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Challenges to Studying the Health Effects of Wind Turbines among Different Research Designs

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Abstract. As the number of wind turbines around the world increases, controversy regarding the health effects of this renewable energy source remains. The body of research examining the health effects of living near a wind turbine is modest, and there is a need for more research. This paper will discuss the challenges to epidemiological studies of health and wind turbines, specifically the limitations of three well-known epidemiological research designs. The challenges to using a descriptive, experimental, and observational study design to examine wind turbines and health effects will be discussed. Future research will have to choose a research method wisely while also considering challenges like sparse populations living near wind farms, assessing wind turbine exposure, and the unclear definition of wind turbine health effects.

Keywords: wind farms, wind turbines, renewable energy, health, environmental health

1. Introduction

At a time when renewable energies are being promoted in hopes of reducing the use of coal-fired electricity, wind turbines have proven themselves controversial among citizens who live nearby proposed developments[1-5]. Residents of areas near wind turbines have complained of the noise and a range of health effects resulting from the wind turbines[6]. The symptoms of sleep disturbance, headaches, difficulty concentrating, irritability, fatigue, and ear disturbances are referred to as wind turbine syndrome (WTS) but there is little academic research on this syndrome. There is some academic research stating that flicker from the blades can cause photosensitive seizures but it is also speculated that this event would be rare[7-9]. The mechanism by which wind turbines cause health effects or annoyance is still unknown but there are a variety of hypotheses. Wind turbines lead to annoyance, and this may be a result of infrasound being sensed by the body and perceived by the inner ear, or it could be the intrusive sound characteristics of wind turbines which interfere with the restorative properties of a person's home[10-13].

Although there are many reported health effects and significant media coverage, there is a modest body of research examining the health effects of wind turbines. The descriptive studies that have been published are an excellent start to examining this relationship. For example, one study obtained information about housing and satisfaction with the living environment, annoyance related to wind turbines, health aspects, and time spent at work and along with A-weighted sound pressure levels measured at each respondent's dwelling[14]. Despite studies of this type, there is still a need for explanatory studies that go into more depth to explain why wind turbines affect the health of a population, and GIS spatial methods may also benefit research in this field[14,15]. Given the media attention towards wind turbine developments, the lack of research should not seen as resulting from disinterest or apathy from either the general public or academia. It may be that the small body of knowledge is a result of the challenges in researching the health effects of wind turbines.

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2. Study Designs

This paper will review three main research designs: descriptive research designs such as cross-sectional studies; experimental designs such as randomized control trials; and observational designs such as cohort studies, case-control studies, and longitudinal studies. Examples of possible studies that examine wind turbines and health using each of the designs will be discussed along with the challenges in using them. In the case of descriptive studies, examples from the published literature will also be discussed.

2.1. Cross-Sectional Studies

In cross-sectional studies, the exposure and disease outcome are determined simultaneously[16]. First, a population is identified and the presence or absence of both exposure and disease for each subject is determined[16]. The factors or exposures of interest will be measured as well as disease rate[17]. As an example, residents within a certain distance of a wind farm could be contacted via the phone or through the mail, WTS symptoms and exposure to the wind turbine would be measured. The exposure could be measured by hours spent in the home or distance from a wind turbine. Disease could be measured through self-report or salivary or urinary biomarkers that indicate stress. There have been a number of studies examining health and wind turbines that are cross-sectional, sampling residents living within 2.5km of at least two wind turbines, and measuring A-weighted sound pressure levels and comparing them with self-reported satisfaction with the living environment, annoyance, health, and time spent at work[14,18,19].

