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Symptom reporting after the introduction of a new high-voltage power line: A prospective field study

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ABSTRACT

Background

There is public concern about the potential health effects of exposure to extremely low-frequency electromagnetic fields (ELF-EMF) of high-voltage power lines (HVPLs). Some residents living near HVPLs believe ELF-EMF might cause non-specific health complaints.

Objectives

The present study is the first to prospectively investigate whether self-reported health complaints and causal beliefs increase after the construction of a new power line.

Methods

We used a quasi-experimental design with two pretests before and two posttests after a new HVPL was put into operation. Residents living near (0-300 m, n = 229; 300-500 m, n = 489) and farther away (500-2000 m, n = 536) participated in the study. Linear mixed models were fitted to test whether symptom reports and beliefs that power lines caused health complaints increased more in residents living close to the new line compared to residents living farther away.

Results

A significantly ($p < .05$) larger increase from baseline in symptom reports and causal beliefs was found in residents living within 300 m from the new power line when compared to residents living farther away. While symptom reports did not differ at baseline, the belief that a power line could cause these symptoms was at baseline already stronger for residents living close compared to residents living farther away.

Conclusions

We found a negative impact of a new HVPL on health perceptions of nearby residents, even before the line was put into operation.

INTRODUCTION

The potential health effects of exposure to extremely low-frequency (ELF) electromagnetic fields (EMF) from nearby high-voltage power lines (HVPLs) are the subject of a longstanding debate in environmental health. In contrast to high frequency ionizing radiation (e.g. X-rays), no plausible biophysical mechanisms are known for ELF-EMF to cause health effects in humans under the current exposure standards. Several epidemiological studies investigated the potential effects of ELF magnetic fields emitted by power lines on a wide variety of health outcomes, such as brain tumors [1], Alzheimer's disease [2], and non-specific health complaints such as headaches [3]. For most outcomes the World Health Organization judged the evidence indicative of no relationship with magnetic fields [4]. Only for childhood leukemia was the evidence deemed to be sufficiently strong to remain a concern based on pooled analyses of observational studies (e.g. [5]).

The evidence of a relationship between ELF-EMF and non-specific health complaints is considered weak. However, between 1.5% and 13.4% of the general population attributes non-specific health complaints, such as fatigue and concentration problems, to exposure from EMF emitted by various electrical sources such as mobile phones and power lines [6]. A review of experiments exposing participants to real radiofrequency or ELF fields and sham EMF indicate no effects of EMF exposure on symptom reports or on the ability to distinguish between real and sham EMF [7]. However, sham EMF exposure resulted in increased symptom reports in healthy participants who were told that they were exposed to EMF from visibly present electrical equipment [8,9]. These findings suggest that health responses to HVPLs could occur through other psychological pathways unrelated to EMF exposure.

In the medical field an increase in symptom reports after exposure to an inert treatment is described as a nocebo response [10]. Nocebo responses are likely to occur when people hold negative expectations of a treatment [11]. Nocebo-like responses are also found with environmental exposures such as wind turbines [12] and mobile phone base stations [13]. Research on nocebo responses to HVPLs is limited, but studies suggest that people hold negative health expectations of exposure to ELF-EMF from power lines [14-16].

When negative health expectations of living near a power line are prevalent, one may expect to find higher symptom reports in people living closer to a HVPL. Only a few HVPL health studies have examined effects of distance on non-specific health complaints. McMahan and Meyer [17] for instance, found no differences in symptom reports between residents living on the easement of an HVPL or one block away. However, residents who worried more about overhead transmission lines were more likely to report symptoms and this effect was stronger for those living on the easement. A more recent general population study did not find an association between distance to HVPLs and symptom reports [18], but they did find a relationship between perceived proximity of power lines and reporting symptoms, suggesting the potential importance of the perception of proximity for health responses to occur.

