Mini Review

The Controversial Link: Exploring the Impact of Prenatal Radiation Exposure on Low Birth Weight

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ABSTRACT

Prenatal exposure to both ionizing radiation (IR) and non-ionizing radiation (NIR) has raised concerns regarding potential adverse birth outcomes, particularly low birth weight (LBW). The rapid expansion of wireless technologies and the continuous use of diagnostic imaging during pregnancy necessitate a critical evaluation of existing evidence. A literature search was conducted in PubMed, Scopus, and Google Scholar for studies published between 2008–2024. Evidence regarding IR exposure was inconsistent; several cohort studies after nuclear incidents reported increased LBW, whereas others showed no association. Findings for NIR were also heterogeneous, with some cohorts suggesting associations with high maternal mobile phone or extremely low frequency electro magnetic field (ELF-EMF) exposure, while large prospective studies failed to confirm such links. Current evidence does not allow a definitive conclusion on causal relationships between prenatal radiation exposure and LBW. Variability in exposure assessment, inadequate control of confounders, and lack of dose–response data remain major limitations. Well-designed longitudinal studies with objective dosimetry are urgently required.

Keywords

Low Birth Weight; Prenatal Exposure; Ionizing Radiation; Non-ionizing Radiation; Electromagnetic Fields; Pregnancy; Birth Outcomes; Maternal Exposure; Fetal Development

Introduction

Studying the effects of prenatal exposure to ionizing and non-ionizing radiation on developing fetuses is of great importance as it addresses emerging public health concerns in a technology-driven world [1]. With the proliferation of devices that emit non-ionizing radiation, such as smartphones, Wi-Fi routers, and other wireless devices, understanding the potential risks to the developing fetus becomes essential to ensure safe usage guidelines [2]. Ionizing radiation, used extensively in medical imaging and various industrial applications, also poses potential risks during critical periods of fetal development [3]. Investigating these effects allows for the development of evidence-based guidelines to protect pregnant women and their developing fetuses, ensuring that medical advancements and

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technological conveniences do not compromise maternal and fetal health. Low birth weight (LBW), defined as birth weight <2500 g, remains a leading predictor of neonatal morbidity, mortality, and long-term metabolic disorders. Alongside established determinants such as maternal nutrition, socioeconomic status, smoking, and air pollution, environmental radiation has been proposed as a potential risk factor [1]. It not only affects infants' immediate health but also sets the stage for long-term medical and developmental challenges. As environmental factors significantly impact fetal development, this paper examines the roles of ionizing and non-ionizing radiation exposure during pregnancy. This mini review aims to synthesize current evidence and critically appraise methodological strengths and limitations of studies evaluating prenatal ionizing radiation (IR) and non-ionizing radiation (NIR) exposure in relation to LBW.

Material and Methods

A literature search was conducted in PubMed, Scopus, and Google Scholar for studies published between 2008–2024. Data extraction focused on study design, exposure assessment, confounder control, and reported effect sizes. We targeted studies exploring the relationship between "Non-ionizing Radiation," "Ionizing Radiation," and birth outcomes such as "low birth weight". The screening process was meticulous starting with titles and abstracts, removing duplicates, and then critically analyzing the full texts. Additionally, we reviewed citations within selected articles to ensure comprehensive coverage of relevant studies.

Results

From an initial pool of 308 articles, 35 met our stringent criteria for inclusion. The included studies presented a diverse range of findings concerning the impact of radiation on birth weight. Specifically, roughly half of the ionizing radiation studies did not observe a significant correlation with LBW [4-10]. The results were similarly mixed for non-ionizing radiation, with many studies reporting negligible effects [4, 11-15]. Tables 1 and 2 provide a clear and structured overview of the findings related to both ionizing and non-ionizing radiation exposure, allowing for easier comparison and understanding of the reviewed literature

Discussion

Ionizing Radiation

The association between ionizing radiation and LBW is complex. Many studies have reported no statistically significant associations [5, 6, 8-10, 21], though other studies have found an increased risk in certain circumstances, like exposure to a nuclear disaster or a course of therapy [3, 7, 31-33]. Table 1 sums up the data that most epidemiological studies of prenatal exposure to ionizing radiations do not show statistically significant association with LBW in particular among large-cohort studies that were done post-nuclear accident [5, 6, 8-10, 21]. These findings suggest that fetal development is not likely to be adversely affected by the low-to-moderate levels of ambient IR, as are commonly experienced by the general population. Several cohort studies conducted after the Fukushima and Chernobyl events, reported null associations with the use of individual-level data and the use of standardized measures of outcome [5, 8-10].

