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Acute effects of visits to urban green environments on cardiovascular physiology in women: A field experiment

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A R T I C L E I N F O

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A B S T R A C T

Background: Epidemiological studies have reported positive associations between the amount of green space in the living environment and mental and cardiovascular human health. In a search for effect mechanisms, field studies have found short-term visits to green environments to be associated with psychological stress relief. Less evidence is available on the effect of visits on cardiovascular physiology.

Objectives: To evaluate whether visits to urban green environments, in comparison to visits to a built-up environment, lead to beneficial short-term changes in indicators of cardiovascular health.

Methods: Thirty-six adult female volunteers visited three different types of urban environments: an urban forest, an urban park, and a built-up city centre, in Helsinki, Finland. The visits consisted of 15 min of sedentary viewing, and 30 min of walking. During the visits, blood pressure and heart rate were measured, and electrocardiogram recorded for the determination of indicators of heart rate variability. In addition, levels of respirable ambient particles and environmental noise were monitored.

Results: Visits to the green environments were associated with lower blood pressure (viewing period only), lower heart rate, and higher indices of heart rate variability [standard deviation of normal-to-normal intervals (SDNN), high frequency power] than visits to the city centre. In the green environments, heart rate decreased and SDNN increased during the visit. Associations between environment and indicators of cardiovascular health weakened slightly after inclusion of particulate air pollution and noise in the models.

Conclusions: Visits to urban green environments are associated with beneficial short-term changes in cardiovascular risk factors. This can be explained by psychological stress relief with contribution from reduced air pollution and noise exposure during the visits. Future research should evaluate the amount of exposure to green environments needed for longer-term benefits for cardiovascular health.

1. Introduction

Urbanization is a global phenomenon which shows no signs of slowing down. Consequently, the quality of urban environment has become increasingly important for human health. Urban green environments, such as parks and urban forests, are elements of environment which many intuitively consider healthy. Although the evidence cannot yet be claimed sufficient and there are issues related to potential exposure misclassification and confounding, many epidemiological studies indeed have reported that persons living in greener environments have better mental and cardiovascular health than persons living in more built-up environments (Gascon et al., 2016, 2015; Maas et al., 2009b).

Several mechanisms have been proposed by which living close to green areas may affect positively health: for example, beneficial effects may be partly due to reduced exposure to traffic-related air pollution and noise. Increased amount of green space in a residential area typically implies less traffic. This reduces exposure to air pollution and

Abbreviations: BP, blood pressure; HF, high frequency power; HRV, heart rate variability; LAeq, A-weighted equivalent continuous sound pressure level; PM_{10}, respirable particles, particles with aerodynamic diameter < 10 μm; SDNN, standard deviation of the normal inter-beat intervals; RMSSD, square root of the mean of the sum of the squares of differences between adjacent normal-to-normal intervals

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noise both indoors at home and outdoors near home. In addition, vegetation may decrease pollutant levels locally by affecting dispersion and removal (Jang et al., 2015; Tyrväinen et al., 2005). Both long-term and short-term exposures to traffic-related air pollution have been associated with deteriorations in cardiovascular health (Brook et al., 2010). Traffic noise in turn seems to be associated with cardiovascular health independently of air pollution (Vienneau et al., 2015), and it may be associated also with mental health (Floud et al., 2011; Leslie and Cerin, 2008; Sygna et al., 2014), although there are surprisingly few studies on the topic.

Other proposed mechanisms require the use of green environments. For example, green areas offer opportunities for physical activity which is an established protective life-style factor against cardiovascular disease and depression (Conn, 2010; World Health Organisation, 2010). Some studies have indeed reported that living in proximity to green areas increases the likelihood of frequent exercise (e.g. Gong et al., 2014; Richardson et al., 2013). However, many other have not found evidence of an association between supply of green areas and level of physical activity (e.g. Hillsdon et al., 2006; Ord et al., 2013). Green areas have also been suggested to enhance social interactions (Maas et al., 2009a; de Vries et al., 2013), which may or may not involve exercise, but the health relevance of this has not yet been widely studied (Hartig et al., 2014; Ruijsbroek et al., 2017).

Last but not least, it has been suggested that, because of intrinsic qualities of natural elements, green areas have also more direct positive effects on wellbeing and further health. These effects could be explained by restoration of attention as a result of escaping daily routines and constant need of concentration (Kaplan 1995), or by innate triggering of positive emotions (Ulrich 1983). There is an increasing amount of experimental studies, as reviewed by Bowler et al. (2010), reporting that short visits to green environments such as parks, urban woodlands, and forests improve mood and attention, and enhance psychological stress recovery. We have recently reported visits to urban green environments to be associated with increased feelings of restoration, vitality, and positive mood (Tyrväinen et al., 2014)

Evidence on the importance of good mental health for physical health has increased especially for cardiovascular diseases over the last few decades: for example chronic depression, anxiety, and working stress have been associated with increased cardiovascular morbidity (Gan et al., 2014; Kivimäki et al., 2006; Pietilä et al., 2015; Sparrenberger et al., 2009). A plausible effect mechanism has been provided by studies reporting acute psychosocial stress, mental effort, and worry to be associated with rapid changes in the levels of cardiovascular risks factors such as blood pressure, heart rate, and heart rate variability (HRV), a measure of autonomic nervous control of heart (e.g. Peters et al., 1998; Pieper et al., 2007). Noteworthy, short-term exposure to air pollution, such as experienced during commuting in a city centre with busy traffic, has been found to be associated with the same risk factors (e.g. Kubesch et al., 2015, Lanki et al., 2006; Sarnat et al., 2014).

