



# Multiple health benefits of urban tree canopy: The mounting evidence for a green prescription



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## ABSTRACT

The purpose of this study was to enhance the understanding of the health-promoting potential of trees in an urbanized region of the United States. This was done using high-resolution LiDAR and imagery data to quantify tree cover within 250 m of the residence of 7910 adult participants in the California Health Interview Survey, then testing for main and mediating associations between tree cover and multiple health measures. The results indicated that more neighborhood tree cover, independent from green space access, was related to better overall health, primarily mediated by lower overweight/obesity and better social cohesion, and to a lesser extent by less type 2 diabetes, high blood pressure, and asthma. These findings suggest an important role for trees and nature in improving holistic population health in urban areas.

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## 1. Introduction

Rapid global urbanization brings economic, educational, and social opportunities. However, an increasing number of urban dwellers are not within easy access and contact with nature that is fundamental to human health and well-being (Wolf and Robbins, 2015). Investing in green infrastructure and natural environments within urbanized settings is becoming increasingly important. Humans evolved and have lived in mostly natural settings until very recently (Turner et al., 2004). Although many residents in urban areas typically benefit from superior access to health care, education, and other services compared to their rural counterparts, these benefits are offset by the sedentary aspects of modern living and the presence of urban threats to physical and

psychological health (Ng and Popkin, 2012; Vlahov and Galea, 2002).

Urbanization is often associated with social stress, physical threats (e.g., crime, traffic safety), and adverse environmental exposures (e.g., noise, air pollution) (Lederbogen et al., 2011; Peen et al., 2010; Vlahov and Galea, 2002). Contemporary lifestyles are generally associated with large reductions in occupational, domestic, and transportation-related physical activity, offset by only a small increase in leisure activity (Brownson et al., 2005; Ng and Popkin, 2012). In combination with changes in dietary intake, these trends have led to the high current rate of obesity and associated health risks, quality of life reduction, and health care cost increases (Jia and Lubetkin, 2005; Li et al., 2005; Ogden et al., 2014; Withrow and Alter, 2011). Urbanization and modernization are trends that will continue; therefore researchers have recommended the cultivation of urban nature to help counteract these health threats (Frumkin, 2001; Largo-Wight, 2011; Hartig et al., 2014).

Decades of research suggest that exposure to nature and green spaces can help to reduce stress, promote restoration, and generally improve mental health (Bowler et al., 2010; Bratman et al.,

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2012; Maller et al., 2006). Frederick Law Olmsted, a 19th century landscape architect and designer of major urban parks across the USA, noted that access to green space and sunlight was needed to “re-create” oneself (Olmstead, 2010). Hypothesized explanations of the mental health-promoting influence of natural environments espouse that nature can help to replenish directed attention (Kaplan and Kaplan, 1989; Kaplan, 1995) and reduce stress (Ulrich, 1983, 1979). Others have hypothesized that humans have an innate affiliation and need for connection with the natural world (the biophilia hypothesis), and we have yet to fully adapt to urban environments (Kellert and Wilson, 1993; Wilson, 1984).

This study was an effort to provide evidence to support this theory. In an exploratory study situated in the Sacramento California region, more neighborhood tree cover was found to be significantly associated for adults of age 18–64 with more vigorous physical activity, less obesity, better general health, less asthma, and better social cohesion (Ulmer et al., 2014). The purpose of the analysis reported here was to enhance the understanding of the interrelationships between the health-promoting characteristics of tree cover in an urbanized area. The primary hypothesis was that more neighborhood tree cover was associated with better general health. The secondary hypothesis was that the association between more tree cover and better general health was explained by the cumulative effect of more tree cover on better social cohesion, more physical activity, and less prevalent overweight/obesity, type 2 diabetes, high blood pressure, and psychological distress. This study fills a gap in the existing research by focusing specifically on exposure to tree cover independent from other types of green space or vegetation, and by assessing tree cover associations with a comprehensive range of health measures within a local human population.

