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The impact of psychological factors on self-reported sleep disturbance among people living in the vicinity of wind turbines

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ABSTRACT

Canada's wind energy capacity has grown from approximately 137 MW (MW) in 2000 to over 9700 MW in 2014, and this progressive development has made Canada the fifth-largest market in the world for the installation of new wind turbines (WTs). Although wind energy is now one of the fastest growing sources of power in Canada and many other countries, the growth in both number and size of WTs has raised questions regarding potential health impacts on individuals who live close to such turbines.

This study is the first published research using a prospective cohort design, with noise and sleep measurements obtained before and after installation of WTs to investigate effect of such turbines on self-reported sleep disturbances of nearby residents. Subjective assessment of sleep disturbance was conducted in Ontario, Canada through standard sleep and sleepiness scales, including the Pittsburgh Sleep Quality Index (PSQI), Insomnia Severity Index (ISI), and Epworth daytime Sleepiness Scale (ESS). Both audible and infra-sound noises were also measured inside the bedroom. Descriptive and comparison analyses were performed to investigate the effect of WT exposure on sleep data.

Results of the analysis show that participants reported poorer sleep quality if they had a negative attitude to WTs, if they had concerns related to property devaluation, and if they could see turbines from their properties. This study provides evidence for the role of individual differences and psychological factors in reports of sleep disturbance by people living in the vicinity of WTs.

1. Introduction

Low operating cost and extensive availability make wind one of the most advantageous and effective alternatives to fossil energy. Like many countries, Canada has set a policy goal to extensively increase use of wind energy as a response to the threat of climate change, vowing to produce 20% or more of its electricity from wind by 2025 ("Canadian Wind Energy Association," 2016). Wind energy, as a low-carbon power source, is intended to have positive impacts on the health of the population at large. However, as wind farms are being sited closer to residential area to reduce transmission losses and costs, health-related effects of exposure to wind turbine (WT) noise have attracted much public attention. As the number of exposed people is growing, public resistance to such visible sound sources is becoming the main obstacle to wind energy development (van den Berg et al., 2008).

Sleep disturbance is relatively common in the general population and has multiple causes, including medical conditions, stress, and external stimuli such as noise. Human beings perceive, evaluate, and react to environmental noises during sleep (Dang-Vu et al., 2010). With respect to WT noise, the key issue is whether the noise is loud enough to disrupt sleep. Published results from previous cross-sectional studies have been inconsistent in terms of possible effects of WT noise on sleep. On one hand, those studies that used an objective method to measure exposure found no, or only a week association between noise and sleep disorders. As an example, a large Canadian study that provided the most-comprehensive assessment of the association between exposure to WT noise and sleep found no sleep-noise association for a noise level under 46 dB(A) (Michaud et al., 2015). A few other cross-sectional studies with reasonable sample size did find only a weak dose response relationship between noise and self-reported sleep (at levels between 40 and 45 dB(A)) or found that annoyance ratings were more strongly associated with self-reported sleep disturbance than noise (Bakker et al., 2012; McCunney and Mundt, 2014; Pawlaczyk-Łuszczyńska et al., 2014; Pedersen and Persson Waye, 2004a, 2004b). This findings are consistent with WHO's conclusion that significant sleep disturbance from environmental

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noise begins to occur at noise levels greater than 45 dB(A) (Fritschi et al., 2011).

On the other hand, those studies that used "distance to nearest WT" as an exposure measure, almost all agreed that self-reported sleep disturbances were more frequent in subjects living closer to WTs than in subjects living further away (Krogh et al., 2011; Kuwano et al., 2013; Nissenbaum et al., 2012; Paller, 2014; Shepherd et al., 2011a).

Based on the current findings, it is not possible to conclude that self-reported sleep disturbance is caused directly by WT noise or whether other factors have played a role as well. Most critically, due to the cross-sectional design of previous studies, there is a complete lack of prospective longitudinal designs and temporal sequence of exposure–outcome relationships cannot be demonstrated.

This epidemiological study was undertaken to explore the possibility of sleep disturbance and the role of psychological factors in self-reported sleep disruption in people living within close proximity of WTs, in a pre- and post-study design. We hypothesized that non-noise variables, such as attitude, visual cues and concern about property devaluation play an important role and likely contribute to observations that people living near WTs report higher levels of sleep disturbance.

2. Methods

2.1. General study design and questionnaire development

This research employed a prospective cohort design and included a sleep questionnaire, comprised of validated instruments relating to sleep disturbance, daytime sleepiness and insomnia. In order to measure participants' sleep quality, the Pittsburgh Sleep Quality Index (PSQI) was used. The PSQI is a 19-item self-rated sleep questionnaire evaluating sleep quality and disturbances over a previous month; these items are grouped into seven domains: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. Each component of the PSQI obtains scores ranging from 0 (no impairment) to 3 (maximum impairment). A total score, ranging from 0 to 21, is obtained by adding up the 7 component scores; higher scores indicate worse sleep quality, and a score >5 suggests poor sleep quality (Buysse et al., 1989).