On the other hand, there are limited number of studies that have reported increased LBW risks under certain exposure conditions. Most of the positive associations were reported in ecological designs or in cohorts exposed to higher levels of radiation, e.g., areas with greater Cs -137 deposition [20] or in populations exposed to therapeutic irradiation [18, 19]. Particularly, Hayashi et al. [7] noticed the increase more pronounced adverse birth outcomes right after the Fukushima incident, indicating the potential role of acute exposure timing, psychosocial strain, and healthcare system disruptions. Similarly, Scherb et al. [20] used an ecological study with a large population and found a spatiotemporal relationship between radioactive fallout and high LBW; however, this type of study is inherently limited by exposure misclassification and confounding residual. The biological plausibility, supported by clinical and experimental evidence, appears to be dose-dependent; large amounts of ionizing radiation (>100 mGy) can disrupt placental vascularization and induce genomic instability, thus restraining fetal development. More importantly, diagnostic imaging that is performed in pregnancy usually provides exposure that is way below these levels and this is probably the reason behind the mostly null findings in studies that focus on medical diagnostic exposure [10]. Collectively, the seemingly heterogeneous nature of studies is to large extent due to the differences in dose of exposure, study design, and

Table 1: Selected Studies on Ionizing Radiation Exposure and Low Birth Weight

Author, Year	Participants	Significant association with LBW?	Key Findings
SMJ. Mortazavi et al. 2013 [4]	1200	No	No significant difference in newborn weights
T. Mangones et al. 2013 [16]	328124	No	Ecological analysis of regional birth data showed no radiation-related prevalence of defects, LBW, and prematurity
K. Fujimori et al. 2014 [5]	15972	No	No significant adverse outcomes across Fukushima
M. Hayashi et al. 2016 [7]	12300	Yes	Higher adverse outcomes post-Fukushima accident
S. Yasuda et al. 2017 [8]	16001	No	No increased SGA incidence post-Fukushima disaster
X. Gong et al. 2017 [17]	94,106 LBW cases and 3,386,971 Controls	No	Maternal residential proximity to nuclear facilities was not a significant factor for LBW
RC. Reulen et al. 2017 [18]	2783	Yes	Increased risks of preterm delivery and LBW
C. Leppold et al. 2017 [9]	1101	No	No changes in birth outcomes post-Fukushima disaster
M. Hatch et al. 2017 [10]	2582	No	No significant effect of fetal dose on birth weight
LEXM. Van De Loo et al. 2019 [19]	275	Yes	Increased probability of delivering a LBW infant compared to those without radiotherapy
H. Scherb et al. 2020 [20]	26,158 million	Yes	Increased LBW prevalence related to Cs-137 deposition
S. Yasuda et al. 2022 [21]	6875	No	No correlation with congenital anomalies, LBW or preterm

LBW: Low Birth Weight, SGA: Small For Gestation Age

Table 2: Selected Studies on Non-Ionizing Radiation Exposure and Low Birth Weight

Author, Year	Participants	Significant association with LBW?	Key Findings
SMJ. Mortazavi et al. 2013 [4]	1200	No	No significant difference in newborn weights
N. Col-Araz 2013 [11]	500	No	No significant correlation with maternal tech use
M. Mahram et al. 2013 [12]	222	No	No significant differences in neonatal outcomes
F. De Vocht et al. 2014 [22]	295629	Yes	Found association between maternal residential proximity to sources of ELF-EMF and suboptimal fetal growth.
F. De Vocht et al. 2014 [23]	140356	Yes	Found an association between living in close proximity (within 50 m) to residential ELF-EMF sources and suboptimal growth of the fetus, especially in female newborns.
V. Baste et al. 2015 [13]	100730	No	No association with maternal cell phone use
T. Eskelinen et al. 2016 [14]	373	No	No association with ELF fields and pregnancy outcomes
L. Migault et al. 2016 [15]	18000	No	No association between exposure groups and birth weight
X. Lu et al. 2017 [24]	461 pairs	Yes	Excessive phone use linked to lower birth weight
E. Tsarna et al. 2019 [25]	55507	No	No association between maternal cell-phone use and fetal growth or birth weight.
ÖK. Karuserci et al. 2019 [26]	527	Yes	Negative correlation with mobile phone use
Y. Ren et al. 2019 [27]	128	Yes	Prenatal exposure to higher ELF-MF was associated with reduction of birth weight, circumference of head, upper arm, and abdomen and skinfold thickness of back, triceps and abdomen in girls, but not in boys.
LM. Pesando et al. 2023 [28]	170916	No	Mobile phone ownership linked to better birth weight
M. Büyükeren et al. 2024 [29]	1495	Yes	A significant correlation between higher SAR values of cell phones and the delivery of SGA babies
S. Yamaguchi-Sekino et al. 2024 [30]	443 births	No	No significance in non-ionizing radiation exposure only before pregnancy

LBW: Low Birth Weight, ELF-EMF: Extremely Low Frequency Electro Magnetic Field, SAR: Specific Absorption Rate, SGA: Small-For-Gestational Age exposure measurement and not the differences in underlying biological processes.

