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Changes in quality of life and perceptions of general health before and after operation of wind turbines☆

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ABSTRACT

Ontario is Canada's provincial leader in wind energy, with over 4000 MW of installed capacity supplying approximately five percent of the province's electricity demand. Wind energy is now one of the fastest-growing sources of renewable power in Canada and many other countries. However, its possible negative impact on population health, as a new source of environmental noise, has raised concerns for people living in proximity to wind turbines (WTs). The aims of this study were to assess the effect of individual differences and annoyance on the self-reported general health and health-related quality of life (QOL) of nearby residents, using a pre- and post-exposure design. Prospective cohort data were collected before and after WT operations, from the individuals ($n = 43$) in Ontario, Canada. General health and QOL metrics were measured using standard scales, such as SF12, life satisfaction scales developed by Diener (SWLS) and the Canadian Community Health Survey (CCHS-SWL). The mean values for the Mental Component Score of SF12 ($p = 0.002$), SWLS ($p < 0.001$), and CCHS-SWL ($p = 0.044$) significantly worsened after WT operation for those participants who had a negative attitude to WTs, who voiced concerns about property devaluation, and/or who reported being visually or noise annoyed.

1. Introduction

The province of Ontario is the Canadian leader in wind power, with over 4 GW of installed wind energy capacity. Currently, 2302 wind turbines (WTs) in Ontario supply over five percent of the province's electricity demand, and the goal is to increase this to 15% by 2025 (Canwea, 2015). The increasing growth of renewable energy technologies (RETs) such as WTs is intended to positively affect the health and well-being of Canadians, via reductions in air pollution, nuclear fuel, and greenhouse gas emissions, and a shift away from consuming energy from carbon-based resources. However, there are potential local-level health risks, which may differ from the generally beneficial impacts expected for the larger population. A number of people living near WTs have reported health-related complaints such as headaches, dizziness, nausea, ear pressure, tinnitus, lack of concentration, and sleep disturbances and attributed their symptoms to the WTs (Knopper and Ollson, 2011). Given the crucial role of wind energy for renewable energy targets, it is important to understand the cause of reported health effects and to explore approaches to address them.

Previously, review papers such as by Knopper et al. (2014) and McCunney et al. (2015) have shown that existing evidences do not support a direct link between WT noise and health, and that a complex combination of noise and personal factors contributes to reports of health effects. They concluded that although noise levels affect the risk of a person reporting annoyance, reported health complaints are also related to a number of subjective variables, including nocebo responses, attitude toward WTs, personality characteristics, and whether individuals benefit financially from the presence of WTs. Several studies have observed that people who are worried, anxious, or concerned about an environmental risk are more likely to report symptoms (Claeson et al., 2012; Mcmahan and Meyer, 1995; Moffatt et al., 2000; Petrie et al., 2005). Crichton et al. (2014) demonstrated that positive or negative expectations about WT noise affect self-reported health outcomes. Rubin et al. (2014) also argue that most of the symptoms related to WT noise exposure may also be attributed to a number of

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subjective factors and fear of WTs, which would lead to an annoyed and stressed state, rather than there being any objective adverse health effects arising from WT operations.

Some other studies have also provided evidence that adverse health effects may not be directly related to the physical effects of WTs, but instead emerge from annoyance (Bakker et al., 2012; Pedersen and Persson Waye, 2007). The primary outcome assessed in six peer-reviewed studies related to the health effects of WTs was annoyance (Bakker et al., 2012; Michaud et al., 2016; Pawlaczyk-Łuszczyńska et al., 2014; Pedersen and Persson Waye, 2004, 2007; Yano et al., 2013). The easily perceived modulation of the WT sound increases the risk of it being negatively perceived and leading to elevated annoyance reports (Schmidt and Klokker, 2014). This risk is more pronounced in rural areas due to a combination of higher expectations of ambient quiet and lower levels of background noise (Schmidt and Klokker, 2014); additionally, the visual impacts of WTs are more pronounced in rural area than in urban ones (Pedersen and Larsman, 2008).

Studies investigating the relationship between WT noise and health have relied mostly on cross-sectional designs; prospective cohort studies that document prior baseline health status, in the field, are lacking. The study reported here, for the first time, examines the influence of individual differences and annoyance in the link between WT exposure and general health and Quality of Life (QOL), using a pre and post study design with multiple standard scales for outcome measurement.

2. Methods

2.1. Study areas and population

This study was carried out in a rural area of flat agricultural fields in the Township of West Lincoln, 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.

