Physical Activity and Magnetic Field Exposure in Pregnancy

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Background: Peak magnetic field exposure was associated with increased risk of miscarriage in 2 recent studies. Reduced physical activity levels in healthy pregnancies may affect measured exposure and thus bias results.

Methods: We recruited 100 pregnant women to wear an Actigraph accelerometer and EMDEX magnetic field monitor for a 7-day period. We evaluated the association between physical activity and magnetic field exposure (peaks and time-weighted average) using generalized estimating equations and linear mixed models.

Results: We found a positive association between level of activity and likelihood of incurring elevated exposure in the person-day analysis, most strongly for cutpoints of 16 or 20 mG, for both working and nonworking women among whom odds ratios in the uppermost quartile ranged from 2.1 to 2.6. A positive association was found using person-minutes only among nonworking women.

Conclusion: Physical activity may affect peak magnetic field exposure. If the early nausea and later cumbersomeness of healthy pregnancies leads to reduced physical activity, this could distort measured magnetic field–health outcome associations.

Recent studies have suggested that peak magnetic field exposure (but not mean exposure) is associated with pregnancy loss.[1,2] A prospective study of magnetic field exposure and miscarriage[1] reported peak magnetic field exposure of ≥16 mG based on personal monitoring early in pregnancy was associated with a rate ratio of 1.8 (95% confidence interval [CI] = 1.2–2.2); however, time-weighted average magnetic field exposure was not related to pregnancy outcome. A nested case–control study[2] measured personal exposure later in pregnancy among women whose pregnancies continued and at a comparable time for women who had a loss. Time-weighted average exposure was associated with odds ratios (ORs) of 1.7 for each of the upper 3 quartiles compared with the lowest, and the odds ratios for the second, third, and highest quartiles of maximum magnetic field were 1.4 (95% CI = 0.7–2.8), 1.9 (1.0–3.5), and 2.3 (1.2–4.4), respectively.

An accompanying commentary[3] hypothesized that the association might be an artifact of collecting personal measurement data during or after pregnancy. In the prospective study, early pregnancy nausea (strongly predictive of fetal survival[4]) might lead to reduced physical activity, reducing the likelihood of encountering environmental sources of elevated magnetic fields. During later pregnancy, increased size may reduce activity relative to women with pregnancy losses who are not physically encumbered by advanced pregnancy. In each case, women with continuing pregnancies would be less active compared with those who had a loss, with greater activity hypothesized to be associated with increased opportunity to encounter elevated magnetic fields. There are 2 key assumptions: 1) nausea of early pregnancy and cumbersomeness in late pregnancy are associated with reduced physical activity, and 2) reduced physical activity is associated with a lower probability of encountering environmental sources of high magnetic fields. Addressing the first question would require longitudinal evaluation of symptoms and physical activity during pregnancy or a large cross-sectional study of women of varying gestational ages having different experiences with nausea. We were not able to address the link between symptoms and physical activity in this study, but evaluated the latter assumption, namely the relationship between measured physical activity and magnetic field exposure, among pregnant women.

METHODS

From August 2003 to October 2004, we recruited volunteers by posting flyers in prenatal care clinics in Chapel Hill and Durham, North Carolina, seeking women of 14 to 28 weeks' gestation, ≥18 years old, with a singleton pregnancy, who agreed to wear monitors for 7 consecutive days excluding travel or other atypical situations. They were instructed to wear an Actigraph accelerometer (MTI, Fort Walton Beach, FL) and an EMDEX magnetic field meter (Enertech Consultants, Campbell, CA), both worn at the hip and recording once every minute. Women were instructed to wear the monitors throughout the day, taking them off only at bedtime and when bathing, showering, or swimming. On completion, participants returned the monitors by mail and were interviewed by

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telephone to collect information on sociodemographic attributes, general health, nausea during pregnancy, and employment. Participants provided informed consent and were paid $75 on completion of their interview. The protocol was reviewed and approved by the University of North Carolina School of Medicine Institutional Review Board.

