Environmental Research 158 (2017) 508–521

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Vegetated land cover near residence is associated with reduced allostatic load and improved biomarkers of neuroendocrine, metabolic and immune functions

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ARTICLE INFO

Keywords:
Allostatic load
Green space
Health effect biomarkers
Chronic stress
Depression

ABSTRACT

Background: Greater exposure to urban green spaces has been linked to reduced risks of depression, cardiovascular disease, diabetes and premature death. Alleviation of chronic stress is a hypothesized pathway to improved health. Previous studies linked chronic stress with a biomarker-based composite measure of physiological dysregulation known as allostatic load.
Objective: This study's objective was to assess the relationship between vegetated land cover near residences and allostatic load.
Methods: This cross-sectional population-based study involved 206 adult residents of the Durham-Chapel Hill, North Carolina metropolitan area. Exposure was quantified using high-resolution metrics of trees and herbaceous vegetation within 500 m of each residence derived from the U.S. Environmental Protection Agency's EnviroAtlas land cover dataset. Eighteen biomarkers of immune, neuroendocrine, and metabolic functions were measured in serum or saliva samples. Allostatic load was defined as a sum of potentially unhealthy biomarker values dichotomized at 10th or 90th percentile of sample distribution. Regression analysis was conducted using generalized additive models with two-dimensional spline smoothing function of geographic coordinates, weighted measures of vegetated land cover allowing decay of effects with distance, and geographic and demographic covariates.
Results: An inter-quartile range increase in distance-weighted vegetated land cover was associated with 37% (95% Confidence Limits 46%; 27%) reduced allostatic load; significantly reduced adjusted odds of having low level of norepinephrine, dopamine, and dehydroepiandrosterone, and high level of epinephrine, fibrinogen, vascular cell adhesion molecule-1, and interleukin-8 in serum, and α-amylase in saliva; and reduced odds of previously diagnosed depression.
Conclusions: The observed effects of vegetated land cover on allostatic load and individual biomarkers are consistent with prevention of depression, cardiovascular disease and premature mortality.

1. Introduction

Greater exposure to green and natural environments in urban and suburban settings is associated with various health benefits (WHO, 2016). These benefits include improved mental health (Gascon et al., 2015), reduced incidence of type 2 diabetes (Astell-Burt et al., 2014), improved pregnancy outcomes (Dzhambov et al., 2014), reduced cardiovascular disease (Tamosiunas et al., 2014) and reduced mortality (Gascon et al., 2016).

Exposure to the green environment is linked with these health benefits through various interacting pathways, such as chronic stress alleviation, improved social cohesion, enhanced physical activity, and

Abbreviations: aOR, adjusted odds ratio; AL, allostatic load; BMI, body mass index; CL, confidence limits; CRP, C-reactive protein; DHEA, dehydroepiandrosterone; HDL, high density lipoprotein; IBS, irritable bowel syndrome; ICAM-1, intercellular adhesion molecule 1; IL, interleukin; IQR, interquartile range; LDL, low density lipoprotein; pctl, percentile; SAA, serum amyloid A; TNF, tumor necrosis factor; US EPA, United States Environmental Protection Agency; VCAM-1, vascular cell adhesion protein 1.

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http://dx.doi.org/10.1016/j.envres.2017.07.009
Received 7 March 2017; Received in revised form 3 July 2017; Accepted 4 July 2017
0013-9351/ Published by Elsevier Inc.

reduced air pollution (Hartig et al., 2014). Relative contributions of these different pathways to specific health outcomes may depend on the type of exposure to the green environment (e.g. urban parks vs. vegetation near residence) and specific population subgroup (WHO, 2016). According to the biophilia hypothesis, humans have an innate need to affiliate with the living natural environment (Wilson, 1984). As it appears that people are innately predisposed to find non-threatening natural stimuli relaxing, exposure to these stimuli triggers a parasympathetic nervous system response leading to feelings of enhanced well-being and relaxation, and shifting stressed individuals to a more positive emotional state (Ulrich et al., 1991).

Corroborating the biophilia hypothesis, reviews of epidemiological evidence demonstrated that restoration and stress reduction may be the most important pathways to better mental and physical health in individuals living in greener areas (Dadvand et al., 2016; Triguero-Mas et al., 2015). Studies in different countries have linked greater vegetated land cover as well as improved access to geographically defined green spaces to reduced levels of depression, anxiety and psychological distress (Astell-Burt et al., 2013; Beyer et al., 2014; Pope et al., 2015; Reklaitiene et al., 2014; Taylor et al., 2015).

Previous studies explored biological mechanisms underlying mental and physiological benefits of short-term contacts with nature. For example, an experimental study using wearable electroencephalogram (EEG) devices demonstrated the effects of a short walk in a green urban area on brain activity indicative of enhanced relaxation and restoration (Aspinall et al., 2015). Other studies have demonstrated beneficial effects of “forest bathing” and various short-term contacts with nature on biomarkers of cardiovascular, neuroendocrine and immune functions (Haluza et al., 2014). A cross-sectional observational study in the U.K. demonstrated that, among economically deprived sub-populations, residents of greener neighborhoods have healthier diurnal salivary cortisol patterns indicating reduced effects of chronic stress (Roe et al., 2013; Thompson et al., 2012).

