Association of Sleep Quality with Health-Related Quality of Life in Residents Close to Wind Turbines

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Abstract

Background: In Canada, industrial wind operations are important parts of the country’s long-term energy strategy and Wind Turbines (WTs) are represented as environmentally friendly projects; however, suspected health-related effects of exposure to WT noise have attracted much public attention. Sleep disturbance and degraded Health-Related Quality of Life (HRQoL) have been among the most common complaints reported by residents living close to wind farms.

Objective: The objective of this study was to evaluate the association between changes in sleep quality and HRQoL among residents living close to wind farms.

Methods: Pre- and post-natural experiments were conducted with two data collection periods, before and after WTs became operational; sleep quality was measured by using the Pittsburgh Sleep Quality Index (PSQI), and HRQoL was measured using the 12-item Short Form (SF-12) Health Survey of 50 participants.

Results: Changes in the SF-12 mental component summary (ΔMCS) were correlated inversely with the changes in PSQI score (ΔPSQI, Spearman’s correlation r_S= -0.595). The median values for ΔMCS were significantly associated with ΔPSQI (p=0.039) after controlling for age, sex, distance and attitude to WTs, in a quantile regression analysis.

Conclusion: Changes in sleep quality reported by residents living nearby WTs were a significant independent predictor of the degraded mental health domain of HRQoL.

Introduction

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 Wind Turbines (WTs) has raised questions regarding potential health impacts on individuals who live close to such turbines. Sleep disturbance and degraded Quality of Life (QoL) have been among the most common symptoms and complaints reported by residents living close to wind farms [1-3]. Most investigations that have been conducted so far have focused on WT effects on either health-related QoL or on sleep disturbance; rarely has the association between the two been studied [1,2,4-7].

QoL is defined as “a concept encompassing a broad range of physical and psychological characteristics and limitations which describe an individual’s ability to function and to derive satisfaction from doing so” [8]. Sleep is also an active process that involves distinct characteristics and many vital physiological changes in the body’s organs and is fundamental for physical and mental health. The impact of poor sleep quality is important to consider when assessing QoL in a population. Results from population-based studies from different countries have shown that approximately 30% of adults report one or more of the symptoms of insomnia: difficulty initiating sleep, difficulty maintaining sleep, waking up too early, and in some cases, non restorative or poor quality of sleep [9]. It has been reported that insomnia negatively impacts aspects of waking function related to QoL, and those suffering from insomnia report impaired concentration, impaired memory, decreased ability to accomplish daily tasks and decreased enjoyment of interpersonal relationships [10].

In previous studies conducted on the general population and people with chronic diseases, sleep disturbance and insomnia symptoms negatively impact HRQoL and life satisfaction [11-16]. Since sleep problems are reported frequently in residents close to WTs, information about their association with HRQoL is essential for effective interventions and policies.

In this study, we examined the relationship between changes in self-reported sleep disturbance and HRQoL measures in residents living nearby WTs. This study took advantage of a natural experiment in which new WTs that were not initially in operation later became operational. The study employed a prospective pre- and post-operation design, with two data collection times before
and after WT operation. We hypothesized that changes in sleep quality would be associated with changes in quality of life.

Methods

Participant selection, questionnaire development and calculation of distances between participants’ addresses and the nearest WT have been described in detail in other publications [17,18]. Briefly, this research was carried out in a rural area in the Township of West Lincoln, in southern Ontario, Canada. Operation of five Vistas V100-1.8 MW turbines, with hub heights of 90m and rotor diameters of 100m, began in June 2014. Data was collected in two time periods: 4 months before and 8 months after WT operations began. The recruitment process involved door-to-door visits up to three times to recruit participants. Required criteria included the followings: adult over 18 years of age, general good health and living within 2000m of the WTs. Fifty participants agreed to participate in the sleep and HRQoL study in the first round. Distances between participants’ residence and the nearest WT were calculated using a Global Positioning System (GPS).