Subjective daytime sleepiness was evaluated by means of the Epworth Sleepiness Scale (ESS). The ESS is a questionnaire consisting of eight self-rated items, each scored from 0 to 3, asking participants to rate their chance of dozing off during eight different common situations of daily living. It provides a score between 0 (least sleepy) and 24 (most sleepy) (Johns, 1991). No specific time frame is specified. According to the University of Maryland Medical Center, (2016) an ESS score >10 is considered to indicate significant daytime sleepiness.

The nature, severity, and impact of insomnia were assessed by the Insomnia Severity Index (ISI) (Morin and Barlow, 1993), which is a 7-item self-report questionnaire assessing the severity of sleep onset, sleep maintenance, early morning awakening problems, sleep dissatisfaction, interference with sleep, difficulties with daytime functioning, noticeability of sleep problems by others, and distress caused by sleep difficulties in the previous month. A 5-point Likert scale is used to rate each item (0=no problem; 4=very severe problem), yielding a total score ranging from 0 to 28. The total score is interpreted as follows: absence of insomnia $(0-7)$; sub-threshold insomnia $(8-14)$; moderate insomnia $(15-21)$; and severe insomnia $(22-28)$.

Noise sensitivity and attitude to WTs were also measured in T2 on a 5-point scales with 3 representing a neutral attitude and slightly noise sensitive, respectively (Items are: not sensitive, hardly sensitive, slightly sensitive, rather sensitive, very sensitive and very positive, positive, neither positive nor negative, negative, very negative, respectively). Noise sensitivity and attitude were also dichotomised into "not sensitive" and "sensitive" (1–3 vs. 4–5), and attitude into "not negative" and "negative" (1–3 vs. 4–5). Participants were also asked if they benefited from WTs and/or owned land on which a WT facility was built.

2.2. Noise exposure assessment

At two locations, that varied each night, indoor noise was measured for a total of 16 nights before and 16 nights after operation of the turbines. In total, 64 sets of data were collected. A noise-measurement system was placed in participants' bedrooms (if they agreed) for the duration of their sleep. The system was programmed to turn on and off automatically at the start and end of each period. The indoor microphone was fitted with a windscreen and mounted on a microphone stand in the bedroom at a location close to the participant's head, at the same height as the sleeper and one meter horizontally from his or her head. A Soundbook analyzer (MK1) (Sinus/Messtechik, Germany) was used with a G. R. A. S 40AZ low frequency microphone. The whole system is capable of measuring noise in the 0.5 Hz to 20,000 Hz frequency range. It was calibrated before and after each recording using a known frequency (250 Hz) and SPL (114 dB) source. The results of the sound measurements and recordings were transferred from the Soundbook to a personal computer. Further processing and calculations were performed using the software package Samurai 2.6 (Soundbook.de 2009).

For the purposes of this paper, noise measurement has been analyzed for only one-hour (1 h)/night, and this 1 h were chosen from a period when inside spikes (e.g., from coughing, dogs barking) were minimal. A-weighted and Z-weighted parameters (Laeq-1H, Zaeq-1H) were then extracted from the measured noise data. Additional noise parameters such as L_{ZFmax}, $L_{ZFmin,}$ L_{AFmax}, L_{AFmin}, L_{ZFmax}-L_{ZFmin}, L_{AFmax}-L_{AFmin} over 10 min per night were also extracted. Wind speed data were taken (at 10 m height) from the closest weather station to the WTs.

2.3. Participant selection

This study was carried out in a rural area with flat agricultural fields in southern Ontario, Canada. Operation of five Vestas V100–1.8 MW turbines, with hub heights of 90 m and rotor diameters of 100 m, was started in June 2014. Pre-Construction and environmental studies were completed by the wind company between April to July 2012. The first round of data collection was conducted post turbine erection but pre operation to avoid construction noise effects on sleep quality (March 2014). The second round of data collection occurred after the turbines became operational and it happened in the same time of year (March 2015) to minimize seasonal and temperature effects. The coordinates of both local residential properties and WTs were produced using ArcGIS Desktop Version 10.3.1 (Esri Inc, Redlands, CA). The distance between a participant's residence and the nearest WT was calculated using a Global Positioning System (GPS). All residents living within 2000 m of the turbines were identified and residential address centroids were generated from Municipal Property Assessment Corporation (MPAC) data.

For all 195 eligible households (businesses and unoccupied addresses were excluded) within 2000 m of the WTs, letters of advance notice including study details and the researchers' contact information were placed in mailboxes two weeks prior to survey distribution. For homes without mailboxes, advance notices were delivered to the door. Within two weeks of advance-notice letter