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Exploring links between greenspace and sudden unexpected death: A spatial analysis

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ABSTRACT

Greenspace has been increasingly recognized as having numerous health benefits. However, its effects are unknown concerning sudden unexpected death (SUD), commonly referred to as sudden cardiac death, which constitutes a large proportion of mortality in the United States. Because greenspace can promote physical activity, reduce stress and buffer air pollutants, it may have beneficial effects for people at risk of SUD, such as those with heart disease, hypertension, and diabetes mellitus. Using several spatial techniques, this study explored the relationship between SUD and greenspace. We adjudicated 396 SUD cases that occurred from March 2013 to February 2015 among reports from emergency medical services (EMS) that attended out-of-hospital deaths in Wake County (central North Carolina, USA). We measured multiple greenspace metrics in each census tract, including the percentages of forest, grassland, average tree canopy, tree canopy diversity, near-road tree canopy and greenway density. The associations between SUD incidence and these greenspace metrics were examined using Poisson regression (non-spatial) and Bayesian spatial models. The results from both models indicated that SUD incidence was inversely associated with both greenway density (adjusted risk ratio [RR] = 0.82, 95% credible/ confidence interval [CI]: 0.69–0.97) and the percentage of forest (adjusted RR = 0.90, 95% CI: 0.81–0.99). These results suggest that increases in greenway density by 1 km/km^2 and in forest by 10% were associated with a decrease in SUD risk of 18% and 10%, respectively. The inverse relationship was not observed between SUD incidence and other metrics, including grassland, average tree canopy, near-road tree canopy and tree canopy diversity. This study implies that greenspace, specifically greenways and forest, may have beneficial effects for people at risk of SUD. Further studies are needed to investigate potential causal relationships between greenspace and SUD, and potential mechanisms such as promoting physical activity and reducing stress.

1. Introduction

Sudden unexpected death (SUD), commonly referred to as sudden cardiac death, is one of the leading causes of mortality in the United States (Adabag et al., 2010; Nanavati et al., 2014; Stecker et al., 2014). It is estimated that SUD incidence is between 180,000 and 450,000 each year in the US, although this estimate varies considerably depending on data sources, definition of SUD, methods of estimation and other factors (Adabag et al., 2010; Kong et al., 2011).

Currently, risk factors for SUD are not well understood. Underlying or pre-existing health conditions, such as coronary heart disease, hypertension, diabetes mellitus, dyslipidaemia and ventricular hypertrophy, contribute to the occurrence of SUD (Adabag et al., 2010). Family history of sudden death, and socioeconomic and psychosocial status may also be risk factors (Adabag et al., 2010; Dekker et al., 2006; Mounsey et al., 2017; Ruberman et al., 1984). Several studies also suggest that some environmental factors, such as air pollution and temperature, might trigger the occurrence of cardiac arrest or sudden death (Dales et al., 2004; Dennekamp et al., 2010; Onozuka and Hagihara, 2017). Because of the high number of SUD cases and the low survival rate of sudden cardiac arrest, prevention measures are highly desired.

Greenspace refers generally to areas covered with trees, grass or other vegetation, and includes forests, parks, gardens, and street-side

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landscaping. It is increasingly recognized that greenspace has many benefits to human health. Many studies have shown that exposure to greenspace was associated with a lower risk of obesity (Lee et al., 2017), diabetes (Astell-Burt et al., 2014; Bodicoat et al., 2014; Brown et al., 2016; Dalton et al., 2016; Ngom et al., 2016), hypertension (Brown et al., 2016), and cardiovascular disease (Bijnens et al., 2017; Lane et al., 2017; Paquet et al., 2014; Pereira et al., 2012; Tamosiunas et al., 2014; Yitshak-Sade et al., 2017). The protective benefits provided by greenspace regarding these health outcomes are attributed to its many ecosystem services, such as filtering air pollution and noise, relieving stress and depression, promoting social contact and physical activity, and reducing temperature extremes (de Jesus Crespo and Fulford, 2018; Egorov et al., 2017; Maas et al., 2009; Markevych et al., 2017; Oliveira et al., 2011; Pugh et al., 2012; Roe et al., 2013; Shanahan et al., 2016). Since these health outcomes are also related to SUD, we hypothesized that exposure to greenspace might be associated with a lower risk of sudden cardiac arrest.

The main objective of this ecological study is to explore the relationship between SUD incidence and local greenspace using spatial techniques. Using the Sudden Unexpected Death in North Carolina (SUDDEN) case registry in Wake County, North Carolina (https://www.med.unc.edu/medicine/cardiology/sudden), we first conducted analyses to identify spatial patterns of SUD cases and other relevant variables. Then, we applied Bayesian spatial models as well as Poisson regression models to examine the associations between SUD incidence and multiple greenspace metrics at the census tract level.