The MTI Actigraph monitor (formerly called CSA) is a small (5.1 × 3.8 × 1.5 cm), lightweight (45 g), uniaxial accelerometer that records movement as counts in the vertical plane. Counts per minute were used to rank monitored experience from least to most active. Periods in which the Actigraph recorded ≥20 minutes of zero counts were defined as not wearing the monitors.

Person-minutes were aggregated and rank-ordered from lowest to highest activity for analysis in relation to magnetic fields. Person-days (with a measurement day defined as ≥4 hours) and whole persons (integrated over the 7 measurement days) were also rank-ordered by activity level for analysis. Magnetic field indices included the peak exposure level of ≥16 mG defined by Li et al,[1] other thresholds of peak exposure (4, 10, and 20 mG), and time-weighted average. Candidate predictors of magnetic field exposure from the telephone interview included self-report of general health, nausea any time during the pregnancy, employment outside the home, and sociodemographic characteristics.

The person-minutes, person-days, or persons were rank-ordered, divided into quartiles, and analyzed using the least active quartile as the referent to generate odds ratios for elevated magnetic field peaks and time-weighted averages with 95% confidence intervals comparing more with less active women. The large number of person-minutes (>500,000) required sampling every fifth minute to facilitate the analysis. In the person-minutes and person-days models for the analysis of peak exposures, we used generalized estimating equations[6,7] to account for correlation among measures within women, and for the analysis of mean exposures, we used linear mixed models[8] to account for correlation due to repeated measures.

RESULTS

One hundred women contributed 677 person-days. On average, women wore the monitors for 12.7 hours (interquartile range, 11.4–14.4) per day. Most women were well-educated (89% with at least some college), white (78%), and worked outside the home (64%) (Table 1). Overall, 87% of person-days had at least one exposure ≥4 mG, 51% ≥10 mG, 30% ≥16 mG, and 23% ≥20 mG. Person-days with exposure ≥16 mG were less common among women who were older, black, and currently working outside the home (Table 1). Relative to women who were between 26 and 30 weeks' gestation, women who were earlier in their pregnancy were markedly more likely to have high peak exposure. Nausea during the pregnancy, education, and presence of children in the household were not associated with peak exposure. Those who reported better health status were more likely to have peak exposures ≥16 mG in the person-minute analysis.

TABLE 1. Demographic and Health-Related Characteristics of Study Women and Relation to Peak Magnetic Field Exposure ≥16 mG

		Magnetic Field Exposure ≥16 mG	
Covariate	% (n = 100)	Person-Minutes* Analysis OR (95% CI)	Person-Day* Analysis OR (95% CI)
Maternal age (y)			
<30	41	1.0	1.0
≥30	59	0.8 (0.2–3.1)	0.6 (0.4–1.0)
Education			
High school or less	11	0.2 (0.1–0.8)	1.3 (0.6–2.9)
Some college	55	0.2 (0.1–0.5)	1.2 (0.7–2.0)
Advanced degree	34	1.0	1.0
Maternal race			
Black	22	0.4 (0.1–1.0)	0.6 (0.4–1.1)
White or other	78	1.0	1.0
Current work outside home			
Yes	64	0.7 (0.2–2.7)	0.7 (0.4–1.1)
No	36	1.0	1.0
Children ≤18 yr of age at home			
Yes	57	0.6 (0.1–2.4)	1.0 (0.6–1.6)
No	43	1.0	1.0
Gestational age at measurement (wk)			
13–20	31	6.4 (2.0–20.0)	2.6 (1.5–4.6)
21–25	33	2.2 (0.8–5.7)	1.6 (0.9–2.9)
26–29	36	1.0	1.0
Any nausea during pregnancy			
Yes	80	1.7 (0.7–4.4)	0.9 (0.5–1.8)
No	20	1.0	1.0
General health			
Excellent/very good	81	4.4 (1.5–12.9)	1.0 (0.5–2.0)
Good/fair/poor	19	1.0	1.0

*From GEE model with outcome defined as exposure ≥16 mG in each day.