Quality of sleep was measured using the Pittsburgh Sleep Quality Index (PSQI), and HRQoL was measured using the 12-item Short Form Health Survey (SF-12) questionnaire for all the participants. The SF-12 scale is a validated assessment of both physical and mental health and is a shortened version of the SF-36 scale [19]. The 12 items are rated on a 5-point Linker scale, and eight subscale scores can be derived from the responses: physical functioning, role functioning (physical), bodily pain, general health, vitality, social functioning, role functioning (emotional) and mental health. Results are expressed in terms of two meta-scores: the Physical Component Summary (PCS) and the Mental Component Summary (MCS) (for both, scores range from 0 to 100, with higher scores indicating better health).

PSQI is a self-administered questionnaire that assesses sleep quality during the previous month. It contains 19 self-rated questions yielding seven components: subjective sleep quality sleep latency, sleep duration, sleep efficiency, sleep disturbance, use of medications, and daytime dysfunction. Each component is scored from 0 to 3, with a total score ranging between 0 and 21. Higher scores indicate a lower sleep quality and a PSQI score > 5 indicates poor sleep quality [20]. Each participant provided demographic information, including age, gender, marital status, education, and current employment status. Attitudes to WTs in general and concerns about perceived environmental and WT risks (such as noise, vibration, visual effects, and risk to wildlife and health effects) were measured at both Time1 (T1) and Time2 (T2) through different types and models of questions in the survey. Attitudes at T1 and T2 were not significantly changed (p=0.754), and as no significant differences were found in participants’ attitudes from T1 to T2, T2 data were used in the analysis (attitudes at T1 are not reported). Attitudes to WTs were assessed with a 5-point Linker-type scale, from “very positive”=1, to “very negative”=5, and were also dichotomized into “not negative” (1-3) and “negative” (4-5).

Analysis

The analysis was performed using R statistical software for Windows 10 (R Core Team, Vienna, Austria). Spearman correlation coefficients were used to examine associations between continuous variables. The changes of MCS and PCS from T1 to T2 [(ΔMCS=MCS2-MCS1) and (ΔPCS=PCS2-PCS1)] were used as the response variables. Independent variables assessed in this study included the following: distance to WT (continuous), age (continuous and categorical: middle age: 30-55 and older adult >55), gender (male, female), attitudes to WT (negative, not negative), and interaction between distance and ΔPSQI (ΔPSQI is the difference between the PSQI in T1 and in T2). Descriptive statistics were used to summarize all data. Quintile regression was used to examine the association between ΔMCS score, and ΔPSQI score with adjustments for age, gender, distance and attitude to WTs. The level of significance was set at 0.05 for all analyses.

Results

A total of 50 participants were recruited, of whom 40 completed the questionnaires in both T1 and T2 time periods. The mean age of participants was 54.2 years, and 43.2% were male. Of the participants, 45.9% had a negative attitude to WTs, 51.3% had positive or neutral attitude to WTs, 59.5% lived within a 1000m distance of the closest WT and 40.5% lived between 1000-2000m away (Table 1). An investigation into the relationship between changes of QOL and PSQI scores was performed using ΔMCS and ΔPCS scores. There was a significant negative correlation between ΔPSQI and ΔMCS (r S=-0.595 p<0.001). There was no significant correlation between ΔPSQI and ΔPCS changes (r S=-0.036, p=0.832). The normality assumption was tested using Shapiro-Wilk test. The ΔMCS did not meet the assumption of normality necessary for the use of ordinary linear regression (p=0.003 for ΔMCS and p = 0.7579 for ΔPCS), and the plot of ΔMCS versus ΔPSQI also showed decreasing variability with increasing ΔPSQI (Figure1). Because these two findings violate two key assumptions of linear regression (i.e., normality with constant variance), linear regression in this scenario was of limited value, and sequential (median) regression was used. In quantile regression, the quantiles of a response variables are regressed over a set of covariates, and this regression is suitable for skewed and non-normal distributed data without transforming and trimming the data to reach normality [21]. For categorical variables, the mean of ΔMCS scores were not significantly different for females versus males (p=0.392), middle-aged versus older adults (p=0.321), and for close and far distance groups (p=0.301 the mean of the ΔMCS was only higher in those with negative attitudes about WTs not those with positive or neutral

