

Impact of Non-Ionizing Electromagnetic Waves on Human Pregnancy and Teratogenicity: A Systematic Review

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Abstract: Electromagnetic waves have increased significantly over the past few years, and one important source is cells. The average daily time spent on gadgets rose from 4.75 to 11.36 hours. This radiation of the device has different effects on the most vulnerable groups, including young children, the elderly, and pregnant women; for example, the risk of abortion increases 1.27-fold when exposed to EMFs above 50 Hz and 16 mG. The databases Scopus, Cochrane Library (Wiley), Science Direct, the US National Library of Medicine (PubMed), and another source, Google Scholar, were used to obtain the data. Medical terms were used to obtain the data as well as "RF," OR "RF-EMFs," AND "phone," OR "mobile phone," AND "radiofrequency," OR "cell-phone," OR "electromagnetic field," OR "electromagnetic waves," OR "EMF," OR "EMW," OR "non-ionizing," AND "fetus," AND "pregnant" as keywords. The study report adhered to the PRISMA criteria the Preferred Reporting Items for Systematic Reviews. The study protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) at the National Institute for Health Research (No: CRD42023475665). The impact of electromagnetic waves on pregnancy includes miscarriage, stillbirth, congenital defects in newborns, and premature delivery. During pregnancy, the placenta absorbs electromagnetic field (EMF) radiation from cell phones. This increases fetal temperatures, affecting the metabolic processes and blood supply to the placenta. Higher prenatal exposure to EMFs might result in a decrease in the birth weight, head size, head, upper arm, and abdomen, as well as skinfold thickness of the back, triceps, and abdomen. These findings indicate that pregnant women may have a higher vulnerability to the impacts of electromagnetic wave exposure, emphasizing the significance of providing customized guidance and preventive measures for pregnant women.

1 INTRODUCTION

On March 11, 2020, the World Health Organization declared COVID-19 a global pandemic (Ezpeleta, Navarro, de la Osa, Trepas, & Penelo, 2020). Indonesia, the world's fourth most populous country, is expected to suffer significantly over a longer period than other less-populated countries. The SARS-CoV-2 virus and COVID-19 information both spread widely. One of the easiest and fastest tools for

disseminating information is social media. It is a medley of online spaces for generating and sharing knowledge, concepts, communications, etc. Thanks to social media, a lot of COVID-19 information has surfaced. It allowed for the rapid and widespread dissemination of public health messages, enabling people to decide how to stay safe.

The Indonesian government responded to many situations, offering encouragement to remain at home. Work From Home is a term we use for employees

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(Djalante et al., 2020). The rapid global connectivity of people and information during the COVID-19 pandemic illustrates how the world has grown more digital. (Serra, Lo Scalzo, Giuffrè, Ferrara, & Corsello, 2021) The previous survey found that participants' average daily time spent on gadgets increased from 4.75 to 11.36 hours during the lockdown (Pachiyappan et al., 2020).

Using modern technology, such as cell phones, the Internet, radio, and television, requires an integrated communications antenna. Due to their effects and the waves, they create, they pose a health danger to people. Among the vulnerable populations who are more vulnerable to the effects of these radiations are children, the elderly, and pregnant women. The use of cell phones, a potent electromagnetic wave generator, has greatly expanded in recent years (Ghazanfarpour et al., 2021). Abortion risk increases 1.27 times when exposed to EMFs above 50 Hz and 16 mG (Ghazanfarpour et al., 2021). The previous study described the effects of 2.4 GHz RF radiation on the amount of bone and cartilage in the forelimbs during pregnancy. A significant difference in bone and cartilage volumes between the experimental and control groups could be seen (Saghezchi et al., 2019). Another study found that electromagnetic radiation affects the male reproductive system, causing abnormal morphology, decreased motility, increased peroxidation from oxidative stress, histological abnormalities in the testes, and occasionally atrophy of the testicular tissue in spermatozoa. (Journal et al., 2018). Globally, the COVID-19 epidemic has profoundly impacted people's lives. Some claim that the COVID-19 pandemic has made mobile devices even more crucial for fostering and strengthening social relationships and general well-being (David & Roberts, 2021).

When a woman is pregnant, significant physiologic and immunologic changes occur in her body to support and protect the developing foetus. These changes may increase the risk of catching respiratory viruses for pregnant women and their foetuses. Pregnant women and their progeny may be at an increased risk of contracting COVID-19 (Wastnedge et al., 2021). Instructing them to be extremely strict about following the social distance behaviour standards. This review evaluates electromagnetic pregnancy effects in human.

A previous study demonstrated that exposure to smartphone bluetooth radiation had a substantial impact on body weight, leading to an increased rate of pregnancy progression. Although there was no substantial impact on the overall count of fetuses and the weight of fetal bodies. The injection of bluetooth

radiation for 15 minutes, 30 minutes, and 60 minutes did not clearly demonstrate any teratogenic effects (Fetuses, Fetuses, & April, 2016). Another study found no association between prenatal exposure to radiofrequency radiation and child neurodevelopment for the first three years, but a potential combined effect of maternal lead exposure and mobile phone use during pregnancy was suggested (Choi et al., 2017). This systematic review aims to find out the Impact of Non-Ionizing Electromagnetic Waves on Human Pregnancy and the Teratogenicity in the fetus.

