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The Effect of Extremely Low-Frequency Electromagnetic Radiation on Pregnancy Outcome: A Meta-Analysis

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Abstract

Objectives: To assess the effect of extremely low frequency electromagnetic radiation on pregnancy outcomes.

Design: PubMed, Web of Science, Cochrane Library, Embase and EBSCO were searched until March 10th, 2021. Search type for queue research on influence of electromagnetic field radiation on pregnancy results. Data were screened and extracted independently by two researchers. Review Manager 5.3 software was used for the meta-analysis.

Participants: Pregnant women and newborns who live and do not live near extremely low frequency electromagnetic fields.

Interventions: Sustained exposure to extremely low frequency electromagnetic radiation during pregnancy.

Results: There was no significant increase in the risk of miscarriage, stillbirth, birth defects and preterm delivery in the pregnant women who lived near the electromagnetic fields compared with the control group.

Conclusion: No correlation has been found between maternal ELF-EMF exposure and miscarriage, stillbirth, neonatal birth defects and preterm delivery, while the effects on small gestational age and low birth weight are still uncertain. Related research with high-quality large samples and different regions are still needed for further verification.

Keywords: Extremely low frequency electromagnetic radiation; Pregnancy outcome; Meta-analysis

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Introduction

Humans have been frequently exposed to Extremely Low Frequency Electromagnetic Fields (ELF-EMF) since the late 1970s. The ELF-EMF is Non-Ionizing Radiation (NIR) and does not carry enough energy per quantum to ionize atoms or molecules. The ELF-EMF are generated by electrical devices and power systems (1 Hz to 300 Hz). In recent decades, exposure to ELF-EMF has emerged potential concerns on public health. Exposure to ELF-EMF has an adverse biological effect depending on the current intensity, strength of the magnetic field, and duration of exposure. Accumulated epidemiologic evidence indicates a correlation between exposure to ELF-EMF and childhood cancer incidence, Alzheimer's Disease (AD), and miscarriage [1]. Data on the effects of Extremely Low Frequency Electromagnetic Fields (ELF-EMF) on pregnancy outcomes (Condition of the fetus or newborn after termination of pregnancy, including preterm birth, stillbirth, low birth weight, miscarriage, small for gestational age, etc.) are inconclusive [2]. For example, a report showed ELF-EMF has been studied as a potential risk factor for miscarriage (pregnancy loss at <20 weeks of gestation) and other adverse reproductive health outcomes. This research priority arose from reports of miscarriage and birth defect clusters among Video Display Terminal (VDT) operators in the U.S. and Canada. Although several studies have demonstrated that ELF-EMF is associated with an increased risk of adverse pregnancy outcomes, other studies have shown no evidence of associations [3]. A recent study by Wilson reports that personal magnetic fields exposures were not associated with fertility treatment outcomes or pregnancy outcomes [3]. Prematurity or small for gestational age is a leading cause of neonatal mortality and morbidity in developed countries, and also increase the risk of chronic diseases in adult life. Both are multifactorial phenomena associated with fetal, maternal, placental and environmental factors, and though several risk factors are now well known, the effect of ELF-EMF on it remains unidentified [2]. In this context, we conducted a systematic review and meta-analysis to assess the effect of ELF-EMF on pregnancy outcomes and provide evidence-based medicine evidence on the need for epidemiological research.