Chronic environmental challenges that an individual perceives as stressful are known to have systemic detrimental effects, manifesting in measurable physiological dysregulation. Allostatic load (AL) is a biomarker-based measure of such dysregulation reflecting the physiological consequences of chronically fluctuating neural or endocrine responses resulting from repeated stress (McEwen and Stellar, 1993; McEwen, 2002; Seeman et al., 1997). Numerous studies have used various AL indices which incorporate biomarkers of neuroendocrine, immune, metabolic and cardiovascular system functioning to demonstrate profound health implications of AL including burnout syndrome, reduced cognitive performance, increased risks of cardiovascular morbidity and death (Juster et al., 2010, 2011; Karlamangla et al., 2014; McEwen, 2015; Milot et al., 2014).

AL has been increasingly used in epidemiology and community health research, and linked to adverse social and environmental conditions (Hansen et al., 2014; Jung et al., 2014; Juster et al., 2010; Petrovic et al., 2016; Robinette et al., 2016). While many previously conducted studies of health benefits of short-term exposure to outdoor nature have utilized some AL biomarkers (Haluza et al., 2014), to our knowledge, AL or other composite measures of physiological dysregulation based on multiple biomarkers have not been used to assess effects of long-term exposure to urban green spaces and living natural environments.

The main objective of the present study was to assess an association between vegetated land cover near participants' residences and AL. Additional objectives were: (i) to explore associations between vegetated land cover and individual biomarkers in order to demonstrate potential mechanisms of beneficial health effects; and (ii) to explore associations between vegetated land cover, and diseases and health conditions.

2. Methods

2.1. Study design

This cross-sectional community-based study used archived serum and saliva samples, and associated questionnaire data from a previously conducted study in the Durham-Chapel Hill, North Carolina metropolitan area, which was designed to identify individual and community level factors affecting general health status and risks of selected chronic infections.

2.2. Human subjects: recruitment and data collection

The study protocol involving the use of human subjects was approved by the Institutional Review Board at the University of North Carolina at Chapel Hill. Participants were recruited through advertisement in local newspapers and internet sites.

Enrollment was limited to individuals of at least 18 years of age. Data collection was conducted at the U.S. Environmental Protection Agency (US EPA) Human Studies Facility in Chapel Hill, NC in May-September 2013. All data were collected during a single visit by a study participant, usually in the morning. The participants signed an informed consent form prior to data collection. Venous blood samples were drawn by registered nurses in BD Vacutainer SST Tubes without an anticoagulant (Becton, Dickinson and Company, Franklin Lakes, NJ). Serum was separated by centrifugation following manufacturer instructions. Oral fluid (hereafter called saliva) samples were collected using Oracol samplers (Malvern Medical Developments, United Kingdom), which consist of a cylindrical sponge with a handle and a container. Sampling involves rubbing the gums with the sponge for one minute or until the sponge becomes saturated with saliva (this sampling method produces variable sample volumes from less than 0.1 to 1 mL). Saliva was separated from the sponge by centrifugation in the collection tube at 1500*g* for 5 min. Debris were pelleted by centrifugation at 2500*g* for 5 min. Samples were transferred to microcentrifuge tubes and then further separated from debris by centrifugation at 3000*g* for 3 min and then transferred to a final microcentrifuge tube. Samples were archived immediately after processing at −80 °C.

A brief questionnaire included basic demographic information, as well as data on self-assessed health status and medically diagnosed chronic diseases and conditions.

2.3. Land cover data analysis

The residential vegetated land cover data were derived from 1 m resolution classified land cover data published online by the US EPA as part of the EnviroAtlas mapping application and decision toolkit ⟨https://www.epa.gov/enviroatlas⟩. Land cover data for the contiguous United States has 30 m resolution; 1-meter resolution land cover data are available for selected census urban areas including the Durham-Chapel Hill, NC metropolitan area (Pickard et al., 2015). The classified land cover data for Durham - Chapel Hill were developed with remote-sensing methods from U.S. Department of Agriculture 2010 National Agriculture Imagery Program (NAIP) aerial photography and Supplemental data including Light Detection and Ranging (LiDAR) data. The land cover data for this area include five categories: (i) Water, (ii) Impervious surface, (iii) Soil & barren, (iv) Trees & forest, and (v) Grass & other herbaceous. US EPA previously conducted error analysis of the land cover data through random sampling of approximately 600 photo-interpreted reference points which demonstrated that the land cover classification for this area had an overall accuracy of 83%. For this study, total vegetated land cover was defined as the proportion of land within the Tree & forest and Grass & other herbaceous categories.