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Maternal exposure to extremely low frequency magnetic fields: Association with time to pregnancy and foetal growth

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ABSTRACT

Background: Data on reproductive and developmental effects of extremely low frequency magnetic fields (ELF MFs) are inconclusive. This study tested the hypothesis that maternal exposure to ELF MFs is associated with increased time to pregnancy (TTP), reduced birthweight or small for gestational age (SGA).
Methods: The study cohort consisted of 373 mothers who gave birth between 1990 and 1994 in Kuopio University Hospital, Finland. To increase prevalence of high ELF MF exposure, women living in buildings near known ELF MF sources were included. Maternal exposure to ELF MF before and during pregnancy was assessed with short term measurements in residences and questionnaires. Associations between ELF MF exposure and TTP, low birth weight and SGA were analysed by logistic regression (or linear regression for continuous variables), adjusting for factors known to be associated with the selected pregnancy outcomes, such as maternal smoking, alcohol consumption and socioeconomic status.
Results: The MF exposure of the mothers was slightly higher than in Finnish residences in general, but very high exposures (>0.4 μT) were rare. No consistent association of ELF MF with TTP, birth weight or SGA was found.
Conclusions: ELF MF exposure is not likely to be associated with TTP or prenatal growth at residential exposure levels that were observable in this study.

1. Introduction

The possible association between adverse human reproductive outcomes and maternal exposure to extremely low frequency magnetic fields (ELF-MFs) has only been studied to limited extent, with inconsistent results. Several epidemiologic studies have examined miscarriages among employees using video display terminals (VDT) (Juutilainen, 1991; Delpizzo, 1994; Lindbohm and Hietanen, 1995), but an increased risk of miscarriage was observed only among women who used VDT types with unusually high ELF MF emissions (Lindbohm et al., 1992). Slightly increased risk estimates for miscarriage have also been observed for use of electric blankets during pregnancy (Belanger et al., 1998), but also decreased risks have been reported (Lee et al., 2000). Measurement-based studies on residential exposure have provided limited evidence for increased miscarriage risk associated with ELF-MF exposure (Juutilainen et al., 1993; Li et al., 2002; Lee et al., 2002). In one study, increased risk of early pregnancy loss (pre-clinical miscarriage) was associated with residential exposure of 0.6 μT or higher (Juutilainen et al., 1993). Wang et al. (2013) observed a positive association between residential maximum MF exposure and miscarriage, but the associations between different MF exposure metrics and miscarriage were not consistent.

There is little evidence of increased risks of adverse pregnancy outcomes other than miscarriage (WHO, 2007). Savitz and Ananth (1994) concluded that exposure to residential MF ≥ 0.2 μT was not likely associated with low birth weight. Bracken et al. (1995) concluded that the risk of low birthweight and intrauterine growth retardation was not increased after electrically heated bed use during pregnancy. Two studies (Auger et al., 2011; Auger, 2012) found no association between residential proximity to transmission lines and adverse pregnancy outcomes (preterm birth, low birth weight, small for gestational age (SGA)).

Recently de Vocht et al. (2014) and de Vocht and Lee (2014) suggested that living close to sources of ELF MFs is associated with low birth weight. These studies did not involve other methods of exposure

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assessment than distance to known ELF MF sources such as power lines or substations. This does provide a crude estimate of average MF level, but is considered as poor predictor of MF exposure (WHO, 2007).

In the present study, we investigated the possible association of ELF MFs with time to pregnancy (TTP), low birth weight (LBW) and SGA. TTP was included, as delayed pregnancies might be at least partly related to early pregnancy loss, which was associated with ELF MF exposure in our previous study (Juutilainen et al., 1993).

2. Material and methods

2.1. Selection and characteristics of the study group

The study group was selected from the birth register of Kuopio University Hospital (KUH) using proximity of the mother's residence to power lines, cables and transformer stations as selection criteria. In order to increase the prevalence of high exposures and exposure contrasts, information from the local electric utility was used to select only mothers who lived in apartment buildings with a transformer station on the ground floor, buildings within 100 m from ≥110 kV overhead lines or buildings close to ≥10 kV underground cables were selected. As ELF MF strength is strongly dependent on distance from the source, only some apartments are affected, while the majority will have normal background levels. Besides data recorded at the time of delivery, the birth register contains information from interviews at local maternity stations (e.g. smoking and alcohol use, abortions, TTP). TTP was determined by asking the mother "how long did you try to get pregnant?" or "when did you stop using contraception?" Only women having their first or second child were included in the study. The birth register for the years 1990–1994 included 562 mothers who met the criteria and had responded to the question concerning TTP. For this subgroup, the address information before and during pregnancy was confirmed by questionnaires and by phone for 526 mothers. Measurements of MF exposure were obtained for 373 mothers in residences where they lived during pregnancy. This was the number of women available for the analyses of birth weight and SGA. The mothers ($N = 24$) who had received treatment for fertility problems were removed from the analyses of TTP. For the mothers included in TTP analyses, measurements of MF exposure were obtained in 352 residences where they lived before pregnancy. Questionnaire-based assessment of exposure in before-pregnancy and during-pregnancy residences was obtained for 217 and 216 mothers, respectively.

