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The Impact of Electromagnetic Field Exposure on Diabetes: A Narrative Review

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ABSTRACT

Introduction: This literature review investigates the complex relationship between electromagnetic fields (EMFs) and diabetes, highlighting both therapeutic potentials and associated health risks. Emerging evidence suggests that exposure to specific types of EMFs, particularly pulsed EMFs (PEMF), may enhance insulin sensitivity and promote healing in diabetic patients.

Materials and Methods: Studies have indicated significant improvements in microvascular blood flow and pancreatic function, suggesting a potential role for EMF therapy in diabetes management. Conversely, prolonged exposure to high-frequency EMFs, such as those that cell phones emanate and wireless devices, raises concerns regarding their impact on glucose metabolism.

Results: A correlation was observed between chronic EMF exposure and increased insulin resistance, oxidative stress, and disruptions in hormonal balance, which can exacerbate hyperglycemia. Mechanistic insights reveal that elevated levels of reactive oxygen species (ROS) and alterations in cortisol and glucagon levels may contribute to these adverse effects.

Conclusion: Despite the promising therapeutic applications of certain EMFs, the existing literature presents significant variability in methodologies, limiting the generalizability of findings. Future research should focus on large-scale, longitudinal studies that encompass diverse populations to clarify the long-term effects of EMF exposure on diabetes. This review underscores the need for a balanced approach to EMF exposure, recognizing both its potential benefits and risks for individuals with diabetes, thereby informing clinical practices and public health policies.

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Introduction

Since the beginning of the 20th century, an increase in electromagnetic field (EMF) sources has been observed that come from telecommunications, electricity, household appliances, medical equipment, and many other devices used in daily lives. Although these new technologies have become inevitable and necessary, the EMF produced by them may pose risks to human health [1]. Electromagnetic waves (EMWs) are classified into extremely low-frequency EMFs (ELF-EMFs), radiofrequency EMFs (RF-EMFs), and microwave radiation based on wavelength. Electronics and power lines generate ELF-EMF (33,000 Hz). RF–EMF (100 kHz–300 GHz) creates propagating EMFs when supplied to antennas. Mobile phones, Wi-Fi, satellite systems, radio, TV, and other wireless

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devices that are widely used emit RF-EMF [2]. Among the EMFs that are significant due to their potential effects on health are ELF-EMFs and RF. In contrast to RF, at ELF, the electric field and the magnetic field propagate independently. The health effects of combined ELF- and RF-EMF exposure on DNA damage have been investigated. While exposure to ELF alone did not result in significant DNA damage, the combined exposure to ELF and RF was found to induce DNA breaks. Additionally, RF exposure to human lens epithelial cells led to the production of reactive oxygen species (ROS) and the ensuing damage to DNA[3].

EMFs within the non-ionizing spectrum can induce both thermal and non-thermal biological effects (BE) in bodily tissues, posing direct risks to human and animal health. Furthermore, high-frequency EMF can interfere with the operation of electronic and communication devices, including critical medical equipment, potentially affecting various sectors of society. Ionizing EMF, renowned for their extensive application in medical procedures such as radiography, are subject to stringent safety regulations to protect patients and healthcare workers [4, 5]. Most standards define a thermal effect for frequencies above 100 kilohertz, where body heating predominates [6]. Various thermal effects described are caused by EMFs operating at non-ionizing frequencies. This occurs when the electromagnetic energy is absorbed by the material, converting it into heat [7] due to increased molecular motion and friction resulting from the interaction between a substance and EMWs [8]. Non-thermal mechanisms are those that are not directly related to changes in temperature but rather are associated with an increase in the production of free radicals in tissues [9]. Over the past decade, the non-thermal biological effects of EMFs have become the focus of public attention and have led to concerns [10, 11].

Diabetes mellitus is a long-term condition that can lead to various health complications. Diabetes occurs when the body's blood sugar regulation system malfunctions, resulting in elevated glucose levels. Comprehending the causes and risk factors of diabetes is essential for preventing and managing this serious health condition. The two types of diabetes include type 1 and type 2.