Non-ionizing Radiation

Table 2 shows the results of prenatal exposure to non-ionizing radiation (NIR). Many cohort and cross-sectional studies have found that there was no significant correlation between maternal exposure to typical NIR sources, including mobile phone use or residential extremely low frequency electro magnetic field (ELF-EMF) exposure, and LBW [4, 11-15, 28, 30]. Potentially large prospective cohorts, where self-reported exposure data were used, such as more than 100 000, have repeatedly rejected the presence of adverse effects on birth weight [13, 25, 28], indicating that normal daily exposures might not be a significant risk. However, a number of studies found associations in certain conditions of exposure.

De Vocht et al. [22, 23] found poor fetal development in mothers who lived near ELF-EMF sources, especially those living at within 50 meters, and that fetal development was affected specifically in the female newborn. Equally, Lu et al. [24] and Buyukeren et al. [29] have found lower birth weight or greater risk of small for gestational age (SGA) in mothers with high levels of mobile phone use or greater exposure to SAR. What these results provide is that intensity, duration, and proximity of exposure can be the modifiers of risk, and not the presence of exposure. Notably, research studies that found positive associations tended to have smaller sample sizes, an indirect measure of exposure, or inadequate control of confounding factors like socioeconomic status, maternal health behaviors, and simultaneous environmental exposures. The fact that mobile phone ownership was connected with increased birth weight as noted by Pesando et al. [28] further demonstrates the possibility of residual confounding because device ownership can be a proxy in terms of better access to healthcare or better socioeconomic status and not necessarily biological exposure effects.

Integration and wider implications

A growing body of literature suggests a possible link between occupational NIR exposure to poor reproductive outcomes, such as LBW especially when it comes to the use of diathermy devices [34]. There are also finders of association of prenatal NIR exposure with neurodevelopmental outcomes including attention-deficit/hyperactivity disorder (ADHD) and subsequent behavioral disorders [35].

Although the implications of such findings are of critical public health concern, there is no uniform replication, exposure assessment that is standardized and well-defined biological pathways that make causal interpretation limited. On the whole, the evidence summarized in this review can be best explained by the fact that inconsistencies among studies can be best explained by methodological heterogeneity - in terms of exposure assessment, study design, and adjustment of confounders - and not by underlying biologically incompatible effects. Of particular concern are the differences between low-level daily exposures and high-level or work-related exposures, which is particularly important in the interpretation of observed associations.

Future research directions

Longitudinal studies should be adopted as a priority in the future with objective, quantitative dosimetry to realize cumulative radiation exposure during pregnancy. A better focus on dose-response relationships, exposure critical windows, and placental or molecular biomarkers can be useful in explaining the underlying biological processes. Close interdisciplinary interactions between the epidemiologists, radiologists, obstetricians, and medical physicists will be needed to enhance the exposure characterization and clinical relevance. Moreover, systematic review of available safety recommendations is justified to make sure that the available current recommendations protect pregnant women adequately depending on the changing body of evidence.

Conclusion

Our review paints a picture of a research landscape filled with contradictions regarding how prenatal exposure to ionizing and non-ionizing radiation influences LBW. The evidence is influenced by a myriad of factors, including radiation type, exposure timing, and environmental context. Available studies provide inconsistent and low-to-moderate quality evidence regarding prenatal radiation and LBW. To move forward, the scientific community must embrace more rigorous methodologies and long-term studies that can offer clearer insights. Such efforts are essential not just for academic understanding but also for crafting public health policies that protect maternal and neonatal health effectively.

Authors' Contribution

SMJ. Mortazavi conceived the idea. M. Haghani and SAR. Mortazavi supervised the review process. The draft was prepared by R. Rashidfar, Z. Seyyedi Sarhad, M. Arshadi, F. Zaker and S. Jarideh. All the authors read, revised, and approved the final version of the manuscript.

Conflict of Interest

SMJ. Mortazavi, as the Editorial Board Member, was not involved in the peer-review and decision-making processes for this +manuscript.

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