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Effects of Electric and Magnetic Fields from High-power Lines on Female Urinary Excretion of 6-Sulfatoxymelatonin

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In 1998, the authors studied the effect of residential exposure to electric and magnetic fields from high-power lines on female urinary excretion of 6-sulfatoxymelatonin (6-OHMS) in the Quebec city, Canada, metropolitan area. A sample of 221 women living near a 735-kV line was compared with 195 women the same age living away from any power lines. Participants provided morning urine samples on 2 consecutive days and wore a magnetic dosimeter for 36 consecutive hours to measure personal magnetic exposure. The indoor electric field was assessed by spot measurements. After adjustment for other factors associated with low melatonin secretion, such as medication use or light exposure, nighttime concentration of 6-OHMS was similar in the two groups. When either 24-hour or sleep-time exposure to magnetic field or electric field measurements was used, no exposure-effect relation was evident. However, the trend of decreasing 6-OHMS concentration with age was more pronounced for women living near the lines, as was a lower 6-OHMS concentration in women with high body mass index. Chronic residential exposure to magnetic fields from high-power lines may accentuate the decrease in melatonin secretion observed in some vulnerable subgroups of the population. *Am J Epidemiol* 2001;154:601–9.

age factors; body mass index; electromagnetic fields; melatonin; urinalysis

The effects of chronic exposure to environmental electric and magnetic fields (EMF) have been the subject of intensive research leading to no definitive answers (1). Possible risks for childhood and adult leukemia have been acknowledged (1, 2), but many other health outcomes are still under study. Among them are breast cancer (3, 4), neuropsychological disorders (5, 6), and reproductive outcomes (7). An underlying mechanism that could explain all of these potential effects is alteration of melatonin secretion as a result of EMF exposure (8). Melatonin secretion is important in the regulation of circadian rhythms and sleep (9) but could also be involved in the aging process (10), carcinogenesis (11), and reproduction (12).

A decrease in nocturnal melatonin secretion in rodents chronically exposed to EMF has frequently been reported (1, 4). Experiments on humans acutely exposed to EMF for one night have not resulted in reproducible effects on serum melatonin or urinary excretion of its main metabolite, 6-sulfatoxymelatonin (6-OHMS) (1, 4, 13–15). However, recent epidemiologic studies have suggested an effect of chronic EMF exposure on melatonin secretion. Reduced morning excretion of 6-OHMS has been reported in electrical train workers in Switzerland exposed to 20-μT magnetic fields (16) and in US electric utility workers exposed to levels of 0.2 μT with low variability (17). To our knowledge, only one study has evaluated the effect of chronic residential exposure to magnetic fields; it was carried out in Seattle, Washington, among women exposed to mean levels of 0.1 μT (18). This study found an effect of nocturnal magnetic field exposure on morning 6-OHMS excretion among women using beta blockers and other related drugs, leading to the hypothesis of a particular vulnerability among these persons.

In a previous study, several of the authors (P. L., D. G, and S. G.) reported that people living near high-voltage power lines are particularly exposed to power-frequency EMF (19). In this paper, we present the results of an epidemiologic study in which we tested the hypothesis that chronic exposure to 60-Hz EMF emanating from power lines is associated with reduced 6-OHMS urinary excretion in

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Abbreviations: BMI, body mass index; EMF, electric and magnetic fields; 6-OHMS, 6-sulfatoxymelatonin.

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women aged 20–74 years. In addition, we evaluated whether some characteristics of participants known to reduce melatonin secretion, such as age and medication use, could modify the effect of exposure to magnetic fields.

MATERIALS AND METHODS

Single-family or semidetached houses located within 150 m of a 735-kV power line and houses with similar characteristics in the same boroughs but located 400 m or more from any power line were identified in the Quebec city metropolitan area of Canada. Participants had to be female, aged 20–74 years, and living in the residence for at least the last year. The following criteria were used to exclude subjects for whom results could be difficult to interpret: subjects who worked at night, subjects who had traveled outside the province of Quebec in the last week, and subjects who slept on a heated water bed.