2 MATERIALS AND METHODS

The study report adhered to the PRISMA criteria (Page et al., 2021) the Preferred Reporting Items for Systematic Reviews. The study protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) at the National Institute for Health Research (No: CRD42023475665).

2.1 Search Strategy

In this systematic review, English language restrictions were considered in searching the databases Scopus, Cochrane Library (Wiley), Science Direct, the US National Library of Medicine (PubMed), and another source, Google Scholar, were used to obtain the data. In all articles, references and reports were confirmed. Medical terms were used to obtain the data as well as "RF," OR "RF-EMFs," AND "phone," OR "mobile phone," AND "radiofrequency," OR "cell- phone," OR "electromagnetic field," OR "electromagnetic waves," OR "EMF, OR "EMW," OR "non-ionizing," AND "fetus," AND "pregnant " as keywords.

2.2 Inclusion and Exclusion Criteria

The study's inclusion criteria were limited to women who had intrauterine pregnancies, singleton pregnancies, and conceived naturally without the use of assisted reproductive procedures. The study's exclusion criteria included the following: studies without full text access, correspondences and letters to the editor, a history of chronic diseases, genetic problems, vaginal hemorrhage, birth defects in prior pregnancies, and cigarette smoking. Article published in language other than English were also excluded. The study included pregnant women (P) as participants, with the exposure group being pregnant women who were exposed to non-ionizing radiation

during pregnancy (I), and the control group being pregnant women who did not receive any non-ionizing radiation during pregnancy (C). Pregnancy implications: miscarriage, fetal demise, identification of other prenatal conditions, placental and amniotic abnormalities. Impact on the fetus: increased risk of preterm birth, congenital anomalies, and other birth-related conditions (O). Cohort studies and systematic reviews provide evidence for these associations (S).

2.3 Study Selection

The preliminary search produced 23,687 and 84,160 outcomes. The eligibility of these papers was assessed separately by two authors, according to pre-specified inclusion and exclusion criteria, while discrepancies were resolved with a third investigator. During the initial phase, a total of 94,658 studies were eliminated from consideration because they were either irrelevant or duplicated. After evaluating the titles and abstracts of the remaining papers, a total of 13,189 articles were deemed ineligible for inclusion in the study and hence excluded. During the assessment of the complete texts, 437 out of the remaining 468 articles were disqualified because they did not meet the criteria for eligibility. In conclusion, a grand total of 31 eligible articles underwent review (Figure 1).

2.4 Quality Assessment

The researchers mentions applying the STROBE guidelines for critical appraisal of a cohort study and the evaluation of qualitative studies for the systematic review paper was conducted using the Joanna Briggs Institute (JBI) criteria (Aromataris E, Fernandez R, Godfrey C, Holly C, Kahlil H, 2015). Evaluating the Risk of Bias in a Cohort Study using the New Castle Ottawa Scale (NOS) (Bae, n.d.).

2.5 Data Extraction

Two authors independently performed the study selection and validity assessment, and resolved any disagreements by consulting a third researcher.

3 RESULT

3.1 Electromagnetic Wave

People are exposed to electromagnetic fields (EMFs) that are created by both natural and human activity when they utilize power lines and other electrical