The current study is, to our knowledge, the first to prospectively assess health responses to the introduction of a new HVPL. New HVPLs are being introduced into the environment as a result of the increasing demand for reliable and renewable energy supplies [19,20]. Currently a project is being carried out in the Netherlands investigating health responses to a new HVPL route [21]. In this paper we report the main results of the project. The research question that we address here is whether symptom reports increase more for residents living near a new power line route after it has been put into operation, compared to residents living farther away. In addition, we investigate the effect of proximity to the new line on the belief that reported symptoms are caused by a power line.

METHODS

For full details about the design and rationale of the study we refer to the published study protocol [21].

Setting

The Zuidring is the first 380 kV power line route being introduced in the Netherlands as part of a large infrastructural operation resulting in 350 km of new HVPLs. The Zuidring consists of two overhead parts (i.e. Zuidring-West and Zuidring-East) of 10 km in total.

Design and study population

We used a quasi-experimental design with two pretests (T1, T2) during construction of the Zuidring and two posttests (T3, T4) approximately 2 and 7 months after the line had been put into operation. At T1 major construction work was carried out, while at T2 the power line route was visibly finished but not yet operational. We collected data within an 18 months' time frame. Geographical information about the new power line route was provided by national grid operator TenneT. Distance to the nearest overhead part of the Zuidring was calculated with ArcGIS 9.3.1 software. All households within 500 m of the Zuidring-West (n = 1057) and Zuidring-East (n = 1322) area were included. A random stratified sampling strategy was used to include the same number of households residing within 500-2000 meters of the overhead parts of the Zuidring (see [21]). All available addresses were stratified for area (Zuidring-West and Zuidring-East), distance (500-1000 m, 1000-1500 m, 1500-2000 m) and degree of urbanization (less than 1000 and 1000-2500 addresses per km^2). We drew random samples (using SPSS random number generator) from these strata matching the proportion of addresses in rural and urban areas of the households within 500 m of the Zuidring.

Procedure

All households received a postal letter invitation for one member of the household older than 18 years to participate in a longitudinal questionnaire-based environmental health study relating changes in the environment to changes in health. To reduce potential response bias the letter did not mention the study was about power lines. In the letter we provided a hyperlink to a digital questionnaire with a personal login and password. On request, residents were able to participate through receiving paper versions of the questionnaires. Informed consent was implied through filling out the questionnaire online or by returning the paper questionnaire. Invitations for follow-up were sent through e-mail addresses collected at the first measurement. In case an e-mail address was invalid or missing, invitations were sent through postal mail. The Medical Ethics Committee of the VU University Medical Center Amsterdam approved the study protocol.

Because the response rate at T1 was lower than the anticipated 30%, all residents who did not respond at T1 were invited again at T2 to participate. Onwards from T3 only residents who participated in at least one of the pretests were invited by e-mail and postal letter to fill out a questionnaire. A maximum of three reminders was sent at each measurement wave. Fifty euro gift certificates were randomly awarded to ten participants who filled out a questionnaire.

Outcomes

We used the somatization scale of the Dutch 4DSQ [22] to measure non-specific somatic health complaints. The scale consists of 16 non-specific somatic symptoms commonly reported in general practitioner practices such as headaches, dizziness, and low back pain. For each health complaint, participants indicated whether they were bothered by it during the previous week on a 5-point scale (ranging from no, through to constantly). Following instructions (see [23]) scores were trichotomized and summed resulting in a minimum score of 0 and a maximum score of 32.

Non-specific cognitive health complaints were assessed with a Dutch translation [24] of the MOS Cognitive Functioning Scale [25]. The scale consists of six items tapping the domain of general cognitive functioning (e.g. forgetfulness, difficulty concentrating, trouble maintaining attention). On a 6-point scale (ranging from all of the time, through to none of the time), participants indicated how often they experienced a specific cognitive problem during the previous week. Scores were recoded and an average score was calculated, resulting in a score between 1 and 6. For both cognitive and somatic health complaints, higher scores indicate more reported symptoms.

