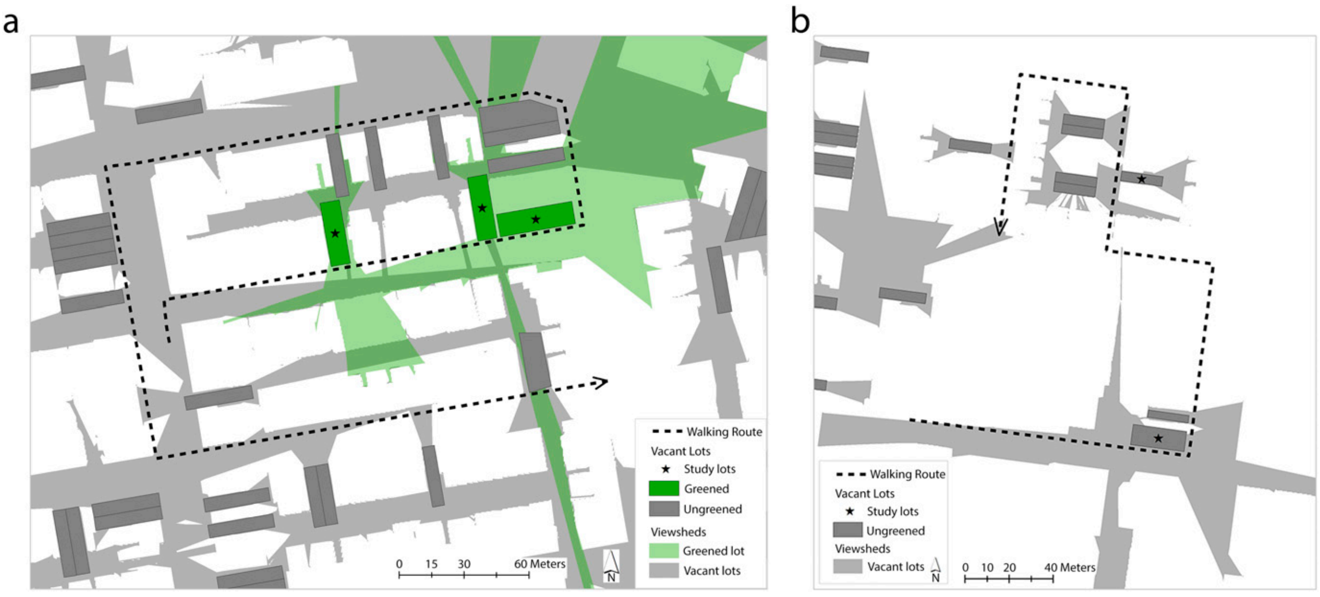
Note. bpm = beats per minute; CI = confidence interval; HR = heart rate.
*P = .05; **P < .01; ***P < .001.

control and intervention sites in response to the greening treatment. DD calculations are a common technique when comparing the difference between 2 before–after differences and are known as a before–after design with untreated comparison groups.

Very importantly, the DD approach can reduce several common threats to validity and better permits estimation of the true effect of an intervention or treatment on an outcome.[27] Participants served as their own controls over time in calculating before–after differences within participants, and we also calculated differences to compare participants in the intervention and comparison groups. We then calculated and interpreted the overall differences between these 2 sets of differences. We completed statistical analyses using Stata 13 version 11 (StataCorp LP, College Station, TX).

RESULTS

Overall, 12 study participants completed the pre- and postintervention walks, 7 at the greening site and 5 at the control site. All were African American, 8 were male, and the



Note. The dotted line indicates walking route for all participants. Green and gray viewsheds show areas of the walk from which trial participants saw greened and nongreened vacant lots as they walked. All vacant lot parcels (greened or nongreened) along the walk are pictured, with study vacant lots starred.