Methods

Search strategy

We searched PubMed, Embase, Cochrane Library and Web of Science from inception to March 10th, 2021 using the following search terms: ("Electromagnetic waves" OR "Electromagnetic Wave" OR "Wave, Electromagnetic" OR "Waves, Electromagnetic" OR "Electromagnetic Energy" OR "Electromagnetic Energies" OR "Energies, Electromagnetic" OR "Energy, Electromagnetic" OR "Radiation, Electromagnetic" OR "electromagnetic radiation[mesh]") AND ("maternal", "pregnancy[mesh]" OR "pregnant" OR "pregnancies" OR "gestation" OR "pregnancy") AND ("Abnormality, Congenital" OR "Congenital Abnormality" OR Deformities OR Deformity OR "Congenital Defects" OR "Congenital Defect" OR "Defect, Congenital" OR "Defects, Congenital" OR "Abnormalities, Congenital" OR "Birth Defects" OR "Birth Defect" OR "Defect, Birth" OR "Fetal Malformations" OR "Fetal Malformation" OR "Malformation, Fetal" OR "Fetal Anomalies" OR "Anomaly, Fetal" OR "Fetal Anomaly" OR "abortion" OR "stillbirth" OR "chorioamnionitis" OR "congenital anomalies" OR "microcephaly" OR "neonatal death" OR "neonatal infection" OR "preterm birth" OR "low birth weight" OR "maternal death" OR "small for gestational age" OR "outcome" OR "complication" OR "Congenital Abnormalities[mesh]"). We only included cohort studies conducted ELF-EMF on pregnancy outcome. We included only English articles.

Inclusion and exclusion criteria

Inclusion criteria: (1) The protocol was pre-specified to include cohort studies conducted in pregnant women and had reported on primary pregnancy outcomes, including preterm birth, SGA, fetal death, stillbirth or LBW. (2) Included studies are pregnant women who live near extremely low frequency electromagnetic fields caused by power lines.

Exclusion criteria: (1) Irrelevant to the subject of the meta-analysis, such as studies that did not use ELF-EMF as the exposure; (2) Insufficient data to calculate the Risk Ratio (RR) or assess the pooled effect of ELF-EMF on pregnancy outcomes; (3) Duplicate studies or overlapping participants; (4) Reviews, editorials, conference papers, case reports or animal experiments; (5) Studies that did not provide details on the identification of ELF-EMF on pregnancy mothers. (6) Mobile phone, TV, X-ray, nuclear radiation, daily microwave oven, electric blanket, etc. (7) The definitions of exposure factors are very different, and the exposure conditions cannot be combined, including grading by exposure time, etc.

Literature screening and data extraction

Literature was screened by 2 independent reviewers according to pre-specified inclusion and exclusion criteria. First, read the full text by reading the titles and abstracts of the articles, after screening out obviously irrelevant articles. while discrepancies were resolved with a third investigator. If the information is incomplete or the full text cannot be obtained, the authors of the literature should be contacted for consultation. Those who have not yet obtained the information will be excluded. Data were extracted using a predesigned form that had been piloted. The following data were extracted independently by two investigators (WNL and FFZ) from the selected studies: (1) Basic information of the studies, including first author, publication year and research type; (2) characteristics of the study population, including sample sizes and locations; (3) primary outcomes: The number of ELF-EMF-exposure and non-exposure pregnant women in the total cohort and by different outcomes (preterm birth and non-preterm birth, SGA and non-SGA, fetal death and live birth, stillbirth and live birth, low birth weight and normal birth weight); (4) definitions of pregnancy outcomes: preterm birth was defined as birth at <37 weeks Gestational Age (GA); SGA was defined as a birth weight of <10th percentile for GA and sex; LBW was defined as a birthweight of <2500 g; stillbirth was defined as fetal death after 24 weeks of pregnancy; fetal death was defined as a corporation of abortions (at 13 to 21 weeks gestation) and stillbirth (at ≥ 22 weeks gestation). We applied these definitions as provided by the included studies.

Quality assessment

We evaluated the methodological quality of included studies using the tool developed by Hoy et al. [4], which is used in assessing the risk of bias in non-randomized studies and has been used in previous meta-analyses [5,6]. We assigned each item a score of 1 (yes) or 0 (no) and summarized scores across items to generate an overall quality score that ranged from 0 to 10. According to the overall scores, we classified studies as having a low (>8), moderate (6–8) or high (≤ 5) risk of bias. Two investigators (WRT and YWX) independently assessed study quality, with disagreements resolved by a third investigator (DM).

