Environment International 109 (2017) 29–41

Contents lists available at ScienceDirect

Environment International

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

Land cover and air pollution are associated with asthma hospitalisations: A cross-sectional study

Ian Alcock[a,*], Mathew White[a], Mark Cherrie[b,a], Benedict Wheeler[a], Jonathon Taylor[c], Rachel McInnes[d,a], Eveline Otte im Kampe[e], Sotiris Vardoulakis[f,g,a], Christophe Sarran[d], Ireneous Soyiri[b], Lora Fleming[a]

[a] University of Exeter, United Kingdom
[b] University of Edinburgh, United Kingdom
[c] University College London, United Kingdom
[d] MetOffice, United Kingdom
[e] London School of Hygiene and Tropical Medicine, United Kingdom
[f] Institute of Occupational Medicine, United Kingdom
[g] Public Health England, United Kingdom

A R T I C L E I N F O

Keywords:
Ecosystem management
Air pollutants
Green space
Urban land use
Pollen
Allergy

A B S T R A C T

Background: There is increasing policy interest in the potential for vegetation in urban areas to mitigate harmful effects of air pollution on respiratory health. We aimed to quantify relationships between tree and green space density and asthma-related hospitalisations, and explore how these varied with exposure to background air pollution concentrations.

Methods: Population standardised asthma hospitalisation rates (1997–2012) for 26,455 urban residential areas of England were merged with area-level data on vegetation and background air pollutant concentrations. We fitted negative binomial regression models using maximum likelihood estimation to obtain estimates of asthma-vegetation relationships at different levels of pollutant exposure.

Results: Green space and gardens were associated with reductions in asthma hospitalisation when pollutant exposures were lower but had no significant association when pollutant exposures were higher. In contrast, tree density was associated with reduced asthma hospitalisation when pollutant exposures were higher but had no significant association when pollutant exposures were lower.

Conclusions: We found differential effects of natural environments at high and low background pollutant concentrations. These findings can provide evidence for urban planning decisions which aim to leverage health co-benefits from environmental improvements.

1. Introduction

Asthma is a chronic inflammatory condition of the airways of the lungs which causes hyper-responsiveness to specific triggers, and leads to a variety of respiratory symptoms (GINA, 2017). Persistent low-level symptoms can be exacerbated by exposure to stressors such as influenza, air pollution and environmental allergens. In the UK, 18% of adults report asthma in the previous 12 months (To et al., 2012), and symptoms are reported by 21% of 6–7 year olds and 25% of 13–14 year olds (Asher et al., 2000). Over 5.4 million people are currently receiving treatment in the UK, at an annual cost to the National Health Service of around £1 billion (www.asthma.org.uk).

Exposure to higher levels of outdoor air pollutants such as nitrogen dioxide (NO_2), particulate matter < 2.5 μm (PM2.5) and sulphur dioxide (SO_2) has been associated with the onset of wheeze and asthma in pre-school infants (Clark et al., 2010), school-aged children (Khreis et al., 2017; Gasana et al., 2012) and adults (Anderson et al., 2013). Exacerbation in those who already have asthma has also been linked to exposure to outdoor air pollution. For example, short-term increases in pollutant exposure are associated with increased asthma symptoms and asthma-related emergency room visits (Zheng et al., 2015; Weinmayr et al., 2010); and long-term background pollutant exposure is associated with increased asthma-related hospitalisations (Roberts et al., 2012). Indoor air quality (alongside other indoor environmental factors) is also important for asthma prevalence (Kanchongkittiphon et al., 2015).

* Corresponding author.
E-mail address: i.alcock@exeter.ac.uk (I. Alcock).

http://dx.doi.org/10.1016/j.envint.2017.08.009
Received 3 March 2017; Received in revised form 16 August 2017; Accepted 16 August 2017
Available online 27 September 2017

The potential for vegetation to mitigate the negative health impacts of air pollution has received considerable interest from urban planners (Escobedo et al., 2011). Trees and plants reduce ambient particulate concentrations by capturing particles on their leaf surfaces (Wuyts et al., 2008; Roy et al., 2012), and leaf stomata can absorb gaseous pollutants (Chaparro-Suareza et al., 2011). Models of urban area airsheds (ground to atmospheric boundary layer) suggest that reductions in particulates from deposition on urban trees are modest (Tallis et al., 2011). Importantly, however, localised improvements to air quality for those living in close proximity to urban trees may be both much higher and of medical significance (McDonald et al., 2016). Trees can also influence wind turbulence and thus the dispersion of air pollutants (Janhäll, 2015). Urban trees may increase pollutant concentrations in some street canyon configurations (Salmond et al., 2013; Vos et al., 2013), but reduce pollutant concentrations when winds are parallel to street canyons (Amorim et al., 2013; Abhijith and Gokhale, 2015).