On the basis of results from a previous study (18), a sample size of 200 per group was required to obtain a power of 80 percent to be able to detect a 20 percent decrease in 6-OHMS excretion among subjects living near the lines. Participants were recruited by systematically sampling one residence out of two in each of the selected areas from February to December 1998. Residents of 1,834 houses were solicited: 733 near the lines and 1,101 far from the lines. Of the 417 eligible women living near the lines, 226 (54 percent) agreed to participate. Of the 516 eligible women living far from the lines, 198 (38 percent) accepted and participated in the study.

Trained technicians visited each participant's house twice, with about a 36-hour interval between visits. Visits alternated between subjects living near and far from the lines. Participants completed a questionnaire on their personal habits and health, including lifestyle and medication use on the days they participated in the study. Personal exposure to magnetic fields was assessed by means of an Emdex Lite meter (Enertech Consultants Ltd., Campbell, California) that participants wore at the waist or in a pocket during their daily activities and kept under the bed at night. This meter took broadband measurements in the 40–1,000-Hz frequency range, and the sampling interval was adjusted to 30 seconds. Subjects also filled out a log sheet of their main activities during the whole participation period. Information on sleep periods and the 24-hour period before the last urine sample were then collated from the log sheet, and the arithmetic mean of the magnetic fields was calculated for each subject.

During each of the two visits, the technicians evaluated the indoor electric field in the daytime, between 7:30 a.m. and 8:30 p.m., by using a Holaday HI-3604 ELF/power frequency survey meter (Holaday Industries, Inc., Eden Prairie, Minnesota), which measures the vertical component of the electric field in the 50–1,000-Hz range. To avoid distortion of the field, one measure was taken in the center of the kitchen, living room, and bedroom, away from any structure or person. The mean of the six instantaneous measures was considered a proxy for electric field exposure in the home. Light exposure at night was evaluated by means of a Luxmeter EXTECH model 401020 (Extech Instruments Corporation, Waltham, Massachusetts). This meter evaluates light intensity from 0 to 2,000 lux, and measurements were recorded every minute with a data logger EXTECH model 383274 (Extech Instruments Corporation). Since urine collection covered the interval between bedtime and awakening, light exposure was measured in the bedroom only, during the sleep episode. In their diary, subjects had to specify whether they turned the lights on during the night and, if so, for how long. All apparatus used to measure EMF and light exposure were calibrated regularly during the study.

First-morning urine was collected after each of the 2 consecutive nights. Each subject was requested to empty her bladder just before going to bed and to collect all urine excreted until she got up for the morning. The entire urine volume collected was kept in the refrigerator in special containers (one for each day). Each day's urine volume was measured, and two 2.5-ml samples were frozen for analysis. The concentration of 6-OHMS was assessed by using a direct radioimmunoassay kit (CIDTech Research Inc., Mississauga, Ontario, Canada), as described by Arendt et al. (20). The intraassay coefficients of variation were 20, 14, 10, and 12 percent for four control samples of 1.0, 4.3, 7.0, and 11.0 ng of 6-OHMS/ml, respectively. The interassay coefficients of variation for these control samples were 9, 10, 5, and 7 percent, respectively. The 6-OHMS results were adjusted for creatinine.

Of the 424 participants, 8 were excluded from statistical analysis because of inadequate urine sampling. We compared EMF exposures and characteristics for participants living near and away from power lines. Measures of exposure were the individual arithmetic means of magnetic field measurements during the two sleep episodes and during the 24-hour period, the indoor electric field measurement, and the variability of the magnetic fields, which was assessed by using the standardized rate of change metric (17). Proportions were compared by using Fisher's exact tests or chi-square tests, and means were compared with Student's t tests or analyses of variance. Correlations between the 2 days were assessed by using Pearson's correlation coefficient. The effect of different variables on 6-OHMS concentration was assessed with analyses of variance for repeated measures by using the MIXED procedure in Statistical Analysis System software (SAS Institute, Inc., Cary, North Carolina). Adjustment for potential confounding was performed by including in the model all variables associated with the 6-OHMS concentration ($p \leq 0.15$). Modification of the effect was assessed for age, use of medication (beta blockers, calcium channel blockers, and anti-anxiety and nonsteroidal anti-inflammatory drugs), body mass index (BMI), standardized rate of change metric, and electric field. Considered statistically significant were p values of ≤ 0.05 (bilateral test).