In the analysis of person-minutes, a clear association between physical activity and peak magnetic field exposure was evident only among nonworking women. In contrast, a consistent positive association was found in the analysis of person-days between physical activity among all women for exposure to peaks of 10 mG and above, with odds ratios over 2.0 for the highest quartile for ≥16 or 20 mG (Table 2). Analysis of persons aggregated over days yielded imprecise results with 75% of women having a peak ≥16 mG and no suggestion of an association (data not shown).

We also examined the relationship between physical activity and mean (time-weighted average) magnetic field exposure (Table 3). Average exposure was slightly increased for women who were in the upper 3 quartiles of physical

TABLE 2. Unadjusted* Association Between Physical Activity and Magnetic Field Exposure for Peak Exposure Cut Points of ≥4, 10, 16, and 20 mG, Stratified by Employment Status.

	Person-Minutes† Analysis (n = 103,174‡ person-minutes) Work Outside Home		Person-Day† Analysis (n = 677 person-days) Work Outside Home	
Quartiles of Physical Activity	Yes (n = 65,945) OR (95% CI)	No (n = 37,229) OR (95% CI)	Yes (n = 428) OR (95% CI)	No (n = 249) OR (95% CI)
Exposed cut point: 4 mG				
Quartile 1 (least active)	1.0	1.0	1.0	1.0
Quartile 2	1.3 (1.1–1.4)	1.2 (0.9–1.5)	1.2 (0.5–2.5)	1.5 (0.5–4.2)
Quartile 3	1.1 (0.9–1.5)	1.2 (0.9–1.7)	1.2 (0.6–2.5)	1.6 (0.5–4.7)
Quartile 4 (most active)	1.0 (0.8–1.3)	1.2 (0.9–1.6)	1.2 (0.5–2.6)	1.7 (0.6–4.7)
Exposed cut point: 10 mG				
Quartile 1 (least active)	1.0	1.0	1.0	1.0
Quartile 2	1.0 (0.8–1.4)	1.2 (0.8–1.7)	1.6 (1.0–2.6)	1.4 (0.8–2.3)
Quartile 3	1.1 (0.7–1.8)	1.5 (0.9–2.6)	1.7 (1.1–2.8)	1.7 (0.8–3.7)
Quartile 4 (most active)	0.9 (0.6–1.4)	1.5 (1.1–2.1)	1.6 (0.8–3.0)	2.1 (1.0–4.4)
Exposed cut point: 16 mG				
Quartile 1 (least active)	1.0	1.0	1.0	1.0
Quartile 2	0.8 (0.5–1.5)	1.2 (0.6–2.5)	2.2 (1.1–4.2)	1.1 (0.6–2.0)
Quartile 3	0.7 (0.3–1.5)	3.0 (1.6–5.7)	1.7 (1.0–3.0)	1.9 (1.0–3.8)
Quartile 4 (most active)	0.6 (0.3–1.3)	2.9 (2.1–4.1)	2.6 (1.3–5.3)	2.1 (1.0–4.6)
Exposed cut point: 20 mG				
Quartile 1 (least active)	1.0	1.0	1.0	1.0
Quartile 2	0.9 (0.4–2.0)	1.4 (0.8–2.5)	1.8 (0.8–3.8)	1.2 (0.6–2.6)
Quartile 3	0.9 (0.4–2.1)	3.5 (1.9–6.4)	1.3 (0.6–2.5)	2.2 (1.0–4.8)
Quartile 4 (most active)	0.6 (0.2–1.7)	3.6 (2.3–5.6)	2.1 (0.9–4.8)	2.2 (0.9–5.4)

*No adjustment for confounding necessary based on score test of all confounders.
†From GEE model with outcome defined as magnetic field exposure ≥the cut point, 4, 10, 16, or 20 mG, with quartiles of physical activity defined as the referent (least active), somewhat active, active, and most active. Quartiles of physical activity determined separately for minute-by-minute and person-level analyses.
‡Every fifth minute used (n = 103,174 used in analysis) due to excessive size of dataset.