FIGURE 1—Site map showing walking route, vacant lots, and viewsheds for (a) the greening intervention site and (b) the control site: Philadelphia, Pennsylvania, 2011.

majority had a household income of less than $15 000.[17]

At the greening site, while in view of the study vacant lots, average heart rate went from 103.3 beats per minute (bpm) before greening to 107.2 bpm after greening, for a total increase of 3.9 bpm (Table 1; Figure 1a). When not in view of any lots, average heart rate went from 101.2 bpm to 107.2 bpm, for a total increase of 6.0 bpm. When in view of nongreened vacant lots, average heart rate went from 99.6 bpm in the preintervention period to 109.1 bpm in the postintervention period, for a total increase of 9.5 bpm. Thus, a monotonically increasing dose–response relationship was seen in pre–post heart rate differences. The final DD estimate between greened and nongreened vacant lots was statistically significantly lower, with a heart rate of −5.6 bpm (SE = 0.27; $P < .001$) for the greened site.

At the control site, the final DD estimate between study vacant lots and nonstudy vacant lots was an overall statistically significant increase in heart rate of 0.5 bpm (SE = 0.12; $P < .001$; Table 1; Figure 1b). This demonstrates the nominal difference in heart rate seen across time at the control site, compared with the decrease in heart rate seen after greening at the intervention site.

As a further test, we divided each walk into segments of city blocks that preceded or were immediately adjacent to study vacant lots (preceding segments) and the remainder of each walk (succeeding segments). At the greening site, during the preceding segment of the walk and while in view of the study vacant lots, the average participant heart rate decreased from 101.8 bpm before the greening treatment to 99.0 bpm after the greening treatment. By comparison, during the succeeding segment of this walk and while in view of nonstudy vacant lots, the average participant heart rate increased from 99.8 bpm to 110.0 bpm.

The pre–post DD estimate of preceding compared with succeeding segments was a reduction of −13.0 bpm. The pre–post DD estimate of preceding compared with succeeding segments while not in view of study vacant lots was 2.6 bpm. We calculated a final difference-in-differences-in-differences estimate of the within-view differences and the out-of-view differences as a statistically significant reduction of −15.6 bpm (SE = 1.72; $P < .001$; Table 2; Figure 2a). At the control site, we calculated a difference-in-differences-in-differences estimate of the within-view differences and the out-of-view differences as a statistically nonsignificant reduction of −1.7 bpm (SE = 1.64; $P = .298$), demonstrating that the effect of decreasing heart rate after greening was present largely at the greening site and not at the control site (Table 2; Figure 2b).