The study protocol was approved by the ethics committee of Laval University Hospital (Quebec). All subjects gave signed, informed consent and obtained monetary compensation (25 Can $ (approximately 16 US $)).

RESULTS

Mean age was similar in the two groups: 45.5 years (standard deviation, 11.2) in the group living near the lines and 45.8 years (standard deviation, 12.4) in the group living

away from the lines ($p = 0.81$). Other general characteristics were mostly comparable (table 1). However, women living near the lines were less educated ($p = 0.04$). Potential risk factors associated with melatonin secretion also were compared (results presented in table 2). Only daylight length during data collection was significantly different between the two groups ($p = 0.04$); a slightly larger proportion of subjects living near power lines was studied in photoperiods shorter than 12 hours. Interestingly, time between evening and morning urination was similar in the two groups, as was bedtime ($p = 0.52$; data not shown). Self-reported health status was comparable. In particular, the proportion of subjects having made at least one medical visit in the last year was similar (85 percent in the group near the lines and 79 percent in the control group, $p = 0.16$), and reasons for consultation were distributed equally in the two groups (data not shown). No subject reported renal or hepatic disease.

Mean 24-hour magnetic field exposure was 2.5 times higher in the group living near the lines than in the control group (geometric mean, 0.33 vs. 0.13 μT; $p < 0.001$). Exposure during sleep was also very different between the two groups (geometric means of the individual mean of 2 nights of exposure, 0.29 vs. 0.08 μT; $p < 0.001$), and mean measurements from the 2 nights were highly correlated ($r = 0.98$, $p < 0.001$; log-transformed data). Exposure to residential electric fields was nearly twice as high in the group living near the lines (geometric mean, 10.5 vs. 5.8 V/m; $p < 0.001$).

Nocturnal excretion of 6-OHMS was highly correlated between the 2 days of measurement ($r = 0.92$, $p < 0.001$; log-transformed data). Association with 6-OHMS concentration was evaluated specifically for potential risk factors and for the only variable found to be associated with proximity to a power line: education. Age, menopausal status, BMI, alcohol consumption, medication use, and education were all associated with 6-OHMS urinary excretion (table 2). Results from the crude analysis (data not shown) and the adjusted analysis were the same, except for light exposure at night, which was associated with 6-OHMS in the crude analysis ($p = 0.04$). Because menopausal status was strongly associated with age, it was removed from further analyses.

TABLE 1. General characteristics of 221 women living near a 735-kV power line and of 195 women living far away from any lines, Quebec, Canada, 1998

Characteristic*	Living near		Living far away		*p* value†
	No.	%	No.	%	
Education					
≤High school	115	52	80	41	0.04
College/technical	61	28	59	30	
University	44	20	56	29	
Family size					
1–2	80	36	62	32	0.64
3–4	102	46	96	49	
≥5	39	18	37	19	
Annual family income (Can $‡)					
<40,000	62	34	41	25	0.10
40,000–59,999	65	36	62	37	
≥60,000	54	30	64	38	
Employed during the last year					
Yes	121	55	112	57	0.62
No	100	45	83	43	
Smoker					
Yes	52	24	42	22	0.64
No	169	76	153	78	
Time (no. of hours) away from home in the last 24 hours					
<3	47	22	41	21	0.97
3–8	91	42	80	42	
≥9	77	36	71	37	
Duration of residence (years)					
<10	79	36	87	45	0.22
10–19	59	27	46	24	
≥20	79	36	61	31	

* Variations in subject numbers are due to missing data for selected variables.
† Obtained by using the chi-square test or Fisher's exact test (for fourfold table).
‡ 1 Can $ = approximately 0.64 US $.