TABLE 3. Unadjusted* Association Between Physical Activity and Average Magnetic Field Exposure

	Change in Log of Average Exposure	
Quartiles of Physical Activity	Person-Minutes† Analysis (n = 103,174§ person-minutes)	Person-Day‡ Analysis (n = 677 person-days)
Quartile 1 (least active)	0.00	0.00
Quartile 2	0.10 (0.08 to 0.11)	0.08 (−0.03 to 0.19)
Quartile 3	0.11 (0.10 to 0.13)	0.10 (−0.02 to 0.22)
Quartile 4 (most active)	0.00 (−0.02 to 0.01)	0.08 (−0.05 to 0.21)

*No adjustment for confounding necessary based on score test of all confounders.
†From linear mixed model with outcome defined as log of average magnetic field exposure and with quartiles of physical activity defined as the referent (least active), somewhat active, active, and most active. Quartiles determined separately for minute-by-minute and person-day level exposures.
‡From linear regression model with outcome defined as log of average magnetic field exposure and with quartiles of physical activity defined as the referent (least active), somewhat active, active, and most active.
§Every fifth minute used in analysis due to excessive size of dataset.

activity based on person-days but only the middle 2 quartiles for person-minutes (Table 3).

DISCUSSION

The association between physical activity and the probability of encountering an elevated peak magnetic field (based on person-days and on person-minutes among nonworking women) supports the hypothesis that physical activity level influences peak magnetic field exposure. These findings suggest that determinants of physical activity, possibly including nausea and other pregnancy-related symptoms, would influence peak magnetic field exposure. The other components in the hypothesized scenario—whether nausea or advanced pregnancy is associated with reduced physical activity—were not evaluated fully. We are unaware of data linking nausea to physical activity, and in fact the results found by both Li and Neutra[5] and the present study indicate that self-reported nausea at unspecified times in pregnancy is not related to peak magnetic field exposure and was not related to physical activity in this study. Analysis of symptoms on the measurement day would be required to accurately address the link between nausea and magnetic fields or physical activity. Physical activity levels decline with advancing pregnancy,[9–11] and evidence from the present study suggests that peak magnetic fields decline with advancing gestation as well, pertinent to the case–control study.[2]

Our study was motivated by the studies of magnetic field and miscarriage from northern California,[1,2] but our measurements differed with regard to the magnetic field sampling frequency. Because we sampled once per minute and they sampled once per 10 seconds, the prevalence of elevated peak exposure was greater in their studies[12] because transient peak fields would be more comprehensively identified. In fact, we found that 30% of person-days had a peak of ≥16 mG, whereas Li et al[1] reported 74%.

We found a notable disparity in results based on person-minutes, in which the association was restricted to nonworking women, versus person-days, which did not show such effect modification. This finding implies that movement among nonworking women increases likelihood of encountering high peak magnetic fields in the active periods, but not so among working women. Perhaps the locations in which such movement is occurring differ for these 2 subsets of women, with more concentrated exposures within the work setting for working women and more diverse settings (streets, stores, other homes) among nonworking women. However, even working women who have more active days are more likely to encounter high peaks, making the contrast of results for person-minutes and person-days difficult to reconcile. Because the previous epidemiologic studies[1,2] collected measurements for person-days, the results based on person-days may be more directly applicable.

These results raise concerns regarding interpretation of personal measurements of any exposure that vary over space and time in which underlying health status may influence movement. Although peak magnetic field exposures may be an extreme version of this situation, the potential for health-related distortion of exposure measurement is a general concern.

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