Original Article

Effect of Occupational Noise-induced Sleep Disturbance on Worker's Health

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Abstract

Aims: In addition to the noise, sleep disturbance (SD) as an outcome of the exposure to the wind turbine noises (WTNs) can adversely affect general health. This study aimed to investigate the effect of SD induced from WTNs on general health indicators. **Materials and Methods:** A total number of fifty tree workers from Manjil wind farm voluntarily participated in this study. Based on the job similarity and vicinity to the sound sources, workers were classified into three occupational groups including repairman, security, and official staff. Individual's health and sleep status were gathered using the 28-item General Health Questionnaire and Epworth Sleepiness Scales, respectively. Noise was measured based on ISO 9612. ANOVA, Chi-square, and linear and multiple regression tests were used for data analysis in the SPSS 20 software environment. **Results:** The mean values of 8-h equivalent continuous A-weighted sound pressure level ($LA_{eq,\ 8\ h}$) among whole workers was 71 ± 10 dB (A). The averages of somatic symptom, anxiety insomnia, social dysfunction, depression, and general health among the participants were 5 ± 2.44, 7 ± 2.35, 11 ± 2.65, 2 ± 1.54, 22 ± 6.53, and 7.3 ± 3.1, respectively. According to the results, SD and noise exposure had an adverse health effect on physical symptoms, depression, and overall general health of participants. Moreover, SD and work experience were effective factors on anxiety-insomnia. SD had greatest effect on general health when all variables are controlled, so that general health will increase by 2.42 units for each unit increase of SD. **Conclusion:** We found that in addition to the sound effect, noise-induced SD also affects worker's health and strengthen sound effects on human well-being.

Keywords: General health, sleep disturbance, wind turbine noise

Introduction

Fear for the disastrous outcomes of climate change has driven many governments worldwide to invest in renewable energy. Compared to the other forms of renewable energy, usability of wind energy is much broader and it makes more economic benefit. Wind energy has very low harmful health effects than other old-style sources of energy which is noteworthy as a positive health benefit. However, this form of energy may lead to some adverse health consequences on the people living closed to the wind farms.[1] The aerodynamic and mechanical sound of wind turbine can cause some health problems.[2,3] According to observations, in areas where outdoor sound level is beyond the 45 dBA, complaints of harmful health outcomes are more prevalent when related to wind turbine noise (WTN).[4] The World Health Organization reported that noises which have low-frequency nature have health problems such as "noise-induced hearing loss, interference with communication, and sleep and rest, psychophysiological disorders, disturbance in mental health and functions, effects on behavior, annoyance, and disturbance of activities."[5] In addition, symptoms of complications such as annoyance, sleep disturbance (SD), stress, and decreased quality of life have been reported among individuals exposed to the WTN.[6,7] Studies have shown that low-frequency sound such as WTN and sound of air conditioner systems may have serious effects on individuals' health and cause SD.[8,9] The WHO reported that SD is one of the main consequences of noise that can

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cause adverse health problems.[10] Bakker *et al*. demonstrated a relationship between the annoyance induced from WTN and SD that means people with more noise annoyance experience more sleep problems.[11] There are a broad literature for the effects of the sound exposure on the SD and health of people living close to the wind turbine power plants[6,11] but, so far, little researches have focused on the workers. Due to the higher exposure of noise among wind farm's workers, their health and sleep are severely at the higher risk. Thus, this research was done to study the effect of occupational noise-induced SD on general health among Manjil wind farm's workers.

Materials and Methods

To conducting this cross-sectional study in 2015, all workers of Manjil wind farm, Iran, were categorized based on their job duties including repairman, security, and official groups. A brief orientation meeting about the aims of study and questionnaire completion method was set with power plant staff. For each occupational group, noise exposure was measured based on the standard method.