TABLE 2. Study participants' mean creatinine-adjusted 6-sulfatoxymelatonin concentrations for selected variables, Quebec, Canada, 1998

Variable	No.	% living near a power line	Adjusted geometric mean*,† (ng/mg cr)	*p* value
Age (years)				
20–39	130	52	19.87 (17.06, 23.13)	0.01
40–59	234	57	16.30 (14.69, 18.09)	
60–74	52	40	14.33 (11.85, 17.31)	
Education				
≤High school	195	59	14.75 (13.07, 16.64)	0.02
College/technical	120	51	18.16 (15.76, 20.92)	
University	100	44	17.32 (14.86, 20.20)	
Postmenopausal‡				
Yes	155	54	14.98 (13.39, 16.76)	<0.01
No	246	52	19.15 (16.95, 21.64)	
Body mass index (kg/m^2)				
<27	308	55	19.08 (17.21, 21.15)	<0.01
≥27	106	49	14.58 (12.60, 16.88)	
Alcohol consumption in the last 24 hours				
Yes	115	51	18.27 (15.80, 21.13)	0.02
No	301	54	15.22 (13.74, 16.85)	
Caffeine consumption in the last 24 hours (mg)				
<300	301	53	16.16 (13.39, 19.51)	0.70
≥300	115	54	16.76 (15.10, 18.60)	
Medication use§ in the last 24 hours				
Yes	90	54	14.85 (12.76, 17.29)	0.01
No	326	53	18.72 (16.87, 20.78)	
Daylight length (no. of hours) during data collection				
8–9:59	106	60	15.96 (13.60, 18.72)	0.92
10–11:59	78	62	16.70 (13.94, 20.01)	
12–13:59	95	48	16.93 (14.53, 19.73)	
14–15:59	137	46	16.83 (14.78, 19.16)	
Bedroom nocturnal light exposure >50 lux				
Yes	139	50	17.16 (15.00, 19.62)	0.96
No	243	54	17.09 (15.22, 19.19)	
Light use at night				
Yes	177	48	15.83 (14.00, 17.91)	0.12
No	239	57	17.56 (15.61, 19.76)	
Time (no. of hours) between evening and morning urinations				
<7	27	67	16.19 (12.50, 20.97)	0.43
7–7:59	114	52	15.34 (13.24, 17.76)	
8–8:59	171	54	17.32 (15.19, 19.75)	
≥9	104	49	17.34 (14.98, 20.07)	

* Geometric mean of creatinine-adjusted 6-sulfatoxymelatonin (6-OHMS) (ng/mg cr) urinary excretion adjusted by repeated analysis of variance for age, body mass index, alcohol consumption in the last 24 hours, medication use in the last 24 hours, light use at night, and education.

† 95% confidence interval in parentheses.

‡ Geometric mean of 6-OHMS (ng/mg cr) urinary excretion adjusted by repeated analysis of variance for body mass index, alcohol consumption in the last 24 hours, medication use in the last 24 hours, light use at night, and education.

§ Beta blockers, calcium channel blockers, and anti-anxiety and nonsteroidal anti-inflammatory drugs.

Nocturnal 6-OHMS urinary excretion was similar in the two groups (table 3). No significant trend was found between 6-OHMS concentration and quartiles of exposure to EMF. However, further analyses revealed that age and BMI were

significant modifiers of the effect of magnetic fields on 6-OHMS concentration. In particular, the decrease in 6-OHMS concentration with age and BMI was significantly more pronounced for those living near the lines than for the control group (table 4). Interaction was mainly present for age when exposure during the sleep period was considered and for BMI when the 24-hour exposure period was considered (table 5). No modification effect was found for medication use, standardized rate of change metric, or electric field exposure.

DISCUSSION

High-power lines are among the strongest sources of residential exposure to power-frequency EMF (19, 21, 22). To our knowledge, the present study is the first to evaluate the effect of such particularly high residential exposure to EMF. The type of exposure to EMF generated by those high-power lines is rather stable (19). Since one of our criteria for eligibility was living in the residence for at least a year, this study measured the effect of chronic exposure to EMF. Nocturnal urinary excretion of 6-OHMS was chosen as an index of melatonin secretion because it is well correlated with peak and mean nocturnal plasma melatonin concentration (23, 24). Because melatonin secretion has been reported to differ with gender (25, 26), only women were studied to reduce variability in the measures.

