Environment International 121 (2018) 443–452

Contents lists available at ScienceDirect

Environment International

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

Greenspace seems protective of both high and low blood pressure among residents of an Alpine valley

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ARTICLE INFO

Handling Editor: Yong Guan Zhu

Keywords:
Cardiovascular disease
Garden
Green spaces
Greenness
Hypertension
Mediation

ABSTRACT

Background: There is some data suggesting that residential greenspace may protect against high blood pressure in urbanized areas, but there is no evidence of effects on hypotension, in less urbanized areas, and in idiosyncratic geographic contexts such as mountain valleys.
Objectives: The current study aimed to investigate the associations between residential greenspace and blood pressure in an alpine valley in Austria.
Methods: We conducted a cross-sectional survey of a representative sample of 555 adults living in the Lower Inn Valley, Austria. Several definitions of blood pressure were employed: continuously-measured systolic (SBP) and diastolic blood pressure (DBP), doctor-diagnosed hyper- and hypotension, and high- and low blood pressure medication use. Greenspace metrics considered were: Normalized Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI), and tree cover as measures of surrounding greenness in circular buffers of 100 m, 300 m, 500 m, and 1000 m around the home; distance to different types of structured green space; and having a domestic garden and a balcony. Relationships were examined across different definitions of blood pressure and greenspace and evaluated for potential effect modification by demographic factors, presence of a domestic garden/balcony, adiposity, and traffic sensitivity.
Results: Higher overall greenness was associated with 30–40% lower odds of hyper/hypotension and 2–3 mm Hg lower SBP. Similar pattern was revealed for tree cover, however, associations with hypertension were less consistent across buffers, and SBP and DBP were lower only in association with greenness in the 100-m buffer. Having a domestic garden also seemed protective of high DBP. Residing near to forests, agricultural land, or urban green spaces was not related to blood pressure. Higher $NDVI_{500\text{-}m}$ was stronger associated with lower SBP in those having a domestic garden, while the effect on DBP was stronger in overweight/obese participants.
Conclusion: These findings support the idea that greenspace should be considered as protective of both high and low blood pressure, however, underlying mechanisms remain insufficiently understood.

1. Introduction

Hypertension is a major risk factor for the development and progression of cardiovascular disease, accounting for roughly half of deaths due to ischemic heart disease and stroke worldwide (WHO, 2013). In addition to classic behavioral factors (WHO, 2013), multiple studies have demonstrated the potential of the residential environment to modify the risk of hypertension. For instance, traffic-related air pollution (Yang et al., 2018) and noise (Dzhambov and Dimitrova, 2018; Kempen et al., 2018) can promote high blood pressure via a cascade of neuroendocrine processes, including autonomic nervous system imbalance, oxidative stress, and endothelial dysfunction (Münzel et al., 2017). However, other residential features, such as greenspace, can have a protective effect (Nieuwenhuijsen et al., 2017; Dadvand and Nieuwenhuijsen, 2019). Through the lens of Ulrich's psycho-evolutionary theory (Ulrich, 1983), engagement with nature may support normal blood pressure by shifting the vegetative nervous system balance towards parasympathetic activation and by reducing levels of stress hormones (Ulrich et al., 1991; Hartig et al., 2003; Park et al., 2010; Li et al., 2011). Green areas also lack traffic sources and, under

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https://doi.org/10.1016/j.envint.2018.09.044
Received 23 August 2018; Received in revised form 24 September 2018; Accepted 25 September 2018

certain conditions, vegetation might mitigate air pollution and noise (Markevych et al., 2017). In addition to disrupting harmful pathways, green spaces are typically characterized by high restorative quality, allowing respite from everyday stress (von Lindern et al., 2017) and motivating health-enhancing behaviors like outdoor physical activity and social interactions (Markevych et al., 2017).

Epidemiological research on the relationship between greenspace and blood pressure is gaining momentum. Residents of neighborhoods with higher greenness and those living near green spaces (i.e., "exposed" to higher greenspace) have been found to be at lower risk of hypertension (Grazuleviciene et al., 2014; Brown et al., 2016; Groenewegen et al., 2018; Jia et al., 2018) and even death due to hypertension-related causes (Vienneau et al., 2017). Greenspace might also reduce systolic and diastolic blood pressure (Markevych et al., 2014; Bijnens et al., 2017; Lane et al., 2017). Yet, findings to date are conflicting and not generalizable to all residents. For example, Jendrossek et al. (2017) did not observe a positive effect on maternal hypertension. A meta-analysis showed that residents exposed to high amounts of greenspace had −1.97 mm Hg (95% CI: −3.45, −0.49) lower diastolic blood pressure compared with their counterparts. No significant effect was found for systolic blood pressure (−1.50 mm Hg; 95% CI: −3.43, 0.44) and incidence of hypertension (OR = 0.99; 95% CI: 0.81, 1.20) though (Twohig-Bennett and Jones, 2018).