Noise measurement

In this study, a calibrated sound level meter analyzer (model TES 1358, China) was used for noise measurement. The WTN exposure level of employees at each job group was measured by 8-h equivalent sound level ($LA_{eq, 8 h}$) based on ISO 9612.[12] To achieve this goal, 15-min equivalent sound exposure level was measured for each workstation. Finally, the 8-h equivalent sound exposure level for each job group was obtained based on the field measurements and calculations in the mentioned standard.

Questionnaires

A general questionnaire was used to collecting sociodemographic data for each individual. Individual's general health and SD data were obtained using the 28-item General Health Questionnaire (GHQ-28) and Epworth sleepiness scale (ESS), respectively. GHQ-2 consists of 28 questions and is designed to assess the four aspects of distress including somatic symptoms, anxiety and insomnia, social dysfunction, and depression that each subscale consists of seven questions. In the GHQ-28, the respondents are asked to compare their recent psychological states with their usual states. Based on individual's health, for each item, there are four possible answer (0 = better than usual, 1 = same as usual, 2 = less than usual, 3 = much less than usual). In this tool, the Likert scoring procedure (0, 1, 2, and 3) is applied and the total scale score ranges from 0 to 84. The higher the score, the poorer is the psychological well-being of the person. The obtained scores of all four subscales (somatic, anxiety-insomnia, social dysfunction, and depression) and questionnaire total score were 0–21 and 0–84, respectively, with lower scores indicating better well-being. Reliability and validity of questionnaire have been demonstrated by Goldberg and Noorbala.[13,14]

The ESS is a self-administered questionnaire with 8 questions. It provides a measure of a person's general level of daytime sleepiness, or their average sleep propensity in daily life. It has become the world standard method for making this assessment. The ESS asks individuals to rate, on a 4-point scale (0–3), their usual chances of dozing off or falling asleep in 8 different situations or activities that most individuals engage in as part of their daily lives, although not necessarily every day. The total ESS score is the sum of 8-item scores and can range between 0 and 24. A number in the 0–9 range is considered to be normal while a number in the 10–24 range indicates that expert medical advice is required. The higher the score, the higher is the person's level of daytime sleepiness. The ESS has a global reliability and validity estimated by Cronbach's alpha in the range of 73% to 88%.[15]

Statistical analysis

Finally, data were extracted and entered to and analyzed by SPSS 20, IBM, Armonk, NY, United States of America and the results were reported. The one-way analysis of variance (ANOVA) and Chi-square test were used to compare the general health and SD across job groups, age, work experience, educational level, and type of working shift. Then, the effect of noise exposure on the sleep and health of workers was studied by the simple linear regression. Multiple regression test was used to investigate the effect of sociodemographic variables and SD on general health and its subscales.

Results

In this cross-sectional study, 53 staff of the Manjil wind farm participated. The mean (standard deviation) age and work experience were 30.8 ± 5.9 and 14.1 ± 5.5 years, respectively. The values of $LA_{eq, 8 h}$ among repairman, security, and official groups were equal to 83 dB (A), 66 dB (A), and 60 dB (A), respectively. The average SD among the participants was 7.3. Moreover, the average somatic symptom, anxiety insomnia, social dysfunction, depression, and general health were 5 ± 2.44, 7 ± 2.35, 11 ± 2.65, 2 ± 1.54, and 22 ± 6.53, respectively. The one-way ANOVA was used to compare the general health and SD means among job, age, and work experience groups. Chi-square test was used to compare the GHQ and SD mean among educational level and working shift. The obtained results are shown in Table 1.

According to Table 1, the highest numbers of participants were in repairing groups with 22 (41.5%) employees and administrative staffs were the lowest groups with 14 (26.4%) employees. Approximately 77% of individuals were diploma and higher and daily workers formed 71.7% of total population.

The obtained results showed that mean SD was equal in different educational levels. Differences of average SD among different groups of age, experience, type of shiftwork, and type of job were statistically significant. Moreover, there was a significant difference between general health means in job, age, and work experience groups.