Mean urinary 6-OHMS concentration was almost identical for the group living close to high-power lines (735 kV)

TABLE 3. Study participants' mean creatinine-adjusted 6-sulfatoxymelatonin concentrations for different measures of exposure to electric and magnetic fields, Quebec, Canada, 1998

Exposure	Crude concentration		Adjusted concentration*		
	Geometric mean† (ng/mg cr)	*p* value‡	Geometric mean† (ng/mg cr)	*p* value‡	*p* trend
All participants	18.41 (17.20, 19.70)				
Group					
Living away from any power line	18.38 (16.64, 20.29)	0.95	16.69 (14.84, 18.76)	0.99	
Living near a 735-kV line	18.45 (16.81, 20.25)		16.67 (14.74, 18.85)		
Personal magnetic field exposure during 24 hours					
Quartile 1 (<0.13 μT)	20.19 (17.59, 23.17)	0.05	17.27 (14.80, 20.16)	0.29	0.22
Quartile 2 (0.13–0.20 μT)	17.54 (15.30, 20.10)		16.33 (14.12, 18.88)		
Quartile 3 (0.21–0.36 μT)	20.14 (17.56, 23.09)		17.88 (15.25, 20.97)		
Quartile 4 (≥0.37 μT)	15.93 (13.88, 18.29)		15.10 (12.98, 17.57)		
Personal magnetic field exposure during sleep					
Quartile 1 (<0.07 μT)	18.69 (16.28, 21.45)	0.33	16.62 (14.35, 19.23)	0.59	0.30
Quartile 2 (0.07–0.15 μT)	18.51 (16.12, 21.25)		16.91 (14.52, 19.69)		
Quartile 3 (0.16–0.31 μT)	19.86 (17.29, 22.81)		17.25 (14.75, 20.16)		
Quartile 4 (≥0.32 μT)	16.55 (14.42, 19.00)		15.31 (13.12, 17.86)		
RCMS§ of personal magnetic field exposure during 24 hours					
Quartile 1 (<0.495)	17.66 (15.35, 20.31)	0.73	16.47 (14.17, 19.16)	0.66	0.94
Quartile 2 (0.495–0.710)	19.33 (16.82, 22.22)		17.57 (15.05, 20.51)		
Quartile 3 (0.711–0.934)	17.62 (15.32, 20.26)		15.71 (13.47, 18.32)		
Quartile 4 (≥0.935)	18.85 (16.39, 21.68)		17.10 (14.64, 19.98)		
RCMS of personal magnetic field exposure during sleep					
Quartile 1 (<0.245)	18.05 (15.71, 20.74)	0.48	16.47 (14.06, 19.29)	0.29	0.35
Quartile 2 (0.245–0.396)	19.25 (16.74, 22.13)		17.32 (14.95, 20.08)		
Quartile 3 (0.397–0.517)	19.36 (16.85, 22.23)		17.66 (15.18, 20.55)		
Quartile 4 (≥0.518)	16.88 (14.68, 19.41)		14.95 (12.80, 17.48)		
Personal electric field exposure					
Quartile 1 (<4.69 V/m)	19.26 (16.81, 22.08)	0.73	16.94 (14.58, 19.67)	0.65	0.32
Quartile 2 (4.69–7.37 V/m)	17.51 (15.27, 20.09)		16.44 (14.17, 19.08)		
Quartile 3 (7.38–12.24 V/m)	18.32 (15.99, 20.98)		16.81 (14.40, 19.62)		
Quartile 4 (≥12.25 V/m)	19.28 (16.82, 22.09)		18.42 (15.73, 21.56)		

* Geometric mean of creatinine-adjusted 6-sulfatoxymelatonin urinary excretion adjusted by repeated analysis of variance for age, body mass index, alcohol consumption in the last 24 hours, medication use in the last 24 hours, light use at night, and education.

† 95% confidence interval in parentheses.

‡ *p* value for global mean comparison between exposure levels.

§ RCMS, standardized rate of change metric.