The age of the mothers in the study cohort ($N = 373$) ranged from 18 years to 44 years (mean 28.2 years ± SD 4.7). 57.9% were primiparas and 42.1% secundiparas. Most of the women (47.5%) were workers. Other socioeconomic statuses (SES) included clerical workers (30.8%), students (7.0%) and others (8.8%). The SES was not classified for 4.0% of the women. Most of the mothers were non-smokers before (75.9%) and during (89.0%) pregnancy. 47.7% of the women were total abstainers before pregnancy, and 96.8% during pregnancy. One or more legal abortion(s) had been performed on 23.3% of the 202 mothers for whom this information was available. Data on miscarriages were available for 202 mothers, and 22.8% of them had had one or more miscarriages. The distribution of TTP ($N = 352$) was 0–3 months (69.6%), 4–6 months (17.0), 7–9 months (5.1%), 10–12 months (4.8%), and 13 months or more (3.4).

Most of the newborns ($N = 373$) were boys (52.0%). The mean gestation time was 281.5 days. The birth weight of the newborns ranged from 1990 g to 4820 g (mean 3585 g). SGA was defined as weighting <90% of foetuses in the same gestational age (sex-specific SGA-nomograms developed in KUH were used). 11.4% of the boys and 13.1% of the girls were classified as SGA.

2.2. Magnetic field exposure assessment

Both measurements and questionnaires were used for exposure assessment. The women received a questionnaire entitled "Pregnancy and exposure to physical factors" covering the time one year before pregnancy, and the pregnancy period. Information on address before and during pregnancy was collected both by the questionnaire and by asking the mothers who gave permission to perform MF measurements in their homes. The questionnaire included questions on the mothers' occupation/duties at work, noise exposure at work, at home or at hobbies, use of electrical appliances at work, and exposure to electrical devices during leisure activities at home or at hobbies. Questions were included on the use of electrical appliances that were considered as potential MF sources at home (microwave oven, electric stove, sewing machine, food mixer, blender, water bed) and on electrical appliances that we considered to cause less exposure at home (television, vacuum cleaner, microcomputer, washing machine), according to previous measurements (Juutilainen et al., 1989). The questionnaire data was used to estimate the weekly exposure times to electrical appliances. Exposure to heated water bed and electric stove was evaluated separately, while exposure to appliances that cause relatively high but short-time exposure (microwave oven, sewing machine, blender, food mixer) was summed to produce an estimate of the total weekly exposure hours to these MF sources. Information on occupational MF exposure was obtained by asking the mothers an open question on working near electric appliances (excluding lighting equipment), asking them to name such devices and to estimate distance to them. These data were used for exposure assessment by an experienced occupational hygienist, who classified the women as exposed or unexposed, according to the exposure source and distance. "Exposed" in this classification indicated that exposure to MFs higher than typical residential background levels was likely at work. The classification was based on measured MF data whenever available. Equipment considered to be significant MF sources included, for example, devices with electric motors (such as drills) and computer monitors (cathode ray tube technology was mainly used at the time of data collection).

Residential ELF MFs were measured 1 month to 5 years after the delivery. If a mother had moved, measurements were carried out also in the previous residence. All measurements were conducted in the spring or autumn. Spot measurements were made by using the same methodology as in a previous study on early pregnancy loss (Juutilainen et al., 1993). A self-constructed meter developed at the University of Kuopio (currently University of Eastern Finland) was used. The coil of the MF meter is sensitive to the direction of the MF and it is shielded against electric fields. In each measurement point, the coil was turned to determine MF direction and its maximum strength. A measurement was taken at the front door (outside) of each apartment. Inside the apartments, measurements were done in the kitchen, in the bedroom and in the living room. Five spot measurements were performed in each room at 1 m above the floor, including one measurement at the centre of the room, and four values near each corner, at a distance of 1 m from the walls. In the bedroom, the centre measurement was made at the centre of the bed. The person who did the spot measurements also carried a continuously recording exposure meter (Positron, series 378100, Positron Industries, Montreal, Canada). The meter was set to take readings at 5 s intervals and the total measuring time was 20 min. In total, measurements were carried out in 352 residences in which the study participants lived before pregnancy and in 373 residences where they lived during pregnancy. Due to instrument faults, results of continuous 20 min MF measurement were available for 314 before pregnancy addresses, and 330 during pregnancy addresses.

2.3. Statistical analysis

Statistical analyses were performed by IBM SPSS Statistics Version 21 (Corp, 2012). For continuous dependent variables, regression

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