To estimate the population and number of residential dwellings within a 2 km radius of the wind farm, residential address centroids were generated from Municipal Property Assessment Corporation (MPAC) parcel data (each centroid represents the centre location of the property) and converted into a projected coordinate system (NAD83 UTM 17N) for use in Geographic Information System (GIS) software. For the parcel centroids within 2 km of the five turbines, 221 civic addresses were identified and selected for the study. WT coordinates were extracted from publically available engineering documents that were listed on the Renewable Energy Approval section of the company website (Vineland Power Inc, 2015). The euclidean distance between a participant's address centroid within 2 km of the nearest WT was calculated using standard proximity geoprocessing tools found within ArcGIS desktop. All geospatial data manipulations and analysis were carried out using ArcGIS desktop version 10.3.1 (Environmental Systems Research Institute, Redlands, CA, US).

2.2. Questionnaire development

The General Health Questionnaire consisted of five sections: RETs in Ontario, housing and community factors, environmental stressors (such as noise or visual effects of airplane, railway, WTs, power plants and agricultural machinery), overall QOL and general health perceptions, and demographic questions.

The General Health Survey incorporated a series of validated scales, including the Satisfaction with Life Scale (SWLS; Diener et al., 1985), and the SF-12 physical and mental health assessment scale (Ware et al., 1996), plus several questions adapted from the "Wind Farm Perception Study" (Van den Berg et al., 2008) and the Canadian Community Health Survey (CCHS) (CCHS, 2015). "Wind Farm Perception Study" investigated the perception of Dutch wind farms by its surrounding residents and focused on noise annoyance and visual impact of WTs.

The SWLS is a global measure of life satisfaction that assesses participants' satisfaction with life as a whole. It consists of five items, each scored on a Likert scale of 1–7 depending on the participant's level of agreement or disagreement. The scores of the five questions are summed to obtain the overall SWLS score, which is interpreted as follows: extremely satisfied (31–35), satisfied (26–30), slightly satisfied (21–25), neutral (20), slightly dissatisfied (15–19), dissatisfied (10–14) and extremely dissatisfied (5–9).

The SF-12 scale is a shortened version of the SF-36 scale (Ware et al., 1996), both of which have been used to assess the impact of environmental stressors on health in previous studies (Luginaah et al., 2002; Nissenbaum et al., 2012; Radon et al., 2004; Schreckenberg et al., 2010; Villeneuve et al., 2009). SF-12 is a validated assessment of both physical and mental health, and a practical, reliable measure of functional health and well-being, from the participant point of view. The SF-12 uses 12 questions, rated on a 5-point Likert scale and eight subscale scores can be derived: physical functioning, role physical, bodily pain, general health, vitality, social functioning, role emotional and mental health. Results are expressed in terms of two meta-scores: the Physical Component Scale (PCS) and the Mental Component Scale (MCS). The PCS and MCS scores range from 0 to 100, and are designed to have a mean score of 50 and a standard deviation of 10 in a representative sample of the United States population. A high score indicates better functioning, and scores greater than 50 represent above average health status. Here, SF-12 scores were calculated using Quality Metric's Health Outcomes Scoring Software 4.5 (Qualitymetric.com, 2015). Both PCS and MCS were dichotomized, as follows. PCS scores $\leq$50 were considered 'below average physical health status' and PCS scores >50 were considered 'above average physical health status'. Regarding to MCS, there are no universally accepted cut-points to identify probable diagnoses of a common mental disorder. Vilagut et al. (2013) and Kiely and Butterworth (2015) recommended a cut-point score of MCS $\leq$45.6 and MCS $\leq$ 40, respectively as a screening tool for depressive disorders. However, they recommended that cut-points ranging between 40 and 45 were acceptable. Based on this recommendation and cut-point of MCS-SF36 of $\leq$42 (Ware and Gandek, 1994), MCS scores $\leq$42 were considered 'at-risk for depression', and MCS scores >42 were considered 'not at-risk for depression'.

Participants also rated their general health, mental health and QOL in response to several stand-alone questions and by using a 5-point verbal rating system (VRS) ranging from Excellent = 1 to Poor = 5. In T2 observation, participants also rated their QOL based on the condition of "No Turbine". They were asked to rate their expected QOL, if no turbines existed in their community, and their actual QOL at the time of questioning.

To measure annoyance, participants were asked to rate different stressors in the community on how much they annoy, similar to the 'Project Wind Farm Perception' survey, which measured environmental exposure, annoyance and stress (Pedersen and Persson Waye, 2004). For example, questions asked participants to "please indicate whether you have noticed and whether you are annoyed when you are indoors in your home by WT noise." The participants rated their level of annoyance on a 5-point scale from 1 (do not notice/not annoyed = 1) to 5 (very annoyed = 5), or 'not applicable'. Participants were assigned to the following categories based on their noise perception and annoyance scores: "do not notice" (1) and "notice" (2–5), "not annoyed" (1–3) and "annoyed" (4–5). Noise sensitivity was measured on a 5-point scale, from "not at all sensitive" (1) to "very sensitive" (5). Attitudes to WTs in general