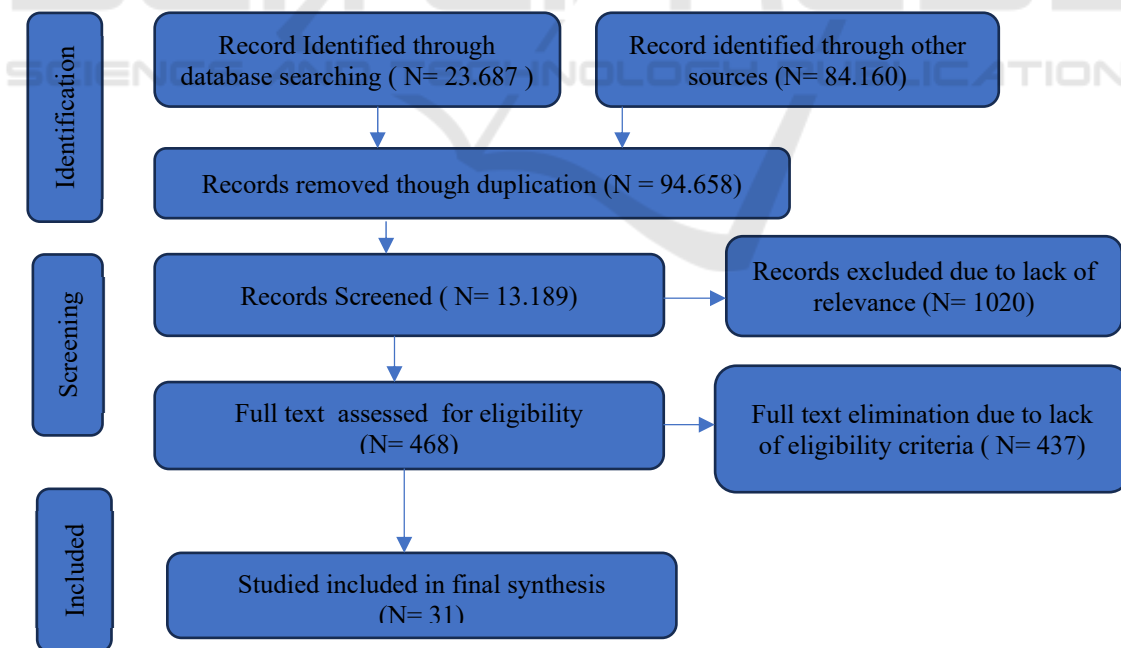


Figure 1. PRISMA Flowchart of selected studies

equipment, as well as when lightning strikes and the earth's magnetic field (MF) (Lee, Neutra, Hristova,

Yost, & Hiatt, 2002). Heat is produced when the body absorbs enough its energy. (9) Contemporary

technology necessitates the utilization of a consolidated communications antenna, such as cellular devices, the Internet, radio, and television. The resultant waves had adverse impacts and threatened people's well-being. The radiation disproportionately affects vulnerable groups such as children, the elderly, and pregnant people. The cell phone is a prominent emitter of electromagnetic waves, which have experienced a notable rise in frequency in recent years (Anguera et al., 2013).

There is a chance that energy will be transferred whenever EMFs fields touch with living tissue, possibly causing the temperature to rise. Due to their absorption by the skin and other superficial tissues, mobile phone nonthermal radiations often only minimally raise the body temperature of the brain or other essential organs (Megha, Suryakantrao, Dev, & Kumar, 2012). Nonthermal mechanisms have a stronger connection to other tissue changes brought on by the quantity of absorbed energy than they do to the actual temperature change (Kivrak, Yurt, Kaplan, & Altun, 2017).

According to the World Health Organization, EMFs primarily contribute to pollutants that harm human health (Khurana, Teo, Kundi, Hardell, & Carlberg, 2009). The susceptibility of fetuses and pregnant women to EMFs arises from their interaction with the cells of the developing embryo. Placental barriers can potentially be negatively affected by short-wavelength electromagnetic waves. Cell phones possess a protective layer that inhibits the passage of substances through blood vessels. Consequently, pregnant women should refrain from using them unless essential (Ghazanfarpour et al., 2021).

3.2 Electromagnetic Wave Effect on Pregnancy

Pregnancy is commonly categorized into three trimesters. The initial trimester spans from the first week to the twelfth week and encompasses the process of fertilization. Conception occurs when the sperm successfully fertilizes the egg. Subsequently, the fertilized egg migrates via the fallopian tube and adheres to the uterine wall, initiating the development of the embryo and placenta. The initial trimester presents the most elevated likelihood of experiencing a miscarriage, which refers to the spontaneous demise of the embryo or baby. The second trimester spans from week 13 to week 28. Sensations of fetal movement can typically be perceived during the latter part of the second trimester. By the time they reach 28 weeks, almost 90% of infants can survive outside

of the womb with the aid of excellent medical treatment. The third trimester spans from 29 weeks to around 40 weeks and concludes with parturition, which is the process of giving birth (Stephanie, Michael, & Karolina, 2019).

Recent research indicates a correlation between maternal cell phone usage during pregnancy and an increased risk of miscarriage, congenital abnormalities, and behavioral issues in offspring. Spontaneous miscarriage is the prevailing complication in the initial stages of pregnancy. Spontaneous abortion, often known as miscarriage, refers to losing a pregnancy before the 20th week of gestation (Regan & Rai, 2000). Exposure to electromagnetic waves was strongly correlated with a higher incidence of abortion in women ($p < 0.01$). The likelihood test substantiated the impact of EMFs on augmenting the probability of abortion (Abad, Malekafzali, Simbar, Mosaavi, & Khoei, 2016). Another study stated that EMFs exposure with frequencies higher than 50 Hz or magnetic field strengths more than 16 mG is linked to a 1.27 times higher risk of experiencing an abortion (Ghazanfarpour et al., 2021). A study found that pregnant women who utilized their mobile phones throughout pregnancy had a higher likelihood of delivering infants with low birth weight compared to those who did not use mobile phones, also (Özge Kömürcü Karuserci, Nilgün Çöl, 2019) miscarriages as well as changes in fetal temperature, HRV (heart rate variability), and assessments of baby body size, (El Jarrah, I Rababa, 2022) (Li, Chen, Ferber, Odouli, & Quesenberry, 2017; Ebadi, Pournorouz, Samaneh, & Mir, 2020; Karimi, Moghaddam, & Valipour, 2020; Seyed Mohammad Javad Mortazavi, Mortazavi, & Paknahad, 2016) prematurity or delivery before reaching 36 weeks of gestation, compared to women with low exposure (Tsarna et al., 2019).