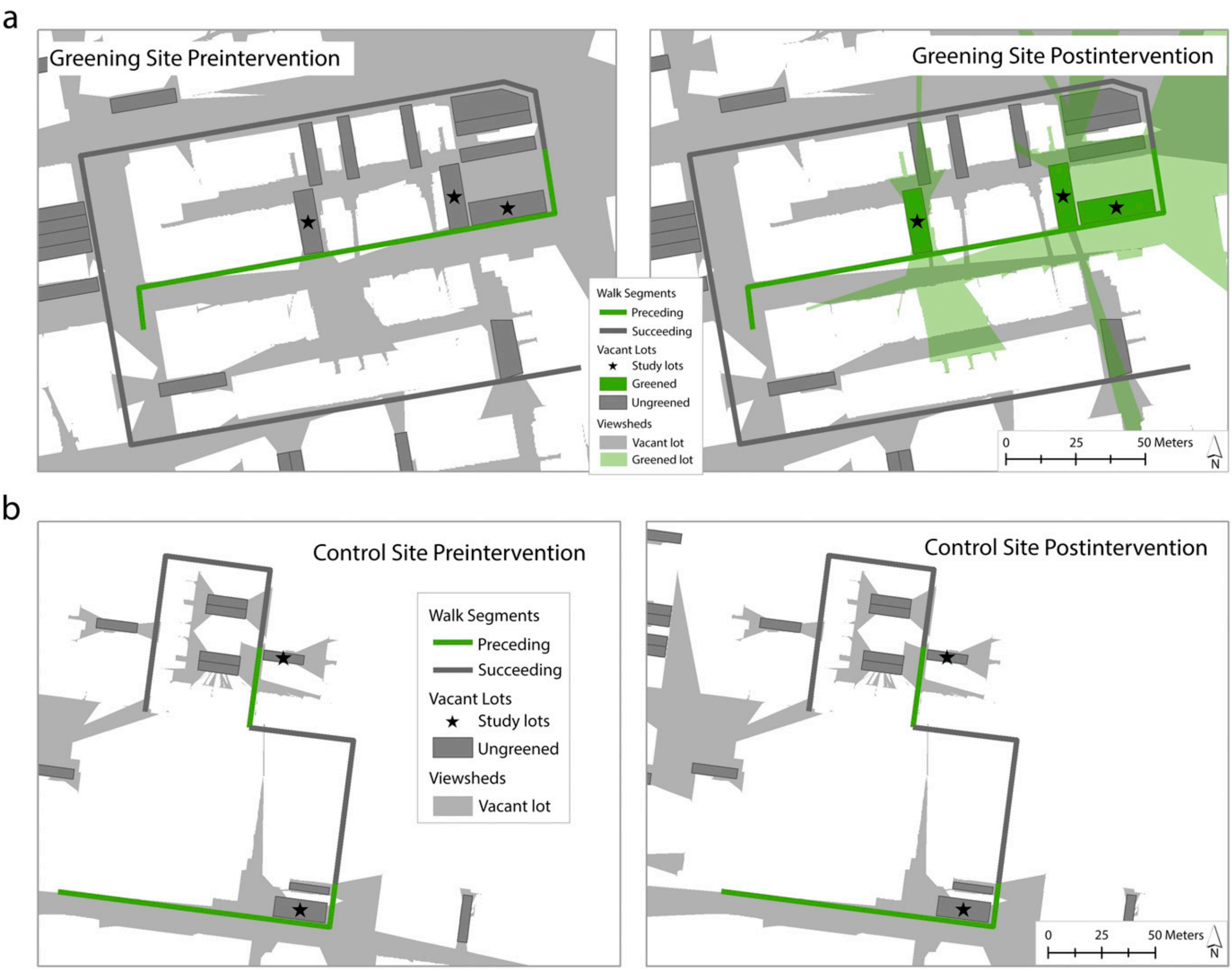
DISCUSSION

Our results indicate that in-view proximity to a greened vacant lot decreases heart rate compared with in-view proximity to a nongreened vacant lot. The reduction in heart rate suggests a biological link between

TABLE 2—Changes in Mean Heart Rate Grounded on Segmented Walk and the Intervention and Control Sites: Philadelphia, PA, 2011

View	Preintervention		Postintervention		
	No. of HR Measurements	HR, bpm, Mean (SD)	No. of HR Measurements	HR, bpm, Mean (SD)	Difference, bpm (95% CI)
Intervention site					
In view of a vacant lot					
Preceding segments of walk	708	101.8 (13.6)	155	99.0 (10.3)	-2.8** (-5.1, -0.6)
Succeeding segments of walk	2551	99.8 (17.5)	2063	110.0 (8.9)	10.2*** (9.3, 11.0)
Difference-in-differences					-13.0*** (-15.5, -10.4)
Not in view of a vacant lot					
Preceding segments of walk	392	98.3 (16.0)	837	106.2 (9.1)	7.9*** (6.6, 9.4)
Succeeding segments of walk	614	103.2 (16.5)	553	108.6 (8.8)	5.4*** (3.9, 7.0)
Difference-in-differences					2.6* (0.5, 7.0)
Difference-in-differences-in-differences					-15.6*** (-18.9, -12.1)
Control site					
In view of a vacant lot					
Preceding segments of walk	779	106.5 (11.0)	729	103.7 (8.5)	-2.8*** (-3.8, -1.8)
Succeeding segments of walk	143	110.2 (9.4)	136	108.3 (9.1)	-1.9 (-4.1, 0.25)
Difference-in-differences					-0.9 (-3.3, 1.7)
Not in view of a vacant lot					
Preceding segments of walk	190	108.6 (9.8)	168	104.4 (8.7)	-4.2** (-6.1, -2.2)
Succeeding segments of walk	1124	110.5 (10.1)	1045	105.4 (8.1)	-5.0** (-5.8, -4.3)
Difference-in-differences					0.8 (-1.2, 2.9)
Difference-in-differences-in-differences					-1.7 (-4.9, 1.5)

