International Journal of Hygiene and Environmental Health xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Hygiene and Environmental Health

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

Spatial clusters of daytime sleepiness and association with nighttime noise levels in a Swiss general population (GeoHypnoLaus)

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A R T I C L E I N F O

Keywords:
Epworth sleepiness scale
Traffic noise exposure
Spatial clustering
GIS
General population

A B S T R A C T

Introduction: Daytime sleepiness is highly prevalent in the general adult population and has been linked to an increased risk of workplace and vehicle accidents, lower professional performance and poorer health. Despite the established relationship between noise and daytime sleepiness, little research has explored the individual-level spatial distribution of noise-related sleep disturbances. We assessed the spatial dependence of daytime sleepiness and tested whether clusters of individuals exhibiting higher daytime sleepiness were characterized by higher nocturnal noise levels than other clusters.

Design and Methods: Population-based cross-sectional study, in the city of Lausanne, Switzerland.

Sleepiness was measured using the Epworth Sleepiness Scale (ESS) for 3697 georeferenced individuals from the CoLaus|PsyCoLaus cohort (period = 2009–2012). We used the sonBASE georeferenced database produced by the Swiss Federal Office for the Environment to characterize nighttime road traffic noise exposure throughout the city. We used the GeoDa software program to calculate the Getis-Ord G_i* statistics for unadjusted and adjusted ESS in order to detect spatial clusters of high and low ESS values. Modeled nighttime noise exposure from road and rail traffic was compared across ESS clusters.

Results: Daytime sleepiness was not randomly distributed and showed a significant spatial dependence. The median nighttime traffic noise exposure was significantly different across the three ESS Getis cluster classes ($p < 0.001$). The mean nighttime noise exposure in the high ESS cluster class was 47.6, dB(A) 5.2 dB(A) higher than in low clusters ($p < 0.001$) and 2.1 dB(A) higher than in the neutral class ($p < 0.001$). These associations were independent of major potential confounders including body mass index and neighborhood income level.

Conclusions: Clusters of higher daytime sleepiness in adults are associated with higher median nighttime noise levels. The identification of these clusters can guide tailored public health interventions.

1. Introduction

Daytime sleepiness can be defined as the inability to maintain wakefulness and alertness during the major waking hours (American Academy of Sleep Medicine, 2014). Excessive daytime sleepiness, defined by the occurrence of multiple unintentional sleep episodes

Abbreviations: ESS, epworth sleepiness scale; FOEN, Swiss Federal Office for the Environment; GIS, geographic information systems; LISA, Local Indicators of Spatial Association

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https://doi.org/10.1016/j.ijheh.2018.05.004
Received 13 January 2018; Received in revised form 10 April 2018; Accepted 15 May 2018
1438-4639/

throughout the day (Ohayon, 2006), has been linked to an increased risk of workplace and vehicle accidents (Horne and Reyner, 1995) as well as with lower professional performance and poorer health (Pagel, 2009). Even at non-excessive levels, daytime sleepiness has been also directly associated with cognitive impairment (Williamson and Feyer, 2000) as well as with an increased risk of stroke, congestive heart disease, cardiovascular and all-cause mortality (Blachier et al., 2012; Newman et al., 2000; Qureshi et al., 1997).

Daytime sleepiness is highly prevalent in the general adult population. In European countries, between 5 and 20% of adults present excessive daytime sleepiness (Ohayon, 2006), thereby substantiating the need to better understand the causes.

Intrinsic and extrinsic sleep disorders, as well as obesity, smoking, depression, and medications (Bixler et al., 2005), can enhance daytime sleepiness through the disruption of sleep or biological rhythms (Stepanski et al., 1984). Among the environmental factors that cause sleep disruptions, nighttime noise has been related to daytime sleepiness through nocturnal arousals and premature awakenings (Muzet, 2007), whereby the regenerative power of sleep is reduced in response to the magnitude and frequency of noise events (Basner et al., 2008; Öhrström and Rylander, 1982). One lab-based study investigating this relationship found that intermittent noises above 45 dB can be directly linked to daytime fatigue (Öhrström, 1993). More targeted studies have identified positive correlations between daytime sleepiness and exposure to noise from wind turbines (Abbasi et al., 2015; Nissenbaum et al., 2012), airplanes (Kwak et al., 2016; Callejas et al., 2015), railways and vehicular traffic (Gislason et al., 2016; Basner et al., 2011).