TABLE 4. Evaluation of the modification effect of age, body mass index, and medication on the relation between electric and magnetic fields from power lines and mean creatinine-adjusted 6-sulfatoxymelatonin concentration, Quebec, Canada, 1998

	Geometric mean*,† (ng/mg cr)			
	No.	Living near a line (n = 221)	Living far away from a line (n = 195)	p value‡
Age (years)				
20–39	130	21.63 (17.89, 26.14)	18.40 (15.23, 22.22)	0.03
40–59	234	16.42 (14.44, 18.68)	16.34 (14.22, 18.79)	
60–74	52	11.06 (8.29, 14.75)	17.16 (13.53, 21.77)	
Body mass index (kg/m^2)				
<27	308	19.93 (17.55, 22.64)	18.24 (16.08, 20.69)	0.02
≥27	106	12.81 (10.54, 15.57)	16.56 (13.72, 19.99)	
Medication§				
Yes	90	14.89 (12.13, 18.28)	14.81 (12.02, 18.25)	0.96
No	326	18.70 (16.43, 21.30)	18.75 (16.55, 21.25)	

* Geometric mean of creatinine-adjusted 6-sulfatoxymelatonin urinary excretion adjusted by repeated analysis of variance for age, body mass index, alcohol consumption in the last 24 hours, medication use in the last 24 hours, light use at night, and education.

† 95% confidence interval in parentheses.

‡ p value of interaction term between exposure and the stratification variables.

§ Use of beta blockers, calcium channel blockers, and anti-anxiety and nonsteroidal anti-inflammatory drugs in the last 24 hours.

and the group living more than 400 m from any power lines. Moreover, no statistically significant decrease was found with increasing exposure measured during a 24-hour period and two sleep periods. However, some subjects seemed particularly vulnerable to the effect of the magnetic field: those who were older or overweight. This effect was present when either proximity of the residence to the lines or personal exposure to the magnetic field was considered. In addition, the effect was independent of the other potential risk factors taken into account in this study, particularly medication use and light exposure at night. The modifying effect of age found to be significant only with the sleep measurements and that of BMI only with the 24-hour measurements might be explained by the fact that such measures are only proxies of long-term exposure and therefore are subject to exposure assessment errors.

In this study, factors commonly associated with decreased melatonin secretion had a significant effect. In particular, 6-OHMS concentration decreased with increasing age, BMI, and medication use. Aging regularly has been reported to be associated with low melatonin output (27–31), even if this finding has been challenged in healthy persons studied under laboratory conditions (32) and in a critical review of the literature (33). Some authors (32) have proposed that decreased melatonin output with age could be due to uncontrolled factors such as use of medication that reduces melatonin secretion in elders. The present study found that the age effect on melatonin was significant, even when controlled for medication and other factors. However, chronic magnetic field exposure modified that relation, since the reduction in concentration between those aged 20–39 years and those aged 60–74 years was more pronounced in the group living near the power lines (49 percent) than in the group living far away from them (7 percent).

The concentration of 6-OHMS was lower in overweight women. The influence of body weight on melatonin secretion or 6-OHMS excretion has been reported previously (26, 34) but without a clear explanation. In the present study, this decrease was more pronounced in women living near the lines (36 percent) than in those living away from the lines (9 percent).

The effect of medication use (namely, beta blockers, calcium channel blockers, and anti-anxiety and nonsteroidal anti-inflammatory drugs) was clear and consistent with previous reports (18, 35). However, contrary to the results of the only other known epidemiologic study on the effects of residential exposure to magnetic fields (18), we found no interaction with EMF exposure. This finding might be explained by the nature or dosages of the medication, which might have differed between the two studies, or other subject characteristics, such as health condition, that may modify the effect of the interaction between EMF and medications. It is also possible that the Kaune et al. (18) results were observed by chance.