## 2. Literature review

A rapidly expanding scholarly literature indicates there is health promotion and disease prevention potential of nature experiences in cities ranging from site to community scale (Wolf and Robbins, 2015). For instance, one body of literature links nature and green space access or views to improved psychosocial health (Branas et al., 2011; Fan et al., 2011; Hartig et al., 2003; Leather et al., 1998; Nielsen and Hansen, 2007; Ulrich et al., 1991). Of studies focused specifically on trees, one study found an association between more streetscape greenery and better mental health status, better social cohesion, and reduced stress (de Vries et al., 2013). Sugiyama et al. (2008) found an association between higher self-reported neighborhood “greenness” (which included tree cover and other green measures) and better mental and social health in Danish adults. A series of studies of public housing residents in Chicago found that residents with more vegetation outside their windows reported less stress, less mental fatigue, and lower severity of life issues, had more social ties, used common spaces more, and reported lower levels of fear, violence, aggression, and other incivilities (Kuo and Sullivan, 2001a, 2001b, Kuo, 2001; Kuo et al., 1998).

More recently, the nature and well-being research has expanded to consider the impacts on physical health. Several researchers have suggested the potential benefit of green spaces towards reducing obesity and improving health in general (Bedimo-Rung et al., 2005; Feng et al., 2010; Lachowycz and Jones, 2013). Lachowycz and Jones (2013) suggested that both physical usage within and psychosocial benefits derived from green space contribute to improving physical health, but those benefits may be moderated by time availability for using green spaces, transportation accessibility, personal motivations, and neighborhood conditions. Recent reviews and original studies have provided some

evidence in support of the benefits of green space for physical activity and obesity, though the findings are somewhat inconsistent (Lachowycz and Jones, 2011; Lee and Maheswaran, 2011; Villeneuve et al., 2012).

The specific impact of tree cover on physical activity, obesity, and physical health has received far less attention than has green space. van Dillen et al. (2012) found that both the quality and quantity of streetscape greenery were related to better perceived general health and fewer acute health-related complaints. In a follow-up study, de Vries et al. (2013) found that quality but not quantity of streetscape greenery was associated with more physical activity in green spaces, and neither quantity nor quality were associated with overall physical activity. The greenery-health associations were partially mediated by better social cohesion, reduced stress, and increased physical activity in green spaces. In an unrelated natural experiment, Donovan et al. (2013) found that extensive loss of tree canopy due to the emerald ash borer (a beetle that feeds on and ultimately kills ash trees) in northern Midwest U.S. communities was associated with increased mortality related to cardiovascular and lower-respiratory-tract illness. Several additional studies of physical activity and obesity have considered the impact of tree cover as one of many environmental variables considered simultaneously, resulting in a wide range of findings including both significant healthful associations, and null associations (Foltête and Piombini, 2007; Lovasi et al., 2013b; Hoehner et al., 2005; Cain et al., 2014; Pikora et al., 2006; Boarnet et al., 2011; Lee and Moudon, 2006; Giles-Corti and Donovan, 2002a; Lovasi et al., 2012).

The literature on tree relationships with respiratory health is also mixed, as certain tree species have been linked to increased allergen exposure, while other studies have identified trees as a potential means for reducing airborne pollutants, particularly from motor vehicles (Dales et al., 2004; Lovasi et al., 2008; Nowak et al., 2006; Wang and Yousef, 2007). A recent study by Lovasi et al. (2013a) found evidence contradicting their earlier study of street trees, finding that greater tree cover within ¼-mile of the prenatal address was associated with higher likelihood of asthma and allergic sensitization to tree pollen in young children. New research also suggests that street-trees may disrupt wind flow that would otherwise help disperse vehicular pollutants, and may actually trap pollutants below the canopy, thereby increasing pollutant concentrations at street level (Vos et al., 2013; Wania et al., 2012).

## 3. Methods

This study made use of several pre-existing cross-sectional datasets for the Sacramento, California, region, which were acquired for this study between 2012 and 2013. These datasets, data development methods, and analytical methods are described in further detail below.

### 3.1. Study area

The Sacramento region has an urban forest which is a dynamic living resource requiring planning and investment to be sustained on an ongoing basis. The biogeographical conditions of the region support tree growth; but urban forestry best practices and stewardship programs are necessary interventions to support this civic investment. Clark and Matheny (1998) outlined three key elements of the sustainable urban forest: resource assessment, resource management, and community engagement. In recognition of environmental and ecosystem services, many communities have established tree canopy goals. The City of Sacramento set a canopy goal of 35% following a NASA thermal flyover assessment in 1998. Necessary routine management practices to sustain the forest

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