Based on the previously reported associations between mental state and cardiovascular physiology, it can be hypothesized that even short visits to green environments may lead to positive changes in cardiovascular risk factors as a result of stress recovery. An increasing number of studies in Europe and US (Gidlow et al., 2016; Grazuleviciene et al., 2015; Hartig et al., 2003, 1991; Sonntag-Öström et al., 2014; Triguero-Mas et al., 2017), and mostly smaller scale studies in Japan (Lee et al., 2014, 2011; Li et al., 2011; Park et al., 2010; Song et al., 2014), have evaluated effects of visits to green areas, in comparison to visits to built-up urban areas, on blood pressure, heart rate or HRV. Several of the studies have reported positive effects, most often for HRV, but drawing solid conclusions has been hampered by the heterogeneity of study designs and results (Bowler et al., 2010). Further, the effect of reduction in air pollution and noise exposure during visits to green environments has been taken into account in only one previous study (Triguero-Mas et al., 2017), where further analyses were hampered by the lack of overall effect of green areas on cardiovascular physiology. Noteworthy, some studies suggest that a mere visual exposure to green environment, in a form of a picture or video, is enough to trigger positive physiological changes (Brown et al., 2013; Lauman et al., 2003).

It can be further hypothesized that psychophysiological responses to visits to green areas are dependent on the quality of the area. For example high biodiversity, natural state, solitude, and tranquility are attributes that may enhance experience of nature during visit and improve restoration (Korpela and Staats, 2014; Voigt et al., 2014). These characteristics are more commonly found in larger forested areas than small urban parks. Other determinants of effects and usage of green areas include e.g. walkability, safety, and facilities (Hartig et al., 2014). There is little information on the modifying effect of the quality of green environments on mental or cardiovascular health (Marselle et al., 2014; Pope et al., 2015).

In order to test the hypotheses above, acute effects of short visits to two types of green urban environments on cardiovascular physiology are estimated in this field study, and compared to the effects of visits to a built-up urban environment. The present study includes adult employed volunteers in contrast to earlier studies which have often relied on student samples. A rare feature of the study is the inclusion of traffic-related air pollution and noise exposures in the analyses.

2. Methods

2.1. Study design

The study took place in Helsinki, the capital of Finland, where volunteers visited once three different types of environments, named here as: urban forest, urban park, and (built-up) city centre. The urban forest (Keskuspuisto) is the largest forested area in Helsinki with a total size of 1000 ha. It is 10 km in length, and consists of 60–100 year old mixed and conifer forests. The urban park (Alppipuisto) is one of the oldest urban parks in Helsinki covering together with a neighboring park 20 ha. It is well-designed with flower beds, water element, old park trees, and facilities such as benches and a performance stage for live music. The environment representing a city centre was close to a main street (Mannerheimintie) and a shopping centre – only single urban trees were found on the area. Photos of the study environments can be found in a previous publication (Tyrväinen et al., 2014).

We followed to some extent the protocol used in field experiments conducted in Japan (Lee et al., 2014; Tsunetsugu et al., 2013). Study participants visited the environments in partly changing groups of four people in a random order; no more than one environment per week. Participants were asked not to communicate with each other during the visits. Each visit consisted of a 15-min period of sitting and viewing the environment, and a 30-min period of unhurried walking in the environment. During the walking period, study participants followed a researcher who kept a steady pace (aiming at 4 km/h) on a prescribed route (approximately 2 km). Another researcher followed the participants, and carried a backpack which contained instruments for monitoring of air pollution, environmental noise, and ambient temperature.

All experiments started at 3 p.m., i.e. after a normal working day for most of the participants. Participants got an SMS reminder in the morning of each experimental day. On each visit, participants first arrived at an office, where blood pressure and electrocardiogram (ECG) monitors were installed by researchers. At the office, each participant also filled in a questionnaire on current health condition, and ate a sandwich and drank a juice in order to standardize energy level. Before leaving the office, participants rinsed their mouths with water to prepare for cortisol measurements. Participants were brought to the study environment from the office in a van (20–30 min driving time).

Blood pressure was measured first at the office in order to test the instruments, and then 3 times during the experiment: in the van after arrival to the study environment (control value), after the viewing period while still sitting, and after the walking period in the van. ECG