The association of low educational levels with reduced 6-OHMS excretion was unexpected and is possibly due to the influence of some lifestyle characteristics associated with melatonin secretion that were not evaluated in our study. Alcohol consumption, smoking, and coffee intake were controlled in this study and cannot explain this finding. It has been reported that women with less than 14 years of education have more sleep disturbances than women with higher educational levels (36), and chronic insomnia has been associated with decreased nocturnal melatonin levels (37). Therefore, it is possible that sleep disorder was an intermediate factor between educational level and 6-OHMS concentration. In any case, whichever unknown factors linked education and melatonin secretion,

TABLE 5. Evaluation of the modification effect of age, body mass index, medication, standardized rate of change metric, and electric fields on the relation between mean personal magnetic field exposure, during 24 hours and during sleep, and mean creatinine-adjusted 6-sulfatoxymelatonin concentration, Quebec, Canada, 1998

Magnetic field exposure	Quartile 1		Quartile 2		Quartile 3		Quartile 4		*p* value‡
	No.	Geometric mean*,† (ng/mg cr)	No.	Geometric mean*,† (ng/mg cr)	No.	Geometric mean*,† (ng/mg cr)	No.	Geometric mean*,† (ng/mg cr)	
				During 24 hours					
Age (years)									
20–39	32	23.43 (18.17, 30.22)	36	18.02 (14.30, 22.70)	33	20.90 (16.32, 26.76)	25	18.10 (13.73, 23.86)	0.09
40–59	59	15.48 (12.95, 18.51)	53	16.21 (13.49, 19.47)	58	17.23 (14.31, 20.75)	60	16.21 (13.60, 19.31)	
60–74	10	17.12 (11.33, 25.87)	14	16.30 (11.55, 23.02)	11	18.30 (12.27, 27.30)	15	8.96 (6.39, 12.56)	
Body mass index (kg/m^2)									
<27	77	19.77 (16.76, 23.32)	68	18.53 (15.63, 21.97)	85	19.61 (16.75, 22.97)	72	19.23 (16.24, 22.75)	0.03
≥27	23	15.79 (11.96, 20.84)	34	14.82 (11.79, 18.63)	17	20.65 (14.93, 28.56)	29	10.45 (8.15, 13.39)	
Medication§									
Yes	14	11.46 (8.01, 16.40)	27	14.58 (11.27, 18.86)	23	17.28 (13.03, 22.90)	23	14.65 (11.08, 19.38)	0.27
No	87	20.37 (17.41, 23.84)	76	18.39 (15.60, 21.67)	79	19.77 (16.62, 23.52)	78	16.64 (14.13, 19.61)	
RCMS¶									
<Median	20	18.31 (12.52, 26.76)	42	17.97 (14.29, 22.59)	61	19.02 (15.88, 22.78)	78	15.18 (12.90, 17.86)	0.94
≥Median	81	17.35 (14.72, 20.44)	60	15.65 (13.13, 18.65)	38	16.73 (12.89, 21.72)	22	14.91 (10.82, 20.54)	
Electric field									
<Median	64	18.69 (15.54, 22.48)	62	15.91 (13.36, 18.95)	41	17.74 (14.27, 22.05)	31	13.06 (10.20, 16.73)	0.27
≥Median	36	16.41 (13.03, 20.66)	39	17.41 (13.93, 21.74)	57	19.13 (15.65, 23.38)	66	17.04 (14.24, 20.39)	
				During sleep					
Age (years)									
20–39	33	19.85 (15.55, 25.33)	31	19.13 (14.88, 24.60)	34	22.44 (17.64, 28.54)	29	18.54 (14.23, 24.15)	0.02
40–59	53	15.69 (13.08, 18.81)	60	16.25 (13.63, 19.38)	57	16.39 (13.65, 19.69)	60	16.96 (14.19, 20.28)	
60–74	16	17.10 (12.32, 23.73)	11	20.98 (14.24, 30.91)	10	14.75 (9.74, 22.33)	13	7.95 (5.57, 11.37)	
Body mass index (kg/m^2)									
<27	71	18.13 (15.35, 21.41)	73	19.67 (16.58, 23.35)	83	20.33 (17.34, 23.84)	75	18.35 (15.47, 21.76)	0.38
≥27	31	16.55 (12.98, 21.10)	28	14.47 (11.22, 18.67)	17	13.77 (9.95, 19.04)	27	12.07 (9.31, 15.66)	
Medication§									
Yes	19	14.36 (10.65, 19.36)	23	14.13 (10.62, 18.80)	24	17.27 (13.01, 22.92)	81	12.87 (9.60, 17.26)	0.70
No	83	18.93 (16.18, 22.14)	79	19.50 (16.52, 23.02)	77	18.88 (15.91, 22.39)	21	17.59 (14.89, 20.79)	
RCMS									
<Median	5	20.03 (11.21, 35.77)	39	17.56 (14.04, 21.95)	75	18.25 (15.35, 21.71)	82	15.31 (12.98, 18.06)	0.70
≥Median	97	16.52 (14.19, 19.24)	63	16.61 (13.79, 19.99)	25	14.70 (11.11, 19.45)	17	15.97 (11.41, 22.36)	
Electric field									
<Median	66	16.84 (14.17, 20.01)	60	17.11 (14.22, 20.58)	38	18.24 (14.53, 22.89)	34	13.14 (10.37, 16.66)	0.31
≥Median	34	16.66 (13.15, 21.10)	40	18.02 (14.41, 22.53)	63	17.18 (14.24, 20.73)	61	17.47 (14.48, 21.09)	