The study in San Francisco with 1063 pregnant women around the San Francisco area showed that rates of pregnancy loss grew significantly with increasing levels of maximum magnetic field exposure in routine day-to-day life (Aghaei, Thayoob, Mahdaviasl, & Darzi, 2014). Anomalies in fetuses and children, such as developmental disorders and malignancies was studied by Kashani et al with a comprehensive examination (Kashani et al., 2023).

Contrary prior studies indicate that inadvertent exposure to 3.5 GHz radiofrequency electromagnetic fields, such as those emitted by 5G signals, had no significant impact on the whole body-averaged specific absorption rate (WBASAR) in neonates (Liu et al., 2017). There is no observed link between

maternal exposure to extremely low frequency electromagnetic fields (ELF-EMF) and miscarriage, stillbirth, newborn birth abnormalities, and preterm delivery. However, the impact on short gestational age and low birth weight remains questionable (Zhou & , Chunlan Ma, YuJun Li, 2022). There is little data to support the claim that being close to electrical power grids, which emit extremely low frequency electromagnetic fields, increases the likelihood of birth abnormalities. Women living in close proximity to electrical networks can be certain that the likelihood of birth abnormalities being influenced is low (Auger et al., 2019).

3.3 Electromagnetic Wave Effect on Placenta

Pregnant women and babies are equally susceptible to harm because EMFs affects the cells involved in the development of the embryo. Exposure to microwave radiation has the potential to harm the protective barrier of the placenta. The membrane acts as a barrier, impeding the movement of chemicals between the blood (Seyed Mohammad Javad Mortazavi et al., 2016). Its interaction with

cells of the embryo's development and can damage the placenta barrier. The membrane prevents the transfer of substances between blood (Abad et al., 2016).

Takei et al stated that when a woman is pregnant, the placenta absorbs EMFs radiation emitted by smartphones, resulting in an elevation of fetal temperatures. The placenta acts as a link between the fetal membranes and maternal tissues, facilitating the exchange of nutrients and oxygen. Consequently, an increase in the temperature of the placenta can potentially affect the fetus by causing alterations in its metabolic processes and the flow of blood to the placenta (Takei et al., 2018).

3.4 Electromagnetic Wave Effect on Fetus

Prior studies revealed that higher prenatal exposure to EMFs might result in a decrease in the birth weight, head size, head, upper arm, and abdomen, as well as skinfold thickness of the back, triceps, and abdomen, in females but not in males (Ren et al., 2019) and lower birth weight and a high rate of infant emergency transport (Lu et al., 2017).

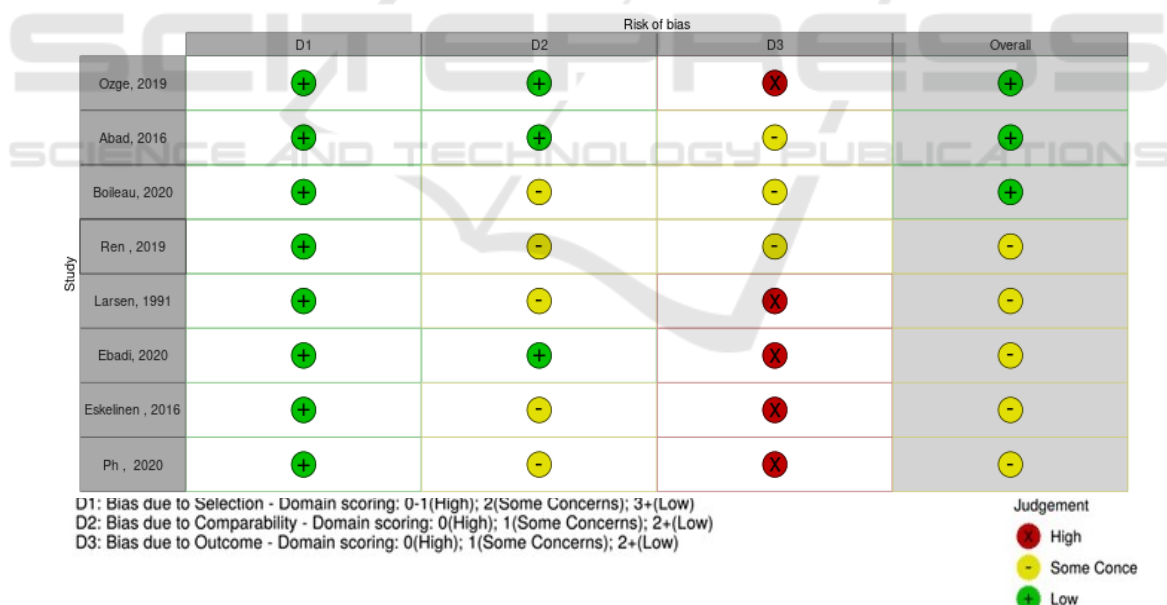


Figure 2. Risk of bias assessment using Newcastle–Ottawa score. Risk of bias assessment for each study according to NOS.(Aromataris E, Fernandez R, Godfrey C, Holly C, Kahlil H, 2015) Plots created using risk-of-bias visualization (robvis) tool (Mcguinness, 2021)