A challenge to the cross-sectional study is that reported diseases are all prevalent cases, which may result in misleading statistics – results would establish a relationship between factors of disease survival and not disease occurrence[16]. If no relationship is found between living near a wind turbine and health, it may result from the residents with the worst symptoms moving away while the residents who can cope remain and are studied. A second challenge is that data is analyzed at the group level, so a relationship does not mean that the same person reported both the exposure and the disease[17]. If a group of people reported WTS and another group reported living near a wind farm, the variables will be related despite a meaningless relationship. A third challenge is that both exposure and disease status are determined simultaneously, so the study results will give no insight into establishing a cause and effect relationship[16]. These challenges may be overcome by using a panel study, which collects several rounds of cross-sectional data from the same individuals[20]. A panel study gives insight into changes in exposures and disease over time, and the temporal sequence of exposure and disease onset, by introducing a longitudinal feature into a cross-sectional study[20].

2.2. Randomized Control Trials

In a randomized control trial (RCT), a defined population is randomly assigned to two groups and it is assumed that the two groups will vary by a factor manipulated by the researcher[16]. A randomized control trial study could be used to explore the effects of vibration and low frequency noise (LFN) on subjects in a laboratory setting. Studies have examined the mechanical response of the body to LFN, the self-rated vibratory sensation and annoyance, differentiation between wind turbine noise output, and the mechanism by which vibration is perceived[21-25]. The LFN from a wind turbine could be replicated in the laboratory using a true randomized control trial, but it is assumed that the conditions in a laboratory would not accurately portray real-life conditions and the results would not necessarily simulate living near a wind turbine[25].

In an RCT framework, a challenge in examining health and wind turbines is whether an experiment in a laboratory can accurately represent real-life[26]. If an experiment done in a laboratory is not an accurate representation, then the results cannot be generalized to the real world[26]. Also, biological or physiological measures taken in the laboratory do not necessarily relate to significant long-term effects[26]. Of course, using an RCT to evaluate the health effects outside of a laboratory is not feasible or ethical. This would involve randomly selecting people or families and moving them to a new home. In the case that it was feasible, the participants would likely be a vulnerable population, making the study unethical.

2.3. Cohort Studies

In a cohort study, the presence or absence of an exposure is of interest, especially if the exposure is a hypothesized or proven risk factor for disease[17]. There are two types of cohort studies: retrospective and prospective, which differ based on when the exposures and disease occurrence are being examined[27]. A

prospective cohort study could recruit residents who live near a wind farm that is nearly operational, measure their exposure as distance to a wind turbine, and follow them over time to see whether WTS starts to appear. A retrospective cohort study could examine records of who lived near a wind turbine, and then collect data on past exposure and disease status.

A cohort study is challenged by attrition (non-responses and losses to follow-up), whereby follow-up with individuals after exposure does not happen and outcomes are not determined[16,17]. This is especially problematic when people with disease are selectively lost in the follow-up[16]. In a study of wind turbines and health, this would occur when residents with WTS move away and the subjects with the disease outcome of interest are no longer subjects in the study. This tendency may be encouraged by discussion of health and wind turbines in the media which creates a expectation of health effects[13]. In a cohort study, it is necessary to withhold the study hypothesis from the person assessing disease status and exposure[16].

A challenge in retrospective studies is their reliance on having access to previously collected, detailed, relevant exposure data[17]. As an example, the Canadian Community Health survey is a cross-sectional survey that estimates health at the regional level, collected annually using a random sample of 65,000 Canadians[28]. The CCHS collects addresses, which can be used to determine distance from a wind turbine, as well as questions that measure factors that are similar to symptoms of WTS: general health, stress, life satisfaction, distress, loss of productivity, psychological well being, headaches, concentration, fatigue, hearing, and sleep[28]. Despite the availability of this data, the questions were not specifically designed to measure WTS and there may be inadequate information on potentially confounding factors[17].

2.4. Case-Control Studies

Case-control studies start with a group of "cases" who are individuals with a disease, and "controls" who do not have the disease[16]. After disease status has been established, exposure is measured. In a study of wind turbines and health, cases can be identified when a patient describes symptoms similer to those of WTS to a medical professional at either a doctor's office or hospital. A control group could be residents of the same area who report health effects to the medical professionals from living near mobile phone towers. After identifying cases and controls, the exposure that subjects in each group had to wind turbines would be assessed. The expectation would be that a higher number of cases were exposed compared to the controls[16].