Effect of noise exposure on the sleep and health of workers was studied by simple linear regression. According to the results, every 1 dB increase in sound exposure will lead to

Table 1: Comparison of the general health and sleep disturbance means across independent variables

Independent variables	Frequency (%)	Sleep disturbance	General health
Type of job			
Official	14 (26.4)	ANOVA	ANOVA
Security	17 (32.1)	*P*=0.001	*P*=0.001
Repairman	22 (41.5)		
Education			
Less than diploma	12 (22.6)	χ^2	χ^2
		P>0.05	*P*>0.05
Diploma less than or equal to	41 (77.4)		
Type of shift work			
Day	38 (71.7)	χ^2	χ^2
Rotation	15 (28.3)	*P*=0.001	*P*>0.05
Age			
<36	23 (43.4)	ANOVA	ANOVA
36-41	19 (35.9)	*P*=0.001	*P*=0.005
>41	11 (20.7)		
Experience			
<12	19 (35.9)	ANOVA	ANOVA
12-19	23 (43.4)	*P*=0.04	*P*=0.009
>19	11 (20.7)		

SD: Sleep disturbance, ANOVA: Analysis of variance

an increase of 0.28 and 0.34 in SD and general health scores among the workers.

In this research, multiple regression test was used to investigate the effect of independent variables on general health subscales. In this model, repairing group was considered as a reference group. The assumption of this model was investigated before fitting a regression model. Assumption of linearity and constancy of error variance was investigated using standardized residual plots against predicted values. The residual plots in all 4 regression models indicated the linearity and constancy of error variance. As well as, assumption of normality of data was confirmed by the normal probability plot.

After checking the assumptions of regression model, a multiple regression model was fitted for all 4 subscales. In the first model, the impact of independent variables on physical symptoms was studied. According to the results, SD and noise exposure had a positive effect on physical symptoms. SD had the greatest effect on physical symptoms, so that when other variables are controlled, physical symptoms will increase by 0.89, as per unit increase of SD [Table 2].

In the second model, the effect of independent variables on anxiety and insomnia was investigated. According to the presented results in Table 2, the SD and work experience were effective factor on anxiety and insomnia. SD was greatest affective factor on anxiety and insomnia, so that when all variables are justified, anxiety and insomnia will increase by 0.531, for every 1 unit increase of SD. Moreover, in situations where all variables were constant, an increase of 0.231 in anxiety and insomnia occurred as each year increase of work experience [Table 2].

In third model, effect of independent variables on social dysfunction was investigated. The results showed that there is no significant association between the independent variables used in model and social dysfunction of employees [Table 2].

In the fourth model, the effect of independent variables on depression was investigated. According to the results, SD and noise exposure had a significant effect on depression. In this regard, SD had greatest effect on depression, so that when other variables are justified, depression will increase by 0.694 for every 1 unit increase of SD. The coefficient of B for repairman (−2.972) showed that difference in average depression among different occupational groups such as repairman and security staff is statistically significant. Because of negative coefficient, it can be said that depression in security force is lower than repairman. The results of all four models are presented in Table 2.

The effect of all independent variables on general health was investigated by multiple regression test. The results showed that SD and noise exposure had a significant effect on participant's general health. SD had greatest effect on general health when all variables are controlled, general health will increase by 2.42 for every 1 unit increase of SD [Table 3].

Finally, by comparing the results of the five models, it can be concluded that SD had greatest effect on physical symptoms and it had the least effect on anxiety and insomnia. As well as, SD had greatest effect on employee's general health.