The Newcastle–Ottawa scale (NOS) was employed for the evaluation of the studies' quality. This scale is utilised to assess the calibre of cohort studies. This tool has been demonstrated to possess both validity and reliability through multiple researchs. Each study can obtain a maximum of ten stars based on the NOS. The evaluation of the selection can be assigned a rating of up to five stars, taking into account parameters such as the size of the sample, the number of non-respondents, and the accuracy of determining the exposure. The comparability can be rated up to two stars, reflecting the degree to which the study accounts for the most important factor. The maximum rating for the outcome, which includes the evaluation and statistical analysis, is three stars. research rated with nine or 10 stars are categorised as high-quality, whilst research rated with seven or eight stars are categorised as medium-quality. Studies with a rating below six stars are categorised as low-quality (Bae, n.d.).

4 DISCUSSION

The findings indicated that the average specific absorption rate (SAR) in the maternal body rose as pregnancy advanced. The Specific Absorption Rates (SARs) in the fetus varied based on the spatial arrangement of the smartphone and the fetus, peaking at 18 weeks of gestation in this study. Furthermore, we have verified that the rise in temperature experienced by both the mother and the fetus during pregnancy is more pronounced at 18 weeks of gestation compared to 26 weeks of gestation. This is due to the placenta's effective cooling influence on both the maternal body and the developing baby. The significance of the positional link between the smartphone, placenta, and fetus is substantial. We have also verified that the Specific Absorption Rates (SARs) for smartphone radiation were significantly lower compared to the SARs for radiation from simplified sources (Takei et al., 2018).

Pregnant women may experience distinct impacts from exposure to electromagnetic radiation compared to women who are not pregnant. Research has demonstrated a correlation between exposure to electromagnetic fields (EMFs) and a heightened likelihood of experiencing abortion or miscarriage (Ebadi et al., 2020; Abad et al., 2016; Ghazanfarpour et al., 2021; Robert, 1999). The risk of miscarriage is determined by variables such as the strength of the electromagnetic fields, proximity to the radiation source, and the frequency intensity of the waves (Li et al., 2002). Potential risk factors for miscarriage

include exposure to extremely low frequency electromagnetic fields (EMFs) and mobile phones. Furthermore, prolonged exposure to electromagnetic fields during pregnancy, namely at frequencies exceeding 50 Hz or magnetic field strengths surpassing 16 mG, has been linked to a heightened likelihood of miscarriage. These findings indicate that pregnant women may have a higher vulnerability to the impacts of electromagnetic wave exposure, emphasizing the significance of providing customized guidance and preventive measures for pregnant women. The study findings indicated that fetuses and children whose parents were exposed to electromagnetic fields (EMFs) had decreased average antioxidant levels in umbilical cord blood and increased average oxidant levels in the umbilical cord. Human placental villi, when subjected to radiofrequency electromagnetic fields (RF-EMF) during the initial phases of pregnancy, exhibited reduced levels of the antioxidant enzyme TXNL-2. A reduced quantity of placental antioxidants serves as a crucial protective mechanism against the physiological impacts of RF-EMFs during pregnancy (Kashani et al., 2023). The exposure of fibrous tissues to electromagnetic waves results in a reduction of antioxidant factors and an increase in oxidative stress parameters. This, in turn, causes damage to proteins and nucleic acids in the placenta. Such damage can have serious consequences, including the impairment of normal trophoblastic functions and potentially even cell death (Cervellati et al., 2009). Electromagnetic wave exposure was correlated with a higher degree of apoptosis (Ghazanfarpour et al., 2021). The researchers also noted a reduction in oxygen consumption and an increase in apoptosis in the placental cells that were exposed to these specific wave ranges. Lopucki et al. discovered that exposure to electromagnetic fields (EMF) led to an elevated release of calcium ions in placental tissue. This finding implies that EMF may impact the activity of calcium channels, as shown in other types of tissue (Wdowiak, Mazurek, Wdowiak, & Bojar, 2017).

5 CONCLUSION

Based on the analysis of journals carried out, 31 journals were collected with criteria following this systematic review. In summary, the existing data is inadequate to establish definitive correlations between exposure to electromagnetic radiation and pregnancy outcomes. In order to obtain more robust results, further investigation including larger cohorts

and a wider range of geographic locations is necessary.

CONFLICT OF INTEREST

The authors make no disclosures of any conflicts of interest that might be seen as tainting the objectivity of the study presented.