Data synthesis and statistical analysis

All the statistical analyses were performed using RevMan 5.3 software. For dichotomous variables, relative risk (RR) and 95% Confidence Interval (CI) were used as effect indicators. A value of $P<0.05$ was considered significant. Heterogeneity analysis was performed on the results of the included studies (test level $\alpha=0.1$). If $P>0.1$ and $I^2<50\%$, it means that there is no statistical heterogeneity among the studies, and a fixed-effects model is used, otherwise, a random-effects model is used for analysis. If substantial heterogeneity was observed, we conducted subgroup analyses and sensitivity analysis to investigate the possible sources of heterogeneity.

Patient and public involvement

No patient involved.

Results

Literature search

A total of 1,021 records were retrieved from the four databases. Before screening, 360 other irrelevant literatures such as systematic reviews, reviews, repeated literatures, animal experiments, etc. were excluded. After screening of titles and abstracts, we excluded 627 studies irrelevant to the subject. Among the 34 articles assessed based on full texts, 12 articles were excluded for duplicates or did not meet inclusion criteria, 2 articles full text were not found, 13 articles were excluded for lacking specific data. A total of 7 studies were finally

Table 1: Evaluation of the quality of cohort studies included in the meta-analysis.

Items	Elisabeth Robert 1993	Manoochehr Mahram 2013	Nathalie Auger 2019	KG Blaasaas 2004	Qiang Wang 2013	Frank de Vocht 2014
1. Was the study's target population a close representation of the national population in relation to relevant variables?	1	1	1	1	1	1
2. Was the sampling frame a true or close representation of the target population?	1	1	1	1	1	1
3. Was some form of random selection used to select the sample, OR was a census undertaken?	1	0	1	1	0	1
4. Was the likelihood of nonresponse bias minimal?	1	0	1	1	0	1
5. Were data collected directly from the subjects (as opposed to a proxy)?	0	1	0	0	1	0
6. Was an acceptable case definition used in the study?	0	0	1	0	1	1
7. Was the study instrument that measured the parameter of interest shown to have validity and reliability?	1	1	1	1	1	1
8. Was the same mode of data collection used for all subjects?	1	1	1	1	1	1
9. Was the length of the shortest prevalence period for the parameter of interest appropriate?	1	0	1	1	1	1
10. Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	1	1	1	1	1	1
Summary item on the overall risk of study bias	8	6	9	8	8	9

included in the review. Flow chart for the selection of studies the literature selection process is shown in Figure 1.

Quality assessment

Table 1 evaluates the cohort studies using the coding manual for cohort study. The quality of the included articles was evaluated from ten aspects in the following table. The total score of the coding manual is 10 points. If the total points are greater than or equal to 8, it is considered as a high-quality article. As is shown in Table 1, 6 articles are high-quality literature.

Basic information of the included literature

A total of 7 studies were finally included in the review, and comprised a total of 3055,644 total sample. All of the literature are cohort studies. Information obtained from each full-text study included first author, publication year, area, primary outcomes and so on. Basic information extraction is shown in Table 2.

Analysis results

Adverse pregnancy outcomes: Miscarriage, stillbirth, birth defects, and preterm birth were included in the analysis as bad pregnancy outcomes. A total of 7 studies were finally included. $P<0.00001$, $I^2=97\%$, A random effects model was used. Total effect Z=1.35, P=0.18, [RR=1.30, 95% CI (0.89, 1.90)]. The results showed that there was no statistically significant between the two groups. There was no significant increase in bad pregnancy outcomes among pregnant women who lived near electromagnetic fields compared with those who lived far away from magnetic fields (Figure 2A).

Birth defect: A total of 4 studies were included. $P<0.00001$, $I^2=99\%$, A random effects model was used. Total effect Z=0.85, P=0.39, [RR=1.29, 95% CI (0.72, 2.33)]. The results showed that there was no statistically significant between the two groups. There was no significant increase in newborn birth defect risk among pregnant women who lived near electromagnetic fields compared with those who lived far away from magnetic fields (Figure 2B).