<table>
<thead>
<tr>
<th>Variables and Demographic Characteristics</th>
<th>%</th>
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<tbody>
<tr>
<td>Gender Male</td>
<td>43.2%</td>
</tr>
<tr>
<td></td>
<td>Female</td>
</tr>
<tr>
<td>Distance to Nearest Wind Turbine &lt;1000m</td>
<td>59.5%</td>
</tr>
<tr>
<td></td>
<td>&gt;100m</td>
</tr>
<tr>
<td>Age (mean, range)</td>
<td>54.25(33.78) ( SD=12.27)</td>
</tr>
</tbody>
</table>

Table 1: Demographic characteristics and health scores of respondents.
attitudes \((p=0.018)\). The mean of the \(\Delta \text{PSQI}\) score also was not different for females versus males \((p=0.453)\), or the two age groups (middle age \(<=55\), older adult \(>55\)) \((p=0.602)\), or two different distances (less than or greater than 1000m, \(p=0.212)\). However, changes of PSQI were significantly different in the group with a negative attitude about WTs, not those who had positive or neutral attitudes \((p=0.002)\). Detailed results of association of \(\Delta \text{MCS}\) and categorical factors are already published in table 2 of our previous publications \([17,22]\).

The results of quintile regression indicate that higher changes in \(\Delta \text{PSQI}\) scores were significantly associated with higher changes in \(\Delta \text{MCS}\) scores \((p=0.039)\). The \(\Delta \text{PSQI}\) score remained a significant independent predictor of \(\Delta \text{MCS}\), after controlling for age, sex, attitude, distance and interaction of distance and \(\Delta \text{PSQI}\), as shown in Table 2. The quintile regression coefficient indicates that, for a unit change in \(\Delta \text{PSQI}\), the predicted median value of \(\Delta \text{MCS}\) will decrease by 1.46 units. \(\Delta \text{PSQI}\) and \(\Delta \text{PCS}\) were not associated \((p=0.988)\) after controlling for age, gender, distance and attitude to WTs.

In figure 2, regression coefficient \((\beta)\) represents the rate of change of \(\Delta \text{MCS}\) as a function of changes in each percentile of \(\Delta \text{PSQI}\), with the 95\% confidence intervals. This plot implies that the coefficient estimate does not significantly vary by quintiles. Additionally, because the quintile coefficient is within the ordinary linear model coefficient estimate confidence interval, we can conclude that the coefficient estimates for \(\Delta \text{MCS}\) do not differ between the quintile and linear models. However, we used the quintile regression method in this study because the linear model assumptions were violated in our data application.

Table 2: Quintile and Ordinary Regression Results: Effects of PSQI changes (PSQI) on Median and Mean of MCS changes (\(\Delta \text{MCS}\)), and PCS changes (\(\Delta \text{PCS}\)).

<table>
<thead>
<tr>
<th>Outcome</th>
<th>(\Delta \text{PSQI}) (\beta)-estimate</th>
<th>(\Delta \text{MCS}) (\beta)-estimate</th>
<th>(\Delta \text{PCS}) (\beta)-estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>25%</td>
<td>-1.14</td>
<td>-1.50</td>
<td>-0.005</td>
</tr>
<tr>
<td>50%</td>
<td>-1.46</td>
<td>0.039</td>
<td>0.015</td>
</tr>
<tr>
<td>75%</td>
<td>-0.99</td>
<td>0.015</td>
<td>0.015</td>
</tr>
</tbody>
</table>

Discussion

The aims of this study were to assess whether changes in reported sleep quality were associated with HRQoL’s changes, after WTs became operational. We found that those participants, who live nearby the WTs and reported poor sleep quality, also reported reduced HRQoL, particularly in the domain of mental health (MCS). The association between sleep quality and HRQoL is adjusted for confounding variables such as age, gender, attitude towards WTs, distance from WTs, and interaction between distance and PSQI. Sleep quality was not associated with Physical Health Changes (PCS).

