Health & Place 36 (2015) 1–7

Contents lists available at ScienceDirect

Health & Place

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

Is tree loss associated with cardiovascular-disease risk in the Women's Health Initiative? A natural experiment

Geoffrey H. Donovan [a,*], Yvonne L. Michael [b], Demetrios Gatziolis [a], Jeffrey P. Prestemon [c], Eric A. Whitsel [d]

[a] USDA Forest Service, Pacific Northwest Research Station, Portland, OR, USA
[b] Drexel University, Department of Epidemiology and Biostatistics, Philadelphia, PA, USA
[c] USDA Forest Service, Southern Research Station, Research Triangle Park, NC, USA
[d] University of North Carolina, Gillings School of Global Public Health, Chapel Hill, NC, USA

ARTICLE INFO

Article history:
Received 23 February 2015
Received in revised form
12 August 2015
Accepted 24 August 2015

Keywords:
Natural environment
Pubic health
Cardiovascular disease
Lower respiratory

ABSTRACT

Data from the Women's Health Initiative were used to quantify the relationship between the loss of trees to an invasive forest pest—the emerald ash borer—and cardiovascular disease. We estimated a semi-parametric Cox proportional hazards model of time to cardiovascular disease, adjusting for confounders. We defined the incidence of cardiovascular disease as acute myocardial infarction requiring overnight hospitalization, silent MI determined from serial electrocardiograms, ischemic or hemorrhagic stroke, or death from coronary heart disease. Women living in a county infested with emerald ash borer had an increased risk of cardiovascular disease (HR=1.25, 95% CI: 1.20–1.31).

Published by Elsevier Ltd.

1. Introduction

A growing body of research supports a health-promoting role for the natural environment. However, two related methodological issues can make it challenging to interpret the results of this research. First, when studying the health effects of residential exposure to green space, it can be costly and time consuming to experimentally manipulate the natural environment. Therefore, many studies are cross-sectional (Astell-Burt et al., 2013; Bell et al., 2008; Coombes et al., 2010a; Dadvand et al., 2012; Donovan et al., 2011; Groenewegen et al., 2006; Hu et al., 2008; Kuo and Sullivan, 2001; Lovasi et al., 2011; Maas et al., 2006; Nutsford et al., 2013; Stigsdotter et al., 2010; Witten et al., 2008). Second, the association between the natural environment and health outcomes is prone to confounding by unmeasured factors (Frumkin, 2013). For example, long-term cigarette smokers are less likely to live in areas with green space (Villeneuve et al., 2012), and the probability of living in areas with fewer trees can vary significantly by race (Jesdale et al., 2013).

In a previous study (Donovan et al., 2013), we addressed these two challenges by quantifying the relationship between the spread of an invasive tree pest—the emerald ash borer (EAB)—and county-level cardiovascular and lower-respiratory mortality. The emerald ash borer has killed over 100 million ash trees since it was first detected in Detroit, Michigan in 2002. This significant, and rapid, loss of trees is a unique natural experiment in which observed and unobserved characteristics of participants at the individual or aggregate level are independent of exposure. In addition, although tree cover in urban areas is correlated with socio-economic status (Heynen et al., 2006; Jesdale et al., 2013), the loss of trees in far less likely to be correlated with demographic changes because of the speed and pattern of EAB's spread (Fig. 1). Crucially, the spread of EAB allowed us to study the relationship between public health and tree loss longitudinally rather than the relationship between trees and public health at one point in time. We found that counties infested with EAB had increased rates of cardiovascular and lower-respiratory mortality, and the magnitude of this relationship increased as an infestation progressed. From 2002 to 2007, EAB infestation was associated with an additional 15,000 deaths from cardiovascular disease and an additional 6000 deaths from lower-respiratory disease across 15 states in the Midwest and East.

Although our approach avoided some of the challenges of past cross-sectional studies, it did have other limitations. In particular, we focused on county-level mortality, so our results may be subject to

* Correspondence to: PNW Research Station, 620 SW Main, Suite 400, Portland, OR 97205, USA. Fax: +1 503 808 2033.
E-mail address: gdonovan@fs.fed.us (G.H. Donovan).

http://dx.doi.org/10.1016/j.healthplace.2015.08.007
1353-8292/Published by Elsevier Ltd.

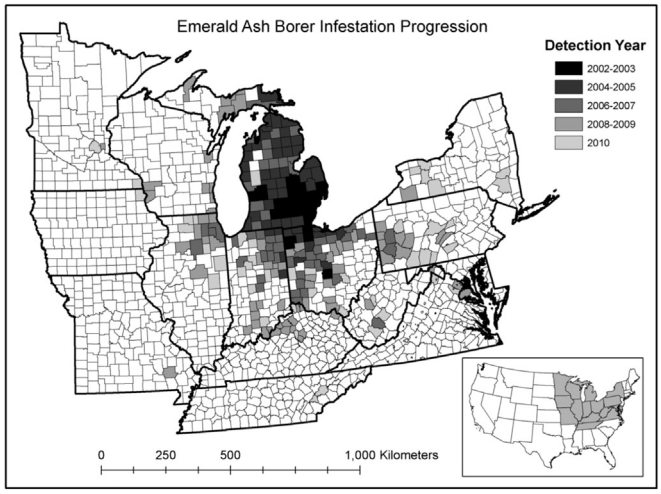

Fig. 1. Spread of the emerald ash borer by county 2002–2010.

ecological bias. To address this limitation, we make use of individual-level outcome data from one of the largest studies of women's health undertaken in the U.S—the Women's Health Initiative (WHI)—to determine whether loss of trees from EAB is a risk factor for cardiovascular disease.