Preterm birth

A total of 2 studies were included. $P=0.95$, $I^2=0\%$, A random effects model was used. Total effect Z=0.74, P=0.46, [RR=1.08, 95% CI (0.87, 1.35)]. The results showed that there was no statistically significant between the two groups. There was no significant increase in preterm birth risk among pregnant women who lived near electromagnetic fields compared with those who lived far away from magnetic fields (Figure 2C).

Miscarriage and stillbirth

The outcomes of miscarriage and stillbirth were similar. So, analyze it as one situation, and a total of 2 studies were included. $P=0.001$, $I^2=84\%$, A random effects model was used. Total effect Z=0.93, P=0.35, [RR=1.48, 95% CI (0.65, 3.33)]. The results showed that there was no statistically significant between the two groups. There was no significant increase in miscarriage and stillbirth risk among pregnant women who lived near electromagnetic fields compared with those who lived far away from magnetic fields (Figure 2D).

Subgroup analysis

we conducted subgroup analyses by European region and non-European region (Asia and North America). The results showed pooled effect size for the European region Z=0.74, P=0.46, [RR=1.30, 95% CI (0.65, 2.63)], non-European region Z=1.04, P=0.30, [RR=1.13, 95% CI (0.90, 1.43)], Between subgroups $P=0.71$, $I^2=0\%$, there was no statistically significant, but the heterogeneity is significantly reduced (Figure 2E).

Sensitivity analysis

Sensitivity analysis was performed by excluding each study in turn. After omitting the article KG Blaasaas 2004, Heterogeneity was significantly reduced, $P=0.07$, $I^2=50\%$, however, there was no significant change in heterogeneity after omitting the other articles. This suggests that the source of heterogeneity in combined effect sizes for bad pregnancy outcomes is KG Blaasaas 2004 (Figure 2F).

Discussion

Epidemiologic studies have provided inconsistent results on the association between exposure to ELF-EMF and various health

Table 2: Basic Information of articles included in this meta-analysis.

Author	Publish year	Location	Primary outcomes	Exposure conditions definitions	Total sample size (person)	Year of inclusion
Elisabeth Robert [7]	1993	France	chromosomal aberrations, central nervous system anomalies, skeletal malformations, cardiac defects, facial clefts, hypospadias anomalies of the digestive system, and anomalies of the urinary system	maternal residence in a municipality in which at least one point of habitation was located within 500 meters (0.5 cm on the 1/100,000 scale map) of 225 or 400 kV overhead power lines	5925	1988-1989
Manoochehr Mahram [8]	2013	Iran	preterm labor, neonatal birth weight, length, head circumference and congenital malformations	the areas under the ELF-EM elds were registered on the maps.	380	2011
KG Blaasaas [9]	2004	Norway	Birth defects: Central Nervous System (CNS) defects, cardiac defects, respiratory system defects, esophageal defects, and clubfoot	the estimated magnetic field was 0.1 μT or above.	744324	1980-1997
Nathalie Auger [10]	2019	Canada	Nine major categories of birth defects were included, covering the central nervous system, sense organs (eye, nose, ear), orofacial clefts, heart, respiratory, digestive, abdominal wall or diaphragm (gastroschisis, omphalocele, diaphragmatic hernia), genitourinary, and musculoskeletal systems.	calculated the distance between the postal code centroid and the nearest transmission line and transformer station in meters. (<200).	2164246	1989-2016
Frank de Vocht [11]	2014	England	Low Birthweight (LBW), Small for Gestational Age (SGA) and Preterm Birth (PTB) (included spontaneous preterm birth)	linear residential proximity of 200 m or less based on measurement data indicating that magnetic field strengths from overhead power lines would not exceed normal domestic background levels at distances of more than 200 m from high voltage lines.	140356	2004-2008
Nathalie Auger [12]	2012	Canada	stillbirth	The referent was defined as ≥ 100 m, The straight-line distance between postal code centroids and the nearest power line were calculated with MapInfo Professional 8.0.	516685	1998-2007
Qiang Wang [13]	2013	China	miscarriage	the estimated magnetic field was 0.1 μT or above.	413	2010-2012