In the human studies, there are many factors that can affect response variable. Because of the genetic, environmental, and personal differences, hundreds of variables are effective on the response variable and many of these variables justify a very small portion of the variations of response variable. It is not possible to identify and model all of the influencing factors on response variable. Hence, the focuses are on the identifying of most effective factor on response variable. In this study, four variables including age, work experience, SD, and occupation type are the most effective variables on responses. Determination coefficient in the regression model shows the predictive power of the model. Determination coefficient in the fitted model on insomnia-anxiety, social dysfunction, and general health was more than 40%. It can be concluded that these variables could justify more than 40% of variations of response variables in the regression equation. In physical symptoms and depression models, all four independent variables justified more than 20% of variations of response variable. The small difference between the determination coefficient and adjusted determination coefficient means that independent variables which are added into the model are selected properly. Hence, the results of this study showed that all of five fitted models have suitable predictive power because all variables entered into the model are selected properly.

Discussion

Of the major adverse outcomes of environmental noise are SD and reduced general well-being.[11] The results of this study

Table 2: The effect of all independent variables on somatic symptom, anxiety insomnia, social dysfunction, depression

Independent variable	Unstandardized coefficients		Standardized coefficients (β)	*t*	Significant
	B	SE			
Somatic symptom					
Constant	−0.915	2.520	-	−0.363	>0.05
Age	0.059	0.100	0.144	0.591	>0.05
Experience	−0.123	0.104	−0.278	−1.177	>0.05
SD	0.893	0.217	1.159	4.122*	0.001
Official	0.728	0.815	0.132	0.893	>0.05
Security	−2.796	1.163	−0.568	−2.403*	0.02
Anxiety and insomnia					
Constant	3.895	2.169	-	1.796	>0.05
Age	−0.080	0.086	−0.202	−0.928	0.013
Experience	0.231	0.090	0.544	2.579*	0.006
SD	0.531	0.187	0.716	2.849*	>0.05
Official	0.056	0.702	0.011	0.080	>0.05
Security	−1.517	1.001	−0.320	−1.516	>0.05
Social dysfunction					
Constant	4.935	2.666	-	1.851	>0.05
Age	−0.002	0.106	−0.004	−0.017	>0.05
Experience	0.142	0.110	0.296	1.289	>0.05
SD	0.397	0.229	0.474	1.730	>0.05
Official	1.391	0.863	0.233	1.613	>0.05
Security	0.575	1.231	0.108	0.467	>0.05
Depression					
Constant	−0.400	2.902	-	−0.138	>0.05
Age	−0.024	0.115	−0.055	−0.205	>0.05
Experience	0.023	0.120	0.050	0.192	>0.05
SD	0.694	0.250	0.865	2.779*	0.008
Official	−0.352	0.939	−0.062	−0.375	>0.05
Security	−2.972	1.340	−0.580	−2.218*	0.031

*Significance at 5% level. SD: Sleep disturbance, SE: Standard error

Table 3: The effect of all independent variables on general health

Independent variable	Unstandardized coefficients		Standardized coefficients (β)	*t*	Significant
	B	SE			
General health					
Constant	6.021	5.2	-	1.158	>0.05
Age	−0.016	0.207	−0.015	−0.078	>0.05
Experience	0.182	0.215	0.155	0.848	>0.05
SD	2.422	0.447	1.177	5.416*	0.001
Official	1.815	1.683	0.124	1.079	>0.05
Security	−6.655	2.400	−0.506	−2.773*	0.008

*Significance at 5% level. SD: Sleep disturbance, SE: Standard error

showed that SD and adverse health effects on general health are increased as a result of exposure to WTN.

There are many studies that confirm the effect of WTN on sleep.[7,11] Decreased sleep quality and quantity arise from WTN can cause other adverse health effects which is the matter of this study. The results of Table 1 showed that WNT is related with worker's SD significantly. Based on Table 2, SD is one of the affective variables on the somatic symptom. In this regard, it can be said that WTN directly and indirectly (through the SD) can affect somatic symptom although indirect effect is greater.