The potential impacts on asthma of tree cover and green spaces in general are further complicated by their generation of allergenic pollen. Even though not all asthmatics react to pollen, short-term variation in local pollen concentrations is associated with allergy medication purchases (Ito et al., 2015), asthma symptoms (DellaValle et al., 2012), and asthma-related emergency department visits (Ito et al., 2015; Jariwala et al., 2011; Orazzo et al., 2009). Moreover, there is evidence from laboratory and field experiments to suggest that environmental air pollutant and allergenic pollen exposures may interact (Motta et al., 2006; Ghiani et al., 2012). For example, studies show that NO_2 can impact on pollen morphology (Chassard et al., 2015; Zhao et al., 2015), as well as change the pollen protein content or protein release processes, although effects are species and concentration dependent (Frank and Ernst, 2016). There is also evidence that grass pollen allergen molecules can bind to other fine particles in polluted air and become concentrated (Namork et al., 2006). In addition, airways damaged by air pollutant exposure may be more susceptible to hyper-responsiveness with allergen exposure (D'Amato et al., 2010). Consistent with these mechanisms, there is evidence of the interactive effects of pollen and other aeroallergens with air pollutants on increased hospitalisation for asthma (Cakmak et al., 2012; Hebbern and Cakmak, 2014).

The net effects of urban trees and green spaces on asthma exacerbation are likely therefore to result from opposing influences which are not easily separated in empirical investigation, and are necessarily compounded in the experience of asthma sufferers in their contacts with natural environments. Indeed, a wider variety of exacerbating and mitigating environmental factors than those discussed above may be involved. Even as they remove particulate and gaseous pollutants, urban woodlands and green spaces may reduce air quality through the emission of biogenic volatile organic compounds which contribute to the formation of ozone (Domm et al., 2008). Effects on asthmatics may also result from exposure to fungal spores and moulds (Sharpe et al., 2014), saprophytic bacteria and polyphenolic compounds (Rook, 2013). Exposure to natural environments may also impact on asthma through effects on human skin proteobacteria, which can in turn affect atopic sensitisation (Ruokolainen et al., 2015). In addition, green space can promote physical activity and reduce stress (Hartig et al., 2014), which may in turn reduce the risk of asthma attacks, given the potential for overweight/obesity (Beuther et al., 2006) and stress (Vliagoftis, 2014) to exacerbate the condition.

Few studies have investigated the net effect of these multiple and potentially conflicting influences of urban trees and green space on asthma. Findings from the limited previous investigations are inconsistent, possibly due to differences between studies in the spatial resolution or local characteristics of vegetation, or in asthma outcome measure, sampled population, or covariate controls. Individual level analyses of the effects of green land cover measures on asthma outcomes have suggested beneficial (Maas et al., 2009; Sbihi et al., 2015), null (Lovasi et al., 2013; Dadvand et al., 2014; Andrusaityte et al., 2016) and even harmful relationships (Lovasi et al., 2013; Dadvand et al., 2014; Andrusaityte et al., 2016); ecological level analyses have suggested both beneficial (Ayres-Sampaio et al., 2014; Erdman et al., 2015; Lovasi et al., 2008) and null relationships (Ayres-Sampaio et al., 2014; Erdman et al., 2015; Lovasi et al., 2008; Pilat et al., 2012).

Importantly, previous studies are generally at relatively low spatial resolution (leading to imprecision in exposure estimation) and there are almost no examples of large population studies which relate asthma surveillance data at high geographic resolution with local natural environment characteristics. The current study aimed to address this issue by examining emergency hospitalisations for asthma in a small-area ecological analysis of all urban residential areas in England and testing associations with two green space land use measures (neighbourhood green space and domestic gardens) and with tree density. Furthermore, we also recognised the importance of potential interactions between natural environment and air pollutant exposures, driven by processes of pollutant deposition, pollutant dispersion, pollen allergen development and the bio-availability of pollen allergens, as well as direct synergistic exposure effects for asthma sufferers. We therefore aimed to examine not only how asthma hospitalisations are associated with natural environments when adjusted for the effects of air pollutants, but also how the associations between hospitalisations and natural environment exposure might vary at different levels of air pollutant exposure. An understanding of these relationships is needed to inform targeted interventions, public health policies and urban planning.

2. Methods

2.1. Overview

English Hospital Episode Statistics (http://www.content.digital.nhs.uk/hes) were used in a cross-sectional ecological analysis to examine associations between emergency hospitalisations for asthma (ICD-10 J45/J46), natural environments and background air pollutant concentrations. Hospitalisations (n = 660,505) for the study period 1st April 1997 to 31st March 2012 amongst residents of urban areas in England were summed by geographical areas called 'Lower-layer Super Output Areas' (LSOAs, defined by the UK government for statistical reporting for England). LSOAs encompass similar sized populations and have a mean physical area of c. 0.9 km^2 in urban areas (n = 26,455, with a total population in 2001 of c. 41M). Period (1997–2012) population standardised emergency hospitalisations for asthma for each urban LSOA were linked to other data at LSOA level, specifically: area level measures of public green spaces, domestic gardens and tree cover (collectively referred to as '*natural environments*' henceforth); air pollution; and Indices of Deprivation (IOD). Negative binomial regression models were used to explore associations between asthma and these factors. Analyses were performed in Stata 14 (StataCorp, College Station TX).

2.2. Asthma data

Standardised hospitalisation rates for asthma (1997–2012) were calculated for each urban LSOA from the area total hospitalisations and from data on the (2001) area population size. Using data on the (2001) age structure of the population of each of the LSOAs, a direct standardisation was undertaken of these LSOA crude rates, to the 2013 European Standard Population (ESP). These standardised hospitalisation rates (per 100,000 ESP, referred to as the '*asthma rate*' henceforth) enabled comparison between areas.

2.3. Natural environment data

Two measures of 'natural' environment density, 1) LSOA percentage of green space and 2) LSOA percentage of gardens, were derived from the Generalised Land Use Database (GLUD, Department for Communities and Local Government, 2007), which divides the total