* Geometric mean of creatinine-adjusted 6-sulfatoxymelatonin urinary excretion adjusted by repeated analysis of variance for age, body mass index, alcohol consumption in the last 24 hours, medication use in the last 24 hours, light use at night, and education.

† 95% confidence interval in parentheses.

‡ *p* value of interaction term between exposure and the stratification variables.

§ Use of beta blockers, calcium channel blockers, and anti-anxiety and nonsteroidal anti-inflammatory drugs in the last 24 hours.

¶ RCMS, standardized rate of change metric.

control for education in all analyses precluded their influence on our results.

Self-reported medical conditions were distributed similarly between the study groups, and few diseases possibly associated with decreased melatonin secretion were reported. Daylight length or light use at night were slightly different between the two groups, but these factors had no significant influence on 6-OHMS concentration in our subjects. Light exposure at night was probably too low and too short in duration (<10 minutes) to influence melatonin secretion (38, 39). The absence of the influence of daylight length has been reported before and could be due to use of artificial light sources during dark periods in the evening or morning (40). We also found that the 6-OHMS concentration was higher in participants who reported alcohol consumption in the 24 hours prior to urine collection. It has been reported that ethanol can reduce plasma melatonin secretion (25, 41, 42); on the other hand, alcohol consumption can induce hepatic enzymes and thus increase melatonin metabolism and excretion.

Participation in the present study was moderate (45 percent), and it was lower in the control group than in the group living near the power lines. This differential participation rate could have influenced our results if characteristics related to participation affected 6-OHMS excretion. Few data were available on characteristics of nonrespondents. Time of residence was similar for participants and nonparticipants. Older subjects were less inclined to participate but participated at the same rate with regard to proximity of the lines (data not shown). Most of the factors recognized as potentially associated with melatonin secretion, including age, were evaluated and integrated, when necessary, in the analyses. Therefore, we have no indication that the differential participation rate affected the validity of our results. We did not take into account our participants' menstrual cycle phase during data collection. Variation in melatonin secretion with the menstrual cycle is still a controversial issue, and many controlled laboratory studies have failed to find such an association (43–46). In addition, all different phases of the menstrual cycle were probably represented randomly in our two groups of subjects. Therefore, this variable probably did not significantly influence the results.

In conclusion, we found no overall effect of EMF on urinary excretion of 6-OHMS. However, higher mean magnetic field exposures increase the effect of certain factors that previously have been associated with reduced melatonin secretion, namely, higher age and excessive body weight. Decreased nocturnal 6-OHMS concentration could be due either to a displacement of the secretion peak or a reduction in overall melatonin secretion. Our protocol could not distinguish these two potential effects. Research into the action of melatonin on human health is still in an early stage; however, because of the many potential effects of this hormone, particularly with regard to aging and carcinogenicity, these findings, if confirmed, may help to explain the possible health effects of EMF.

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