To assess causal beliefs, we asked participants to indicate on a 5-point scale (from 1 = certainly not, to 5 = certainly and 6 = not applicable) whether they believed that their health complaints during the previous week were caused or worsened by an overhead power line (amongst 10 other environmental factors; e.g. wind turbines and busy roads). All scores of participants who did not report any health complaints were recoded to a missing value. For participants who did report health complaints the not applicable score was recoded to 1 (certainly not).

Covariates

The baseline questionnaire included questions on gender, age, education, occupational and marital status and years of residency at the current address. Homeownership status was assessed at T2. These socio-demographic characteristics might be related to distance to an overhead power line (e.g. [26]) and confound the relationship with the outcomes.

Statistical analyses

Linear mixed models with an unstructured residual covariance structure were fitted comparing the residents living within 500 m to residents living farther away. Because distance in the 0-500 m group was heavily skewed to the left (median distance = 369 m), we further subdivided the group into 0-300 m and 300-500 m. In the first model we entered distance (with 500-2000 m group as reference category), time (with T1 as reference category) and the interactions between distance and time. The interaction terms represented the difference in change from baseline between residents living nearby (0-300 m or 300-500 m) and farther away (500-2000 m) at the three time points (T2, T3, T4). If an interaction term is significant it indicates that health perceptions of residents living closer to the new line changed differently after its construction when compared to residents living farther away. This would be indicative of a health response to the introduction of the new HVPL. In the second model the parameter estimates were adjusted for the covariates. The significance level was set at 0.05. We performed all analyses with IBM SPSS Statistics 20.

RESULTS

Response rates and participant characteristics

Response rates and participant characteristics at baseline are displayed for each distance group (Table 1 and Table 2). In total, 40.7 % of the respondents participated at all four measurement waves, 23.2 % at three, 17.3 % at two and 18.8 % at one. Participants who moved out of the area during the study, or cases where questionnaires were not filled out by the same person at every measurement wave, were excluded (n = 89).

Table 1. Number of participants who fully completed a questionnaire by time-point and distance group.

Distance group	T1 n (% response[a])	T2 n (% response)	T3 n (% response)	T4 n (% response)
0-300 m	163 (23.0%)	177 (26.6%)	160 (67.2%)	154 (66.4%)
300-500 m	351 (21.0%)	353 (22.5%)	301 (58.4%)	292 (57.7%)
500-2000 m	386 (16.2%)	401 (18.3%)	352 (63.3%)	336 (61.3%)
Total	900	931	813	782

[a]Response rates were calculated relative to the number of participants who were invited at each measurement wave within each distance group (at T3 and T4 only residents who participated at T1 and/or T2 were invited, explaining the higher response rates at these time-points).

Residents living closer to the new power line were more likely to respond to our invitation (Table 1) and residents who participated were of higher socio-economic status than residents living farther away (Table 2). We tested whether the attrition was different between the distance groups, or depended on baseline values on the three outcome measures, but no significant associations were found.

Symptom reports

At baseline, symptom reports of residents living nearby (0-300 m and 300-500 m) did

Table 2. Baseline characteristics of participants according to distance from the new HVPL route.

Baseline characteristics[a]	0-300 m group (n = 229)	300-500 m group (n = 489)	500-2000 m group (n = 536)
Gender			
Female (%)	123 (53.7)	265 (54.2)	289 (53.9)
Male (%)	106 (46.3)	224 (45.8)	247 (46.1)
Missing	0	0	0
Age			
Mean (SD)	52.0 ± 10.5	51.3 ± 12.4	52.4 ± 14.5
Missing	0	0	1
Education level			
Lower (%)	32 (14.0)	108 (22.1)	136 (25.6)
Middle (%)	72 (31.6)	177 (36.2)	175 (32.9)
Higher (%)	124 (54.4)	204 (41.7)	221 (41.5)
Missing	1	0	4
Occupational status			
Working (%)	157 (70.7)	327 (69.9)	320 (61.5)
Not working (%)	65 (29.3)	141 (30.1)	200 (38.5)
Missing	7	21	16
Married or living together			
Yes (%)	198 (86.8)	401 (83.0)	407 (76.6)
No (%)	30 (13.2)	82 (17.0)	124 (23.4)
Missing	1	6	5
House owner			
Yes (%)	170 (96.0)	301 (85.0)	298 (73.2)
No (%)	7 (4.0)	53 (15.0)	109 (26.8)
Missing	52	135	129
Residency before plans Zuidring			
Yes (%)	178 (82.4)	362 (78.0)	328 (64.7)
No (%)	38 (17.6)	102 (22.0)	179 (35.3)
Missing	13	25	29
Start of participation with study			
T1 (%)	176 (76.9)	373 (76.3)	403 (75.2)
T2 (%)	53 (23.1)	116 (23.7)	133 (24.8)
Area			
Zuidring-West (%)	66 (28.8)	237 (48.5)	239 (44.6)
Zuidring-East (%)	163 (71.2)	252 (51.5)	297 (55.4)