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APPENDIX

Table 1. Cohort Study of non-ionizing electromagnetic wave in pregnancy

No	References	research design	duration of exposure	frequency	main outcome	measured outcome
1	Mobile phone use during pregnancy: Which association with fetal growth? (Boileau et al., 2020)	observational cohort study	- 1368 mothers - Mean phone time during pregnancy: 29.8 minutes per day - Range of phone time during pregnancy: 0.0-240.0 minutes per day	- The study found a higher frequency of growth restriction at birth with greater mobile phone use during pregnancy . - Phone time was recorded in minutes per day.	- The main outcome was the association between mobile phone use during pregnancy and fetal growth. - The study focused on the impact of phone time on growth restriction at birth, defined by an AUDIPOG score 10th percentile.	- Growth restriction at birth (AUDIPOG score 10th percentile) - APGAR score at birth, fetal malformations, birth weight, head circumference (secondary objectives)
2	May electromagnetic field exposure during pregnancy have a negative effect on anthropometric measurements of the newborn ? (Özge Kömürcü Karuserci, Nilgün Çöl, 2019)	observational cohort study	- 400 pregnant woman - TV exposure: 1-3 hours, 4-6 hours, 7-12 hours, more than 12 hours - Mobile phone exposure: 30 minutes, 30-60 minutes, 60 minutes - Computer exposure: 1 hour, 1-3 hours, 3 hours - Wi-fi exposure: 1 hour, 1-3 hours, 3 hours	TV, mobile phone usage and living near a base station	- Negative effect on anthropometric measurements of the newborn - Adverse effects on fetal development	- Negative correlation between maternal mobile phone usage and newborn's birth weight - Negative correlation between multiple mobile phone usage and birth week, birth weight, and birth length of the newborn
3	Prenatal exposure to extremely low frequency magnetic field and its impact on fetal growth_ (Ren et al., 2019)	observational cohort study	- 128 pregnant woman - Observat ion in 24 hours	- The study measured extremely low frequency magnetic fields. - The frequency band ranged from 40 to 1000 Hz.	- Prenatal exposure to higher ELF-MF associated with decreased fetal growth in girls - No significant association between prenatal ELF-MF exposure and fetal growth in boys	- Fetal growth measured by birth weight and body measurements - Skinfold thickness and circumference measurements of various body parts
4	Maternal exposure to extremely low frequency magnetic fields: Association with time to pregnancy and foetal growth'	observational cohort study	373 pregnant women	- The study focuses on extremely low frequency magnetic fields. - The association between	- The main outcome is the association between maternal exposure to extremely low frequency magnetic fields and time-to-pregnancy and foetal growth.	- The measured outcome was time-to-pregnancy and foetal growth. - a mean difference in grams of -45 with a 95%

	(Eskelinen et al., 2016)			frequency and pregnancy outcomes is examined.	- The study found a mean difference in grams of -45 with a 95% confidence interval of -547 grams to 456 grams for all spot measurements and -142 grams (95% CI -505, 221) for bedroom spot measurements.	confidence interval of -547 grams to 456 grams for all spot measurements and -142 grams (95% CI -505, 221) for bedroom spot measurements.
5	The study of the effects of ionizing and non-ionizing radiations on birth weight of newborns to exposed mothers (S. M. J. Mortazavi, Shirazi, & Mortazavi, 2013)	observational cohort study	1200 pregnancy woman	cell phones, cordless telephone, cathode-ray tube and so on)	Did not find any clear relationship between pregnancy and non-ionizing radiation during pregnant	There were no statistical significant differences between the mean weight of newborns whose mothers had been exposed to some common sources of ionizing and non-ionizing radiations such as dental or non-dental radiographies, mobile phone, cordless phone and cathode ray tube (CRT) and those of non-exposed mothers
6	'Association between electromagnetic field exposure and abortion in pregnant women living in Tehran', (Abad et al., 2016)	observational cohort study	During The study included 462 pregnant women from 7 regions of Tehran city in Iran pregnancy	27 MHz-3GHz	Not provide strong evident that EMF causes miscarriage	This study may not provide strong or consistent evidence that electromagnetic field exposure is associated or cause miscarriage. This issue may be due to small sample size in this study
7	Congenital malformations and exposure to high-frequency electromagnetic radiation among Danish physiotherapists (Larsen, 1991)	observational cohort study	25 pregnancies of a staff of physiotherapists	300 kHz and 300MHz	No statistically significant associations between pregnancy outcome and high-frequency electromagnetic radiation were found	
8	Association of personal exposure to power-	observational cohort study	119 Pregnant women	1.10 mG (2.14 mG) and	Personal MF exposures were not	

frequency magnetic fields women seeking fertility treatment in with pregnancy outcomes among a longitudinal cohort study (E. Mary, Lidia MA, Lewis CR, 2020)				15.54 mG (58.73 mG)	associated with pregnancy outcomes	
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Table 2. Systematic Review and Meta Analysis Study of non-ionizing electromagnetic wave in pregnancy