While air and neighborhood noise are important contributors to urban noise pollution, vehicular and rail traffic are the largest contributors (WHO Regional Office for Europe, 2009). In 2010, an estimated 22,500 hospital days were attributed to the effects of transportation noise in Switzerland (Vienneau et al., 2015). Because road traffic noise is strongly associated with road type (e.g. arterial, one way) (Barrigón Morillas et al., 2002) and road network density (Mehdi et al., 2011), urban traffic noise is inherently geographically localized. Despite the demonstrated relationship between noise and daytime sleepiness, and the considerable amount of research dedicated to the spatial distribution of noise (Licitra, 2013), relatively little research has explored the individual-level spatial distribution of noise-related sleep disturbances (Evandt et al., 2017; Jakovljević et al., 2006). Further, we are aware of only one study that has previously explored the spatial distribution of daytime sleepiness in particular (Grandner et al., 2012); yet data were collected and analyzed at the state level so that comparisons with localized environmental phenomena – such as noise – are not possible.

Spatial analysis methods have been developed and introduced in epidemiological research to explore the link between place of residence and health (Auchincloss et al., 2012). Spatial clusters of a trait can be detected by its spatial dependence (spatial autocorrelation), defined as the covariation of properties in geographic space. Thus, geographic information systems (GIS) and high-resolution spatial modeling can be used to better localize individuals suffering from daytime sleepiness and to increase the understanding of the influence of local-level factors, such as noise, on sleepiness.

Our study had two aims: first, we calculated the spatial dependence of daytime sleepiness using a large population-based cohort. Second, we used georeferenced models of road and rail nighttime noise exposure to evaluate the noise levels in the different spatial clusters obtained and determine whether clusters of individuals showing daytime sleepiness were characterized by higher noise levels than observed in other clusters.

2. Data and methods

2.1. Population

The HypnoLaus Sleep study is based on the first follow-up of the CoLaus|PsyCoLaus study (Heinzer et al., 2015; Preisig et al., 2009; Firmann et al., 2008). Briefly, the baseline CoLaus|PsyCoLaus study was conducted between 2003 and 2006 and included a random sample of 6733 subjects (age range: 35 to 75 years) representative of the residents of the city of Lausanne (Switzerland, 140,738 inhabitants in July 2017). The distributions of age groups, gender, and zip codes of participants were similar to the source population. The original aim of this cohort was to study cardiovascular risk factors and psychiatric disorders in the general population and to determine their associations. Between 2009 and 2012, 5064 subjects from the baseline sample also participated in the first follow-up, which included data on daytime sleepiness. In addition to questions on demographic, medical, and treatment history as well as smoking and alcohol consumption, the subjective sleep characteristics of this cohort were evaluated through questionnaires given by trained interviewers. Only individuals living within the urban area of the Lausanne municipality were considered for this analysis (Joost et al., 2016).

CoLaus|PsyCoLaus data were geocoded in QGIS using the MMQGIS extension (http://michaelminn.com/linux/mmqgis/), which contains a geocoding Python plugin facilitating the use of the Google Maps API.

2.2. Ethics

The institutional Ethics Committee of the University of Lausanne, which afterwards became the Ethics Commission of Canton Vaud (www.cer-vd.ch) approved the baseline CoLaus study (reference 16/03, decisions of 13th January and 10th February 2003); the approval was renewed for the first (reference 33/09, decision of 23rd February 2009) and the second (reference 26/14, decision of 11th March 2014) follow-up. The HypnoLaus nested study was also approved by the Ethic Committee of Canton de Vaud in 2009 (reference 33/09). The full decisions of the CER-VD can be obtained from the authors upon request. The study was performed in agreement with the Declaration of Helsinki and its former amendments, and in accordance with the applicable Swiss legislation (LRH 810.30, approved by the Swiss Federal Parliament on 30th of September 2011). All participants gave their signed informed consent before entering the study.

2.3. The Epworth Sleepiness Scale

Sleepiness was measured at the first physical follow-up exam using the Epworth Sleepiness Scale (ESS) (Johns, 1991). The ESS is a self-administered questionnaire with 8 questions. Respondents are asked to rate, on a 4-point scale (0–3), their usual chances of dozing off or falling asleep while engaged in eight different activities. The ESS score (the sum of 8 item scores, 0–3) can range from 0 to 24. A score of 10 or lower is suggestive of normal daytime sleepiness, scores from 11 to 14 are indicative of mild excessive daytime sleepiness, 15 to 17 - of moderate excessive daytime sleepiness, and a score above 18 indicates severe excessive daytime sleepiness (Johns, 1991). The ESS internal and external validity were further demonstrated in different population samples (Johns, 2000; Parkes et al., 1998; Johns, 1992).

2.4. Variables used for adjustment

Age, gender, anthropometry and medication regimens were recorded during the CoLaus physical visit. Body weight and height were measured by trained health care professionals with participants standing without shoes in light indoor clothing. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). Medication regimens were self-reported.