outcomes. It may be associated with neurodegenerative diseases, specifically Alzheimer's disease; however, limited evidence was found to suggest that ELF EMFs are associated with several types of cancer, CVD, and reproductive outcomes [14]. Many research studies regarding the impact of low frequency electromagnetic fields on residents living close to very high voltage overhead power lines were carried out. A review study has shown that childhood leukemia is associated with exposure to magnetic field. Many other studies suggest the role of this exposure and the increased risk of birth defect. In addition, the results from some studies have indicated that exposure to magnetic field may be associated with the increased risk of adverse birth outcomes such as low birth weight and miscarriages. Some studies, however, did not find a statistically significant increased risk of preterm birth and low birth weight in relation to exposure to electro-magnetic field during pregnancy reproductive outcomes [15]. Most residents living in close proximity to overhead power lines are more concerned about the outcome of their pregnancy. The scientific evidence for other outcomes of pregnancy such as preterm birth is quite weak. A total of 7 studies were included for meta-quantitative analysis. Miscarriage, stillbirth, birth defects, and preterm birth were included in the analysis as bad pregnancy outcomes. there was no statistically significant between the exposed group and the non-exposed group. Birth defects, preterm births, miscarriages and stillbirths were analyzed separately, and no statistically significant differences were found. The results showed that there was no statistically significant in pregnancy outcomes among pregnant women who lived near electromagnetic fields compared with those who lived far away from magnetic fields. We conducted subgroup analyses by European region and non-European region. The results suggest that different regions may be one of the sources of its heterogeneity. Sensitivity analysis suggests that the source of heterogeneity in combined effect sizes for bad pregnancy outcomes is KG Blaasaas 2004. Sensitivity analysis showed that the KG Blaasaas 2004 [9] study had a greater impact on the heterogeneity of combined studies. However, after careful evaluation, there was no sufficient reason to exclude this literature study, so it was included. The limitations in this study are listed as follows. First, the definition of magnetic field exposure was not consistent across studies included in the meta-analysis. Second, the distance assessment method used is not completely consistent. Third, birth defects are also defined differently, for example, Elisabeth Robert 1993 [7] and Nathalie Auger 2019 [10] have a more comprehensive description of birth defects. While Manoochehr Mahram 2013 [8] only mentioned congenital malformations. The population of birth defects included in the original literature may vary, which may have some impact on the pooled results. Due to the small number of included studies, the publication bias of the studies could not be fully evaluated. In addition, most of the maternal and neonatal conditions are not clearly recorded in the literature, so it is impossible to explore confounding factors such as birth defects and preterm birth through multivariate analysis of other influencing factors of pregnant women. Electromagnetic field exposure is flowing everywhere, and wherever there are wires, motors and electronic equipment, electromagnetic fields are generated. This is one of the reasons why it is difficult to assess the effects of electromagnetic fields on human health. For research consistency, this study pooled mainly electromagnetic exposures to residential high-voltage lines. Eventually, larger sample size and higher quality studies are needed to clarify the mechanisms of these magnetic fields. Although there is no direct evidence from the current study that ELF-EMF has an effect on pregnancy outcomes, studies, empirical observations, and patient reports clearly indicate interactions between EMF exposure and health problems. On the one hand, there is strong evidence that long-term exposure to certain EMFs is a risk factor for diseases such as certain cancers, Alzheimer's disease, and male infertility. On the other hand, the Emerging Electromagnetic Hypersensitivity (EHS) is more and more recognized by health authorities, disability administrators and case workers, politicians, as well as courts of law. It is very important to take the individual susceptibility into account. The primary method of treatment should mainly focus on the prevention or reduction of EMF exposure, that is, reducing or eliminating all sources of high EMF exposure at home and at the workplace. The reduction of EMF exposure should also be extended to public spaces such as schools, hospitals, public transport, and libraries to enable persons with EHS an unhindered use (accessibility measure). At the same time, individuals should strengthen their physique and maintain homeostasis in order to increase their ability to resist disease and thus resist the bad effects of exposure to electromagnetic fields [16].