[a]For participants entering the study at T2, characteristics were measured at T2.

not significantly differ from residents living farther away (500-2000 m), as indicated by the non-significant overall effect of distance (see Table 3). The significant interaction between time (T3) and distance (0-300 m) for cognitive and somatic symptom reports, indicated a difference in change between health complaints reported

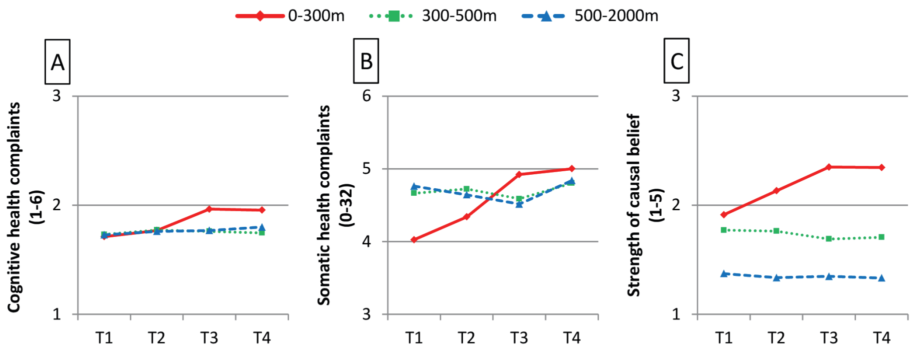

Figure 1. Longitudinal development of cognitive (A), somatic (B) symptom reports and causal beliefs (C), according to distance group (plotted mean scores for every distance group at each time-point).

during construction (T1) and after the line was put into operation (T3) between residents living within 300 m and 500-2000 m. As can be seen from the plotted mean symptom scores in the different groups (Figure 1, panels A and B), only residents within 300 m showed a sharp increase in reporting symptoms at T3. Five months later, at the last measurement (T4), the difference in change from baseline was smaller but still significant. The longitudinal symptom pattern for residents within 300-500 m did not differ from residents within 500-2000 m.

In addition, we tested whether the difference in change occurred between T2 and T3, changing the reference category to T2. The interaction between 0-300 m and time was no longer significant for somatic symptoms (b = .39, 95% CI: -.24, 1.00), but remained significant for cognitive symptoms (b = .18, 95% CI: .05, .30). Adjusting for the covariates reduced the difference in change a little, making the change from baseline non-significant for somatic symptom reports at T4. Rerunning the unadjusted models with exclusion of participants with a missing value on one of the covariates did not show a difference in estimates when compared to the adjusted model. The reduction of the estimates in the adjusted models was therefore associated with the exclusion of participants instead of with adjustment for the covariates.

Causal beliefs

The overall effect of distance (0-300 m and 300-500 m) on causal beliefs was significant (Table 3). This indicates that residents in these distance groups were already more certain at baseline that their health complaints were caused by a power line, than residents in the 500-2000 m group (Figure 1, panel C). The significant interactions between time (T2, T3 and T4) and distance (0-300 m) for strength of causal beliefs (Table 3), indicated a different longitudinal development when compared to residents in the 500-2000 m group. The increase in the belief that a power line caused health complaints was larger for residents in the 0-300 m group (Figure 1, panel C). In addition, changing the reference category of time to T2 showed that the increase between T2 and T3 was significantly larger than the 500-2000 m group as well (b = .27, 95% CI: .09, .45). The longitudinal development of causal beliefs for residents within 300-500 m did not significantly differ from the

Table 3. Effects of proximity on health perceptions during and after the construction of a new HVPL.