Several other recent studies have quantified the relationship between the natural environment and cardiovascular disease. Pereira et al. (2012) focused on the link between coronary heart disease, stroke, and the natural environment in Perth, Australia. In common with many large-scale studies, they measured greenness using the normalized difference vegetation index (NDVI), which is derived from satellite imagery. After controlling for confounders, they found that adults living in neighborhoods with highly variable greenness had a 37% lower rate of coronary heart disease and stroke. Interestingly, total greenness was not significantly related to incidence of either disease. Paquet et al. (2014) examined the relationship between access to public open space and cardio-metabolic risk factors. They found that proximity to open space was associated with lower levels of diabetes and pre-diabetes. In Taiwan, Tsao et al. (2014) measured subclinical cardiovascular disease in 104 volunteers who worked in a forest environment versus 114 who worked in an urban environment. After adjustment for confounders, urban workers had higher total cholesterol, LDL cholesterol, and fasting glucose. Mitchell and Popham (2008) analyzed the health records of over 40 million people in England. They found lower rates of circulatory-disease mortality in greener areas. They also found that health disparities were lower in greener areas. Not all studies found a significant relationship between greenness and cardiovascular disease. Richardson et al. (2012) used a land-use model to quantify the relationship between greenness and city-level mortality in the 49 largest cities in the US. They found no relationship between greenness and cardiovascular mortality demonstrating that green-health relationships observed at the individual level are not always seen at the population scale.

To our knowledge, there have been no longitudinal studies of the relationship between the natural environment and cardiovascular disease. Indeed, there have been few green longitudinal studies of any kind. One notable exception is Alcock et al. (2014), who, found that moving to a greener area was associated with a sustained improvement in mental health.

A number of recent review articles have summarized the literature on the health benefits of nature. For example see James et al. (2015) or Lee and Maheswaran (2011).

1.1. Mechanisms linking the natural environment and cardiovascular disease

In a recent paper, Hystad et al. (2014) outlined four possible mechanisms linking the natural environment and public-health outcomes: (1) Reducing environmental risks factors such as air pollution; (2) Encouraging exercise; (3) Increasing social contacts; (4) Reducing stress. We begin by summarizing the evidence that the natural environment can influence health outcome via these four mechanisms. We then focus on the importance of these four mechanisms for cardiovascular disease.

1.1.1. Air pollution

There is strong evidence that the natural environment can reduce air pollution. For example, research has found that increased greenness is associated with reduced nitrogen dioxide (Rao et al., 2014; Yin et al., 2011), ozone (Alonso et al., 2011), and particulate matter (Nowak et al., 2006). In turn, multiple studies have found that air pollution is associated with increased incidence of cardiovascular disease (Feng and Yang, 2012; Metzger et al., 2004).

1.1.2. Exercise

Several studies have identified a positive relationship between exercise and different measures of access to green space. For example, Coombes et al. (2010b) found that adult exercise frequency was negatively correlated with distance to green space. Roemmich et al. (2006) showed that young children with greater park area in their neighborhood exercised more. However, not all studies found a significant relationship between exercise and access to the natural environment. For example, Foster et al. (2009) failed to find a correlation between access to green space and self-reported recreational walking in adults. Similarly, Witten et al. (2008) found no relationship between exercise and distance to parks. The relationship between the natural environment and exercise may not be clear; however, the relationship between exercise and the risk of cardiovascular disease is well established (Kohl Iii, 2001; Li and Siegrist, 2012).

1.1.3. Social connections

A relatively small body of research has shown a positive correlation between the natural environment and social support. Maas et al. (2009) found that adults with less green space within 3 km of their homes were more likely to self-report loneliness and low levels of social support. Kim and Kaplan (2004) found that higher amounts of open space within a residential development was associated with increased sense of community. In turn, numerous studies have found that a low level of social support is a risk factor for cardiovascular disease (Barth et al., 2010; Heffner et al., 2011).

1.1.4. Stress

A number of experimental studies have shown that exposure to the natural environment can reduce short-term markers of stress. For example, Park et al. (2008) exposed 12 male students to a forested and an urban environment. Subjects in the forest had significantly lower blood pressure, salivary cortisol, and heart-rate variability. Ulrich et al. (1991) exposed 120 volunteers to a stressful video followed by six different videos of urban and natural scenes. Stress recovery was quicker and more complete, when subjects watched a video of a natural scene. Wichrowski et al. (2005) studied stress reduction in 107 people participating in an inpatient cardiopulmonary rehabilitation program. Post intervention, the horticultural-therapy group had lower heart rate and lower total-mood disturbance. Further, elevated cortisol (Fraser et al., 1999), increased heart-rate variability (Tsuji et al., 1994), and high blood pressure (Staessen et al., 2000) are risk factors for cardiovascular disease.