A challenge to a case-control study is finding appropriate controls, but crucial for accurate results[17]. The control group must not be representative of the general population, but be similar to the cases with the exception of sharing disease status[17]. For a wind turbine and health study, an appropriate control group may be a group from a rural area near the wind farm who live near a mobile phone tower or hog rendering plant. Another challenge is selection bias, which occurs when the exposures and disease outcomes in the cases selected for the study are somehow different from the exposures and disease outcomes of those who were not selected for the study[17]. Selection bias can happen when media attention towards a speculated exposure and disease outcome affects behaviours[17]. This is likely to happen in the case of wind turbines and health. Residents with WTS may be more likely to seek medical care, and doctors may diagnose symptoms like sleep disturbance and headache as WTS when in fact it is another disease outcome. Recall bias is also an issue for case-control studies. Recall bias is the result of having a disease - it is expected that persons who have received a diagnosis are more likely to search for an answer as to why it happened, and will therefore remember exposures that a non-diagnosed person would not have remembered when asked for survey research purposes[16]. In the case of WTS, those with WTS will be more likely to report exposure to a wind turbine compared to a control. What also makes WTS especially difficult to examine in a case-control study is that there is no clear definition of the disease, making it difficult to diagnose a "case".

2.5. Considerations for Future Research

Wind turbines and wind farms tend to be installed in areas that are not densely populated: agricultural areas, small villages, or the countryside[14]. This may result in insufficient numbers of people living nearby, living at varying distances, and living within a comparable geographical, cultural, and topographical structure to perform a statistical analysis[14]. There is currently not enough information on people with high exposure to wind turbines[14].

Since the cause or causes of WTS is still unclear, the exposures that lead to WTS are still unknown. It may be useful for researchers to examine: the distance between a turbine and a person's home, noise propagation and models, sight lines and visibility of turbines from a person's house, the effect of weather, and the time a person spends at home each day. However, researching these factors has a few challenges. It is unclear what the radius around a wind turbine should be for recruiting participants as the threshold for health effects from a wind turbine is still unknown. Accurately locating the geographic location of a respondent's home through their street address may be difficult and the resident may be concerned with privacy issues. To model noise exposure with spatial methods, information about noise levels, wind speed, vibration, weather, terrain, time of day, season, and location of residences are needed to accurately use spatial interpolation methods to estimate the noise level across an entire area. Environmental health research examines the complexity of natural and social environments on human health, and geographic information systems (GIS) integrate spatial information into statistical analyses[15,29]. This allows for greater insight into the relationship between health outcomes and social, demographic, economic, and political factors[15]. In particular, when researching wind turbines and health, examining spatial factors like distance to turbines, noise exposure, and visibility with GIS will be a crucial step in understanding exposures and health outcomes. It may be useful to measure aspects of the physical environment and characteristics of a person's house such as bushes, trees, patios and verandas when assessing how wind turbines are experienced in daily life[14].

The diagnosis of wind turbine syndrome is still new, and there is a need for more evidence linking the symptoms to people living near wind turbines. Since symptoms from wind turbines are not clearly defined in the literature, it is not clear what should be measured to assess health. Future research may want to use biomarkers to indicate stress or health effects. There is evidence that salivary samples can be analyzed for proteins or hormones which indicate stress response to noise[30,31]. The number of factors that can influence how a wind turbine is perceived should encourage researchers to assess a subject's health more than once, especially if using spatial-temporal models.

Through a discussion of descriptive, experimental, and observational research designs, it is clear that using any design to examine the effects of wind turbines on health will have challenges. If these challenges are considered and incorporated into study design, they can be overcome, allowing research into this important public health topic to flourish.

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