	Beta estimate (95 % CI)					
	Somatic symptom reports		**Cognitive symptom reports**		**Strength of causal belief**	
Predictor	Unadjusted	Adjusted[a]	Unadjusted	Adjusted[a]	Unadjusted	Adjusted[a]
Time						
T2	-.14 (-.52, .23)	-.08 (-.46, .30)	.02 (-.05, .08)	.03 (-.04, .10)	-.01 (-.12, .09)	.00 (-.11, .11)
T3	-.08 (-.48, .32)	-.08 (-.48, .32)	.05 (-.02, .12)	.07 (.00, .13)	.00 (-.11, .12)	.02 (-.09, .14)
T4	.03 (-.39, .44)	.00 (-.42, .42)	.07 (-.01, .14)	.07 (-.01, .15)	-.01 (-.12, .10)	.01 (-.10, .12)
Distance						
0-300m	-.72 (-1.53, .08)	-.45 (-1.28, .38)	-.04 (-.17, .10)	.02 (-.11, .16)	.54 (.35, .72)**	.55 (.36, .74)**
300-500m	-.05 (-.68, .59)	.06 (-.60, .71)	-.03 (-.13, .08)	.00 (-.11, .10)	.41 (.26, .56)**	.43 (.28, .59)**
Interactions						
T2*0-300m	.51 (-.17, 1.19)	.30 (-.39, .99)	.03 (-.09, .15)	.01 (-.12, .13)	.20 (.01, .39)*	.18 (-.01, .38)
T3*0-300m	.89 (.19, 1.60)*	.73 (.02, 1.44)*	.21 (.09, .33)**	.18 (.05, .30)**	.47 (.26, .67)**	.47 (.26, .67)**
T4*0-300m	.83 (.09, 1.57)*	.74 (.00, 1.49)	.17 (.04, .31)*	.17 (.03, .31)*	.41 (.22, .61)**	.41 (.21, .60)**
T2*300-500m	.13 (-.42, .68)	.04 (-.53, .60)	.02 (-.08, .12)	.01 (-.09, .11)	.02 (-.13, .18)	.02 (-.14, .18)
T3*300-500m	.03 (-.55, .61)	-.07 (-.65, .51)	.01 (-.09, .11)	-.02 (-.12, .08)	-.04 (-.21, .12)	-.06 (-.24, .11)
T4*300-500m	.14 (-.47, .74)	.08 (-.54, .69)	-.05 (-.16, .06)	-.07 (-.19, .04)	-.02 (-.18, .14)	-.03 (-.19, .13)

[a] Estimates adjusted for sex, age, education level, occupational status, marital status, area (Zuidring-West vs. Zuidring-East) and residency before plans of the Zuidring. Because of the large number of missing values on house ownership status we did not adjust for this factor. In a single covariate model, house ownership did not change the interaction estimates of the unadjusted model.
* $p < 0.05$
** $p < 0.01$

500-2000 m group. Adjusting for the covariates only reduced the significant interaction at T2. Rerunning the unadjusted model while excluding participants with a missing value on one of the covariates demonstrated that the reduction was associated with the exclusion of participants in the adjusted model.

DISCUSSION

In this prospective cohort study we looked at the effect of the introduction of an HVPL on symptom reports and causal beliefs in residents living up to 2 km away. Living within 300 m of the new line was associated with an increase in symptom reporting after it was put into operation. This increase in reported symptoms occurred largely parallel to the increase in the belief that these symptoms are caused by a power line. These findings suggest that a new HVPL has a negative impact on health perceptions for nearby residents, even before the line was put into operation.