Moreover, the epidemiologic literature on the topic has prominent gaps. For instance, earlier studies only considered greenspace as protective of high blood pressure (cf. Twohig-Bennett and Jones, 2018). However, low blood pressure is also of public health importance. Aside from diminishing health-related quality of life (i.e., causing fatigue, dizziness, headache, cold limbs, depressed mood, to name a few), hypotension is associated with falls in the elderly (McDonald et al., 2016; Hartog et al., 2017) and also independently increases incidence of adverse cardiovascular events (Ricci et al., 2015), leading to 36% increase in risk of overall mortality (Angelousi et al., 2014). That hypotension has escaped the spotlight of research may be attributed to the fact that such data are rarely available in health surveys and that the potential mechanisms linking hypotension to greenspace are poorly understood. Nevertheless, there is some evidence supporting this conjecture. Lercher et al. observed an association between traffic noise and hypotension in individuals with compromised autonomic regulation (Lercher and Widmann, 2013; Lercher et al., 2014). Another study suggested that anxiety and depression are independently associated with lower blood pressure (Hildrum et al., 2007). Thus, greenspace might decrease risk of hypotension by reducing noise level and psychological stress (cf. Markevych et al., 2017).

Another issue rarely considered is whether the effect of greenspace varies across different geographic contexts (Ruijsbroek et al., 2017). Markevych et al. (2014) looked at greenness and blood pressure in children and observed a beneficial association only in urban, but not rural, settings. In addition to urbanization, topographic features of the residential area might act as effect modifiers. For instance, steepness of the terrain in hilly areas was proposed to protect of diabetes by increasing physical activity (Villanueva et al., 2013; Fujiwara et al., 2017). No previous study has investigated the effect of greenspace in mountain valleys often characterized by temperature inversions, as well as propagation of sound waves over great distances, leading to high levels of air pollution and noise (Heimann et al., 2007). Also, some types of greenspace have been found to be more beneficial to blood pressure than others (urban vs agricultural) (Picavet et al., 2016). This may be related to differences in vegetation characteristics and its potential to reduce traffic emissions (Van Renterghem et al., 2015; Baldauf, 2017) and different usage or visual effects of agricultural fields and green areas in urban settings, where other features of the built environment may interfere with restoration (Hartig et al., 2003; Van den Berg et al., 2014). Although experts have recommended employing a set of different metrics representing different aspects of greenspace potentially relevant to different ways of understanding its effects (Markevych et al., 2017), no previous study on blood pressure has implemented this approach (cf. Twohig-Bennett and Jones, 2018).

Based on the literature gaps outlined above, the current study aimed to investigate the associations between residential greenspace and blood pressure in the Lower Inn Valley (Unterinntal) in Austria. This area is an ideal setting for addressing limitations of earlier research: it comprises peri-urban settlements, neither strictly urban, nor rural in character; residents of those settlements are exposed to high levels of traffic noise and air pollution; at the same time, they have access to landscapes of high aesthetic quality, diverse in their function and vegetation characteristics. We examined this relationship across different definitions of blood pressure and greenspace and evaluated the effect of potential effect modifiers.

2. Material and methods

2.1. Study area and design

Data for the present study come from a comprehensive cross-sectional survey conducted in the framework of an Environmental Health Impact Assessment (fall 1998) in the Lower Inn Valley, Austria. They were never fully analyzed due to an interruption in funding and lack of manpower.

The study area extends about 40 km east of Innsbruck towards the Austrian-German border across a relatively broad valley floor and up to the foothills of the Alpine comb. (Fig. 1) The valley floor is characterized by the river Inn and two heavy traffic routes (a highway and a railway). In addition, major roads link the villages and the highway. The transportation lines follow mostly the course of the river Inn, which is the major water feature in the area. Owing to the dominance of the major traffic routes, the landscape is fragmented and settlements consist of densely populated small towns and villages with a mix of industrial, small business, touristic, and agricultural activities (Wrbka et al., 2004; von Lindern et al., 2016). Given its busy transport infrastructure combined with sensitive topography and meteorology (inversions) high levels of air pollution and traffic noise have been observed in the area (Lercher et al., 1995; Lercher and Kofler, 1996; Heimann et al., 2007). Conversely, landscapes in this part of Austria comprise natural and semi-natural biotopes and agricultural areas with high nature value (Wrbka et al., 2004); in particular, the Lower Inn Valley is situated in a region of renowned scenic beauty (von Lindern et al., 2016).

The data we used for the present re-analysis were originally intended to supplement and deepen the health information collected in a larger representative study to assess the health impact of traffic-related pollution. Interested readers can find a detailed account of the design and sampling scheme elsewhere (Lercher et al., 2014; von Lindern et al., 2016). Briefly, eligible adult participants were sampled randomly with replacement from 648 households located within a 500-m radius from around 31 sound measurement sites, approximately equally distributed across pre-defined noise map bands (35–44, 45–54, 55–64, > 64 $L_{eq,dBA}$). Potential participants were replaced when the sampling criteria (e.g., age, duration of residence) were not met due to the incompleteness or incorrectness of the sampling data base received from governmental sources. Adults who had been residing at the address for at least one year were invited to participate in the door-to-door interview. Some households were represented by more than one member. Households were visited twice, with the second visit focusing on collecting detailed health status information. 572 residents agreed to provide health data during this second visit, and of those, we only considered 555 for the present analyses, because they had both blood pressure data and residential greenspace could be successfully assigned to their home address. Comparison between participants' characteristics and census data and between participants and those who dropped out after the first visit indicated that our analytic sample was mostly representative of the population (except for a higher proportion of