No	References	research design	duration of exposure	frequency	main outcome	measured outcome
1	Exposures to radio-frequency electromagnetic fields and their impacts on children's health – What the science knows? (Lim, Choi, Joo, & Ha, 2023)	Systematic Review	During Pregnancy	100 kHz - 300 GHz	- Risk of inattention or behavioral problems increased with duration of mobile phone use in older children and adolescents. - Shortened pregnancy duration associated with increased maternal mobile phone use.	- Fetal growth or birth weight - Gestational age at birth, preterm delivery, spontaneous abortion, and craniosynostosis
2	Analytical Study on the Effects of Electromagnetic Waves on Human Beings (Kumar, Shah, Kalra, & Pant, 2019)	Systematic Review	During Pregnancy	- Radiofrequency (RF) frequencies: 100 kHz-300 GHz - Intermediate frequency (IF) frequencies: 300 Hz-100 kHz	- Effects of electromagnetic waves on human beings - Health effects due to radiation exposure especially pregnancy	pregnant woman should not kept their mobile phones near (N/A)
3	Impacts of smartphone radiation on pregnancy : A systematic review (El Jarrah, I Rababa, 2022)	Systematic Review	During Pregnancy	100 kHz to 300 GHz	EMF radiation exposure during pregnancy is associated with miscarriages and fluctuations in the fetal temperature and heart rate variability among adults.	Miscarriages Fluctuations In Fetal Temperature Heart Rate Variability Infant Anthropometric Measures
4	Effect of Magnetic Fields during Pregnancy on Fetal Growth and Preterm	Systematic Review	During Pregnancy	300 MHz to 300 GHz	Duration Of Pregnancy Preterm Birth Birth Weight Small for	The duration of pregnancy was shorter for mothers using cell phones for more than one

	Labor: A Review Article (Khojastehfard et al., 2020)				Gestational Age Birth Length	hour per day than those use shorter than one hour.
5	'Effect of electromagnetic waves on human reproduction', 24(1), pp. 13–18. doi: 10.5604/12321966.1228394 (Wdowiak et al., 2017).	Systematic Review	During Pregnancy	0.3–300 GHz	APGAR scale	APGAR scale, was worse in women exposed to a greater Degree to the waves of the GSM band
6	Wireless technologies, non-ionizing electromagnetic fields and children: Identifying and reducing health risks_ (Davis et al., 2023)	Systematic Review	During Pregnancy	2.45 GHz	psychomotor and mental development index	poorer psychomotor development index and a lower mental development index up
7	Wi-Fi is an important threat to human health_ (Pall, 2018)	Systematic Review	During Pregnancy	Wi-Fi antenna connected to the internet and a series of computers, laptops and/or other wireless devices communicating wirelessly with the Wi-Fi antenna	abortion	Spontaneous abortion is often caused by chromosomal mutations, so the germ line mutations may have a causal role.
8	Thermal and non-thermal health effects of low intensity non-ionizing radiation: An international perspective (Belpomme, Hardell, Belyaev, Burgio, & Carpenter, 2018)	Systematic Review	During Pregnancy	- EMFs vary in frequency and wavelength. - RF-EMFs range from 30 kHz to 300 GHz. - ELF-EMFs range from 3 Hz to 3 kHz.	- Increased risk of brain cancer from excessive mobile phone exposure - Adverse effects on male and female reproduction - Neurobehavioral decrements and development of electro-hypersensitivity syndrome - Standards set by national and international bodies are not	- Prenatal exposure to cell phones associated with emotional and hyperactivity problems in children. - Maternal mobile phone use during pregnancy increases risk of hyperactivity and inattention

					protective - Concerns about children's susceptibility and potential long-term health effects - In utero exposure affects fetal programming and neurodevelopment - Impaired learning and memory from exposure to non-thermal intensities - Induction of oxidative stress and inflammation in the brain - Majority of laboratory studies show detrimental effects of EMFs	problems in children. - Prenatal or postnatal mobile phone exposure may have greater neurobehavioral effects in children with elevated lead levels. - EMFs may have synergistic actions with other environmental contaminants known to affect cognitive function.
9	Effect of extremely low-frequency electromagnetic radiation on pregnancy outcome: A meta-analysis (Zhou, Ma, Li, Zhang, & Liu, 2023)	A meta-analysis	During Pregnancy	1 to 300 Hz	miscarriage, stillbirth, neonatal birth defects and preterm delivery	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.
10	Relationship between the Exposure to Magnetic Fields during Pregnancy and Risk of Abortion: A Review Article (Ebadi et al., 2020)	Systematic Review	During Pregnancy	Analog phones, digital phones, and third-generation phones produce emit nearly 450-900 MHz, 850-1900	A significant likelihood of miscarriage in women who exposed to a significant level of the electromagnetic wave was observed	The effect of exposure on the risk of abortion depends on the distance from the source of radiation and the intensity of the frequency of the waves