Note. bpm = beats per minute; CI = confidence interval; HR = heart rate.
**P* = .05; ***P* < .01; ****P* < .001.



Note. The solid line indicates the walking route for all participants. The green line is the segment of the walk leading up to and including study vacant lots. The gray portion of the line indicates all other portions of the walk. Green and gray viewsheds show areas of the walk from which trial participants saw greened and nongreened vacant lots.

FIGURE 2—Site map showing segmented walking route, vacant lots, and viewsheds for (a) the greening intervention site and (b) the control site: Philadelphia, Pennsylvania, 2011.

vacant lot greening and reduction in acute stress. To our knowledge, this is the first neighborhood walking trial in which a physiological marker was measured in real time for individuals in their native environments. Dynamic data such as these will be important in further detailing the impact of neighborhood physical conditions on stress in particular and on health in general. Future trials that dynamically measure additional biological information, such as cortisol and blood pressure, are needed to further advance our understanding of this pathway.

There were multiple limitations in this study. First, the degree to which heart rate changes in response to the environment depends not just on the stress response but also on a variety of individual factors such as baseline cardiovascular health, individual differences in heart rate reactivity, and medication use, factors that are difficult to control in the field. However, using random assignment for physical stressors, multiple counterfactual conditions (including spatial and within-participant comparisons), and finding real differences in heart rate variability in the field may provide greater face validity than do laboratory-situated tests.

Second, we chose to include only people living close to the sites because we did not want changes in heart rate to be attributable to the stress of being in an unfamiliar location. However, familiarity with the environment may have blunted the heart rate response of participants. Further work is needed to fully understand how proximity and familiarity to an environmental change affect physiological response. Third, this study had a small number of sites and participants; larger studies should be conducted.

This study adds real-world experimentation and much needed biological plausibility to a body of literature indicating that structural changes to urban environments, such as vacant lot greening, may be an effective mechanism for improving health.[5,28–30] Vacant lot greening requires no individual action to be effective and is a relatively simple and inexpensive intervention with the potential to affect the health of many residents.[31] If neighborhood blight contributes to the development of stress in a neighborhood, improvements to these physical conditions may lead to widespread downstream health benefits.[32] As evidence in support of such place-based public health interventions accumulates, policymakers can more confidently turn to these structural interventions as sustainable, first-line solutions to difficult urban problems. ■

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This article was accepted December 16, 2014.

Contributors

E. C. South conceptualized and conducted the study and led data analysis and article writing. M. C. Kondo and R. A. Cheney assisted in data analysis and writing. C. C. Branas supervised the study, the data analysis, and the article writing.

Acknowledgments

This work was supported by the National Institutes of Health ([NIH] grants R01AA020331 and R01AA016187 to C. C. B.), the Centers for Disease Control and Prevention ([CDC] grant U49CE001093), and the Robert Wood Johnson Foundation (RWJF) Health and Society Education Fund (to E. C. S.), with additional funding from the US Department of Agriculture (USDA), Forest Service (to M. C. K.).

Members of the Cartographic Modeling Lab at the Perelman School of Medicine at the University of Pennsylvania assisted in working with geographic information systems data.

Note. The NIH, the CDC, the RWJF, and the USDA had no role in designing or conducting the study; collecting, managing, analyzing, or interpreting the data; preparing, reviewing, or approving the article; or deciding to submit the article for publication.

Human Participant Protection

The University of Pennsylvania institutional review board approved this study. All participants provided written informed consent.

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