2. Methods

2.1. Study area

The study area is Wake County, central North Carolina (Fig. 1). With a subtropical climate, Wake County has moderate temperatures in the spring, fall, and winter but high temperatures in summer. With a population of about one million, Wake County is the second-most populated county in North Carolina and one of the fastest growing counties in the US. The population is composed of 68.5% White, 21.2% Black, and 6.9% Asian based on the data from the US Census Bureau in 2016. Wake County also has a large number of residents who may be at risk for sudden cardiac arrest. According to health statistics for 2010, cardiovascular disease was the second cause of death in North Carolina, responsible for 30% of all deaths in that year (Tchwenko, 2012).

2.2. Sudden unexpected death data

The SUD cases in Wake County from March 1, 2013 to February 28, 2015 were collected through the Sudden Unexpected Death in North Carolina (SUDDEN) project, which was approved by the Institutional Review Board (IRB) at the University of North Carolina at Chapel Hill (Study #14-2036). SUD cases were screened from all deaths aged 18 to 64 attended by emergency medical services in Wake County. The identification criteria were described previously (Mounsey et al., 2017; Nanavati et al., 2014) and are briefly illustrated in Fig. S1. For each SUD case, the location of the death event was recorded by a Global Positioning System (GPS). Personal information for each case, including home address, age, gender, race and medical history, was also recorded. Based on the incident location, SUD cases were mapped in a Geographic Information System (GIS) using ArcGIS 10.3 (ESRI, CA); then cases were aggregated by census tract using 2010 boundaries obtained from the US Census Bureau. SUD incidence was calculated using total population aged 18 to 64 multiplied by 2 years as the denominator.

2.3. Demographic and socioeconomic status data

Demographic and socioeconomic status data were obtained for 187 census tracts in Wake County from the US Census Bureau's five-year American Community Survey data summary centered on 2014. The variables included total population, the percentages of populations at

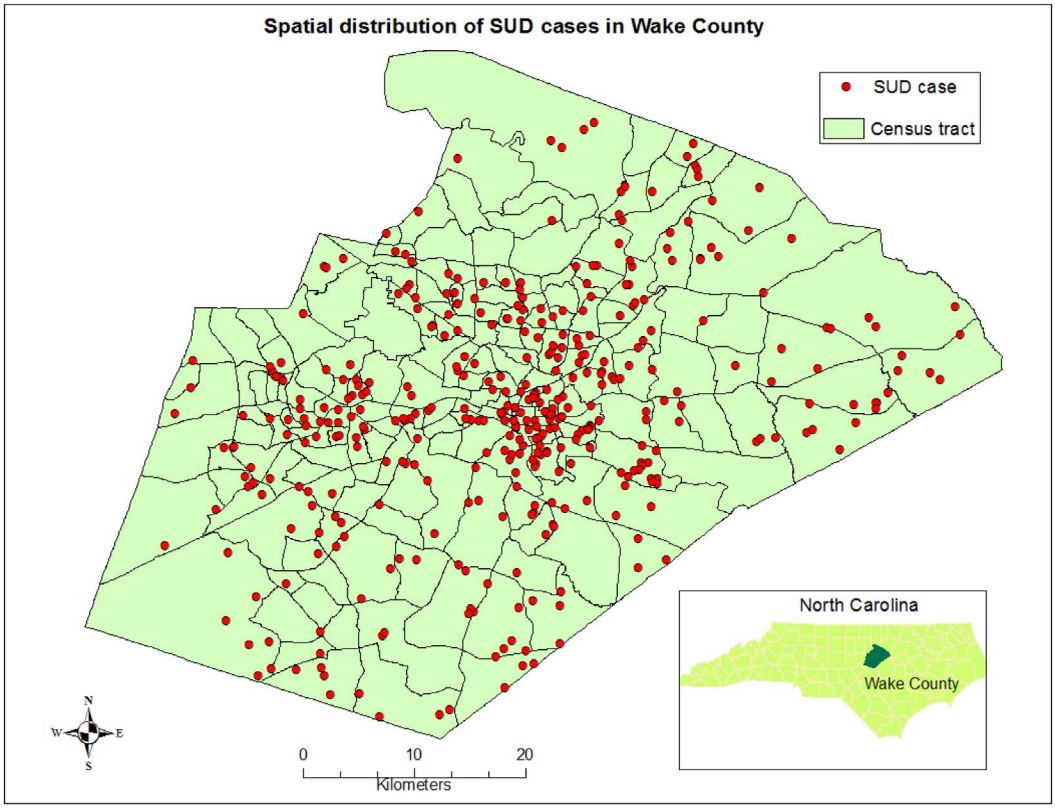

Fig. 1. The study area and the spatial distribution of SUD cases in Wake County.