Conclusion

This meta-analysis shows that no correlation has been found between maternal ELF-EMF exposure and miscarriage, stillbirth, neonatal birth defects and preterm delivery, while the effects on small gestational age and low birth weight are still uncertain. Related research with high-quality large samples and different regions are still needed for further verification.

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References

1. Karimi A, Moghaddam FG, Valipour M. Insights in the biology of extremely low-frequency magnetic fields exposure on human health. Mol Biol Rep. 2020;47(7):5621-33.
2. Migault L, Garlantezec R, Piel C. Maternal cumulative exposure to extremely low frequency electromagnetic fields, prematurity and small for gestational age: a pooled analysis of two birth cohorts. Occup Environ Med. 2020;77(1):22-31.
3. Ingle ME, Minguez-Alarcon L, Lewis RC. Association of personal exposure to power-frequency magnetic fields with pregnancy outcomes among women seeking fertility treatment in a longitudinal cohort study. Fertil Steril. 2020;114(5):1058-66.
4. Hoy D, Brooks P, Woolf A. Assessing risk of bias in prevalence studies: Modification of an existing tool and evidence of interrater agreement. J Clin Epidemiol. 2012;65(9):934-9.
5. Wang R, Yan W, Du M. The effect of influenza virus infection on pregnancy outcomes: A systematic review and meta-analysis of cohort studies. Int J Infect Dis. 2021;105:567-78.
6. Liu Y, Cai Q. Does Cataract surgery improve the progression of age-related macular degeneration? A meta-analysis. J Ophthalmol, 2020;2020:7863987.
7. Robert E. Birth defects and high voltage power lines: An exploratory study based on registry data. Reprod Toxicol. 1993;7(3):283-7.
8. Mahram M, Ghazavi M. The effect of extremely low frequency electromagnetic fields on pregnancy and fetal growth, and development. Arch Iran Med. 2013;16(4):221-4.
9. Blaasaas KG, Tynes T, Lie RT. Risk of selected birth defects by maternal residence close to power lines during pregnancy. Occup Environ Med. 2004;61(2):174-6.
10. Auger N, Arbour L, Luo W. Maternal proximity to extremely low frequency electromagnetic fields and risk of birth defects. Eur J Epidemiol. 2019;34(7):689-97.
11. De Vocht F, Hannam K, Baker P. Maternal residential proximity to sources of extremely low frequency electromagnetic fields and adverse birth outcomes in a UK cohort. Bioelectromagnetics. 2014;35(3):201-9.
12. Auger N, Park AL, Yacouba S. Stillbirth and residential proximity to extremely low frequency power transmission lines: A retrospective cohort study. Occup Environ Med. 2012;69(2):147-9.
13. Wang Q, Cao Z, Qu Y. Residential exposure to 50 Hz magnetic fields and the association with miscarriage risk: A 2-year prospective cohort study. PLoS One. 2013;8(12):e82113.
14. Habash M, Gogna P, Krewski D. Scoping review of the potential health effects of exposure to extremely low-frequency electric and magnetic fields. Crit Rev Biomed Eng. 2019;47(4):323-47.
15. Sadeghi T, Ahmadi A, Javadian M. Preterm birth among women living within 600 meters of high voltage overhead Power Lines: A case-control study. Rom J Intern Med. 2017;55(3):145-50.
16. Belyaev I, Dean A, Eger H. EUROPAEM EMF Guideline 2016 for the prevention, diagnosis and treatment of EMF-related health problems and illnesses. Rev Environ Health. 2016;31(3):363-97.