The results of the present study are consistent with previous studies in the general population and in chronic disease groups, which have found that subjective sleep disturbance was independently predictive of lower quality-of-life scores. The previous studies demonstrated that poor or reduced amounts of nocturnal sleep adversely affect quality of life scores and functional health indicators \([11,14-16,23]\). Leger et al. \([15]\) conducted a population-based investigation and found that insomnia was associated with global decreases in HRQoL, even after controlling for depression or anxiety presence. Kats and McHorney \((2002)\) \([23]\) also found in Somalia to be associated with significantly worsened HRQoL, particularly in the domains of mental health, vitality, and general health perceptions, even after adjusting for chronic medical conditions, depression, and anxiety.

Insomnia and psychiatric disorders such as anxiety and depression are interconnected, and sleep disturbance can be the cause or the consequence of psychological issues \([15,24]\). Sleep disturbance is one of the main symptoms in depression and mental health disorders \([25]\). Ford and Kamerow \([26]\) have conducted a prospective cohort study and demonstrated a 4.5 times higher chance for insomnia to develop depression without treatment than insomniacs who were treated. The association of sleep disturbance and mental health issues has been the subject of many studies, two of which concluded that the pathway between insomnia and depression may be mediated through reduced HRQoL \([16,27]\).
Previous studies suggest that stressful neighborhood conditions could contribute to poor sleep quality through various psychological and physiological pathways [28]. WTs, as a new element of the landscape can be a potential source of stress and fear [29], and trigger the release of stress hormones, promote mental and physiological arousal [30], and so potentially decrease QoL.

This study has some important limitations. On one hand, sleep disruption can affect various physical and mental conditions and ultimately influence HRQoL. On the other hand, physical and mental health is both important determinants of sleep quality. We can only conclude that our findings of sleep disturbance and the mental health component of QoL are related; the study provides no evidence regarding causation (i.e., we are not able to show if sleep disturbance is a cause or consequence of mental health degradation).

In the data analysis examining quality of sleep and HRQoL, we controlled for age, gender, attitude to WTs and distance. However, the sample size of the study limited our ability to control for all variables that may have impacted the quality of sleep and HRQoL relationship, and may have also limited our ability to detect some relationships. Nonetheless, the results support findings from other studies that have linked general measures of disturbed sleep with reduced HRQoL. The relatively small sample size and also the fact that the study was conducted in proximity to a small wind farm also limit the generalizability of the results.

The PSQI and SF-12 assess quality of sleep and HRQoL during the preceding 4-week period, respectively. The look back nature of these measures and the associated risk of recall biases is another limitation of this study. Recall bias for symptoms might have resulted in people who had negative attitudes to WTs and were worried about possible adverse health effects remembering more symptoms from the recent past than people who were not worried, even if the actual level of symptoms was the same in the two groups.

Conclusion

To the best of our knowledge this is the first study to investigate and examine the association between changes in self-reported sleep disturbance and HRQoL measures in residents living near WTs. Perhaps the most important findings of this study were that changes in sleep quality of residents living close to WTs were associated with reduced quality of life in the domain of mental health, but not in the domain of physical health. Our study provides additional evidence that people with sleep disturbance are more likely to be having poorer HRQoL in mental health domains. In summary, our results support our hypotheses that reporting poor sleep quality is associated with degraded quality of life (mental health) in residents living close to WTs.

Acknowledgement

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