				MHz, and 2000MHz of frequency		
11	'Biological effects of non-ionizing electromagnetic fields : Two sides of a coin', (Saliev, Begimbetova, Masoud, & Matkarimov, 2019)	Systematic Review	During Pregnancy	mobile phones, the frequency range is 900-1800 MHz for 3G standard, for 4G frequency is 2-8 GHz, and up to 60 Hz carrier frequency for 5G	Fetal teratogenic	no firm evidence provided about mutagenic and teratogenic potential of EMF for humans yet
12	Effect of electromagnetic field exposure on the reproductive system (Gye & Park, 2012)	Systematic Review	During Pregnancy	a computer monitor (3 to 30 Hz)	abortion	There was a positive relationship between occupational monitor labor during pregnancy and the natural abortion rate
13	'A Review on the Impact of the Electromagnetic Radiation (EMR) on the Human's Health', (Aghaei et al., 2014)	Systematic Review	During Pregnancy	Communication wave, microwave, electrical wave (0.5 -3 GHz)	abortion	Pregnancy loss grew significantly with increasing level of maximum magnetic field exposure in routine day to day life
14	'Insights in the biology of extremely low - frequency magnetic fields exposure on human health' (Karimi et al., 2020)	Systematic Review	During Pregnancy	1 to 300 Hz	miscarriage	exposure to ELF-EMF and miscarriage depends on the current intensity, strength of the magnetic field, and duration of exposure.
15	'The effects of radiofrequency exposure on male fertility and adverse reproductive outcomes: A protocol for two systematic reviews of human observational studies with	systematic reviews of human observational studies with meta-analysis	During Pregnancy	100 kHz–300 GHz	preterm birth, small for gestational age (associated with intrauterine growth restriction), miscarriage, stillbirth and congenital anomalies	spontaneous miscarriage which occurs in 25% of pregnancies, pre-term birth occurring in 10% of pregnancies; stillbirth occurring in 2% of births; congenital

	meta-analysis', (Kenny et al., 2022)					anomalies occurring in up to 5% of newborns and low birth weight occurring in 14.6% of births
16	Electromagnetic fields exposure on fetal and childhood abnormalities: Systematic review and meta-analysis (Kashani et al., 2023)	Systematic review and meta-analysis	During Pregnancy	more than 50 Hz or 0.82mG	still- birth, congenital anomalies, and abortions	Daily exposure to radio waves has increased concerns about infertility, still-birth, congenital anomalies, and abortions
17	Human Adverse Reproductive Outcomes and Electromagnetic Field Exposures: Review of Epidemiologic Studies (Shaw & Croen, 1993)	Systematic Review	During Pregnancy	50-60 Hz	spontaneous abortion	lacking for a strong association between a woman's use of a video display terminal (VDT) during pregnancy and spontaneous abortion.
18	Effect of electromagnetic field on abortion: A systematic review and meta-analysis (Ghazanfarpour et al., 2021)	A systematic review and meta-analysis	During Pregnancy	above 50 Hz	abortion	Exposure to EMFs above 50 Hz or 16 mG is associated with 1.27× increased risk of abortion.
19	Measurement studies of personal exposure to radiofrequency electromagnetic fields: A systematic review (Ramirez-Vazquez et al., 2023)	Systematic Review	During Pregnancy	100 kHz–300 GHz	N/A	base-station exposure was the largest contributor to personal measurements of RF-EMF in both parents and children in South Korea.
20	The Effect of Extremely Low-Frequency Electromagnetic Radiation on Pregnancy Outcome: A	A Meta-Analysis	During Pregnancy	1 Hz to 300 Hz	miscarriage, stillbirth, neonatal birth defects and preterm delivery	No correlation has been found between maternal ELF-EMF exposure and miscarriage, stillbirth,

	Meta-Analysis (Zhou & , Chunlan Ma , YuJun Li, 2022)					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
21	Associations of Maternal Cell-Phone Use During Pregnancy With Pregnancy Duration and Fetal Growth in 4 Birth Cohorts (Tsarna et al., 2019)	A Meta-Analysis	During Pregnancy	1 Hz to 300 Hz	shorter pregnancy duration and preterm birth	Maternal cell-phone use during pregnancy may be associated with shorter pregnancy duration and increased risk of preterm birth, but these results should be interpreted with caution, since they may reflect stress during pregnancy or other residual confounding rather than a direct effect of cell-phone exposure in 55,507 pregnant women
22	Problems in evaluating the health impacts of radio frequency radiation (Ben Ishai, Davis, Taylor, & Birnbaum, 2023)	Systematic Review	During Pregnancy	800–1600 MHz could	miscarriage, fetal temperature, variations in fetal heart rate variability, changes in infant anthropometric measurements	EMF exposure effects on human pregnancy did find significant impacts “heightened risks of miscarriage, changes to fetal temperature, variations in fetal heart rate variability, and

						changes in infant anthropometric measurements. However, the same study cautioned that there was wide variability in assessing exposure in cohort studies, in the type and duration of exposures involved.
23	Use of mobile phone during pregnancy and the risk of spontaneous abortion (Mahmoudabadi, Ziaei, Firoozabadi, & Kazemnejad, 2015)	Systematic Review	During Pregnancy	1 Hz to 300 Hz	spontaneous abortions	mobile phones can be related to the early spontaneous abortions