Until now, only cross-sectional studies investigated the relationship between power line proximity and symptom reporting. One study found a small effect on reporting headaches [3], and two other studies did not find a relationship between proximity and symptom reports [17,18]. One aspect that may explain the difference in findings is that our study was conducted in an area where a new power line was recently installed. In addition, the studies conducted in the nineties only probed a limited number of symptoms, used a binary scale and did not gather information about the exact distance to the line. Although the study of Baliatsas et al. [18] does not have these limitations, participants in their study mostly lived more than 2 km away from a power line, making it difficult to determine effects of power line proximity.

To date, there are few prospective studies investigating health responses to potential environmental risks. One prospective study found that prior environmental concerns predicted symptom attribution after environmental pesticide spraying, but did not predict the number of reported symptoms [27]. Our results suggest that an environmental issue in a community affects symptom interpretation at an early stage, preceding an increase in symptom reporting. During the construction process residents living nearer to the line reported a stronger belief that a power line caused their health complaints, while symptom reports did not differ from reports of residents living farther away. These beliefs became stronger for nearby residents after major construction work was finished, while symptom reports remained stable. The parallel increase in causal beliefs and reported symptoms after the line was put into operation suggests that the effects of an environmental issue on symptom reporting are influenced by beliefs that a new environmental risk has arisen in the area. Future studies should further investigate potential mediating mechanisms that might explain the increase in symptom reports (e.g. health risk perceptions of power lines).

There are limitations to the interpretation of our results. First, we did not measure exposure to ELF-EMF in our study and therefore we are not able to examine its influence. However, exposure to ELF-EMF from power lines rapidly decreases with distance [28]. For instance, upwards of 55 m of the specific power line route we studied, the expected average magnetic field strength is already below the suggested cut-off value of 0.4 μT for the higher relative risk of childhood leukemia [29]. Since only one resident in our study lived this close to the new line, we believe exposure to ELF-EMF is an unlikely explanation for our findings. Second, the higher response rate of residents living closer to the new power line and the overall low response rate indicates potential generalizability issues. These issues deserve further empirical study with HVPLs in other areas. Additional research is also needed to test whether our findings generalize to other potential environmental risks such as mobile phone base stations and wind turbines.

Our study also has several strengths. It is the first study to prospectively investigate power line health effects and we used one of the strongest quasi-experimental designs available [30,31]. Unlike previous studies, we assessed a broad range of somatic and cognitive symptoms as well as causal beliefs about these symptoms in residents who lived across a wide distance range from the new power line. Also, we did not mention power lines in our invitation letter and asked questions about a wide variety of environmental factors, thereby reducing the potential for response bias and demand characteristics.

In terms of practical implications, our results suggest that residents living within 300 m of the planned construction of a new power line are at risk of experiencing more cognitive and somatic health complaints (e.g. concentration problems, headaches) after its construction. Given the physical constraints on the power line planning process it might not be feasible to construct power lines farther than 300 m from households. Undergrounding HVPLs, often discussed by the public as an alternative to overhead HVPLs [32,33], comes at considerably higher costs [34] and research is needed to investigate whether undergrounding HVPLs affects health perceptions differently.

From previous research we know that risk communication might play an important role in whether residents feel exposed to environmental risks and report more symptoms after exposure (e.g. [12,35]). Improving risk communication may therefore provide an alternative strategy to minimize the negative impact of a new HVPL on health perceptions. It has been shown that media reports on the health effects of exposure to EMF are disproportionally negative and not in line with current scientific evidence [36,37] and people do not feel adequately informed by the government on these health risks [38]. Developing communication tools for stakeholders (e.g. [39]) and testing the effectiveness of these tools with regard to reducing adverse health responses is therefore warranted.

CONCLUSIONS

In the first prospective study of power line health effects we observed a positive association between proximity to a new HVPL and symptom reports, and the belief that these reported symptoms were caused by a power line. These findings need to be confirmed in future studies and mediating mechanisms should be further investigated.

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