It is clear in the literature that noise has subjective effects on the workers and somatic symptom is not subjective, so it is expected that noise affect somatic symptom through noise-induced sleep disturbance. The results of Table 2 also showed that SD and work experience affect anxiety and insomnia adversely and the effect of SD is greater. Being prone to anxiety and stress depends on many factors including experience, psychological, biological, and social factors.[16] Anxiety among individuals who live close to wind farms and are exposed to WTN can be due to visibility of sound source, SD, and other factors.[17,18]

In this model, there was a significant relationship between anxiety and noise exposure. This result is consistent with the study of Michaud *et al*.[19] They found that WTN exposure was not significantly related to stress. They found that dizziness and a diagnosed sleep disorder are among affective factor that can adversely increase stress scores.[19] Pedersen *et al*. indicated that stress was related to noise annoyance and not to WTN itself. They also implied that SD is due to WTN exposure and noise annoyance induced from WTN.[20] Joo *et al*. confirmed that increased concentration of the stress hormone is linked with increased SD.[21] This stress itself can be one of the causes of health deterioration. Because of hormonal changes due to sleep disorder, dizziness, and drowsiness, it is expected that an individual should be anxiety and stressed in the workplace. In the previous study, longitudinal relations have also been recognized between SD, anxiety, and depression.[22,23]

Bidirectional association was found between SD, anxiety, and depression.[24] This result shows that SD predicts and is predicted by anxiety and depression. Therefore, effective management of SD may avert the beginning of subsequent such as anxiety or depression.[25] Overall, it can be said that WTN can cause SD and in this way create anxiety and stress indirectly.

In the final model, SD was main predictor of general health. Exposure to the WTN was another affective factor on general health. Based on the results of Table 1, noise exposure, age, and work experience were in relation with general health. It can be said that WTN has potential effect on SD and general health directly and noise-induced SD is a mediator for indirect effect of WTN on general health. Previously, review studies indicated that present knowledge does not support a direct association between WTN and health.[25,26] These studies conveyed that there is a complicated composition of WTN and personal factors which can cause adverse health effects.[25,26] Bakker *et al*. introduce a model in which WTN-induced SD and psychological distress had bidirectional association.[11] They indicated that SD and decreased health can create a potential for greater perception and effect of WTN. In this study, it was found that WTN can affect sleep and health of worker adversely. Noise causes SDs directly and in this way it affects worker's health through SD, indirectly.

The World Health Organization confirmed that the prolonged noise exposure can cause annoyance and SD and they may be affective on health and well-being.[27,28] Shepherd *et al*. indicated that noise annoyance produced by WTN is in relation with anxiety and psychological disorders, and in the high level of WTN which annoyance is in its pick, it is expected that general health and well-being are worse.[29]

The result of the current study showed that effect of SD on general health is greater effect of noise exposure. It can be said that noise makes sleep problems and in this way it leads to health problems indirectly. SDs can cause anxiety that is a reason for other adverse health effects in individuals who are exposed to WTN.[30] There are many factors such as fear, sensitivity, attitude to the WT and personality that can cause adverse health effects among people who are exposed to the WTN. Crichton *et al*. revealed that positive or negative beliefs about WTN affect individual's health.[31] As well as, Jalali *et al*. indicated the negative effect of visibility of WT, noise annoyance, personal attitude to wind turbines, and sensitivity on the health and quality of life of people who are exposed to WTNs.[32] There are several limitations in this study, which prevents a definite opinion about the effects of WTN on general health of workers of wind farm. First of all, the number of understudied workers was small. There is a need to study all the workers occupied in all wind farms of country considering the all possible difference. The self-reported studies have some bias and it is possible to avoid it by conducting objective studies. Fear of getting fired, medical history of workers, WTN exposure while relaxing at home and low financial support can be other affective factors that were out of the scope of the present study.

Conclusion

The evidence from this cross-sectional study suggests that exposure to WTN is associated with SD and adverse health effects. It can be concluded that WTN affect worker's general health through the SD.

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Conflicts of interest

There are no conflicts of interest.

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