Type 1 diabetes (T1D): This is diabetes in which the insulin-producing cells in the pancreas are recognized as invaders and are destroyed by the body's immune system. As a result, the body lacks the hormone (insulin) needed to control blood sugar. It is the most common type in childhood or adolescence, but can occur at any age [12].

Type 2 diabetes (T2D): The prevalence of T2D among obese individuals stands at approximately 29.1%, indicating significant metabolic consequences associated with obesity [13].

Researchers have proposed that a newly identified condition be classified as type 3 diabetes mellitus (T3DM). This condition has been characterized as a metabolic syndrome that may contribute to the development of abnormalities associated with progressive brain insulin resistance. This resistance can interfere with central insulin signaling, promoting neurotoxins accumulation, neuronal stress, and neurodegenerative processes. This emerging understanding underscores the potential link between metabolic dysfunction and neurological decline, warranting further investigation into its mechanisms and implications for public health [14].

Diabetes complications have severe consequences, including high rates of illness and death, which significantly burden healthcare systems. Owing to a diminished metabolic rate, diabetes mellitus impairs both the efficacy and speed of the organism's intrinsic wound healing mechanism [15-17]. Diabetes is a prevalent chronic condition that is rapidly escalating globally. Projections indicate a staggering increase of 592 million individuals with diabetes worldwide by 2035 [18]. The fact that mobile phone use has dramatically increased in the past decade, as well as the prevalence of diabetes, seems worthy of investigation [19]. Blood glucose level is a crucial physiological parameter linked to the body's metabolic and homeostatic processes[20]. Blood glucose level is an important criterion for identifying and controlling diabetes [21]. Evidence

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from in vivo, in vitro, and epidemiological studies suggests a relationship between EMF exposure and changes in insulin and blood glucose levels . However, mechanisms of the EMF effect on glucose metabolism are still not clear [22].

Materials and Methods

To conduct this narrative review, relevant evidence was retrieved using keywords "Electromagnetic Fields" and "Diabetes." The search, conducted in English, included publications indexed in databases such as PubMed, Scopus, Google Scholar, Web of Science, and Science Direct, and was limited to studies published up to September 2, 2024.

The selection process involved screening the titles and abstracts of the studies, with full articles reviewed when necessary. Duplicate entries were excluded, and the full-text versions of the selected papers were retrieved for further analysis.

Results

Diabetes and EMF Exposure

Comprehending the causes and risk factors of diabetes is essential for preventing and managing this serious health condition. While research has explored molecular processes leading to these complications, their exact causes remain unclear. Various factors are known to drive metabolic alterations, including endogenous factors involving the interaction of genes with insulin-related abnormalities and metabolic dysregulations, as well as exogenous factors such as a sedentary lifestyle, dietary habits, and environmental exposure [23, 24]. Regarding increasing blood sugar levels, three factors play a role: genetics, lifestyle, and environment. As a result, T3DM has been labeled as environmental diabetes. EMFs are becoming increasingly significant environmental pollutants due to rising exposure in both residential and workplace settings [25] and can cause T3DM, which is an emerging condition. Unlike traditional T1D and T2D diabetes, where blood sugar levels are unaffected by EMFs, individuals with Type 3 diabetes may manage their blood sugar more effectively with reduced medication. Additionally, those classified as borderline or pre-diabetic may delay the progression to diabetes by minimizing their exposure to EMFs [26]. Research exploring the relationship between EMWs and diabetes is generally divided into two categories: studies that have used EMWs to treat diabetes and studies that have investigated the incidence of diabetes and increased blood sugar and decreased insulin [27]. In the field of diabetes treatment using EMWs, several review studies have been done so far. It seems that the use of a special form of EMWs, mainly very low pulse frequencies that are in the range of the body's natural frequency, in short exposure times during the day (less than an hour) can reduce blood sugar levels (Table 1).

Table 1 highlights the potential benefits of EMFs in managing diabetes, based on studies involving various modalities such as pulsed EMFs (PEMFs) and low-intensity EMWs. Key findings include improved vascular function, normalized blood glucose levels, and enhanced pancreatic regeneration in diabetic models. These results suggest that targeted EMF therapies may offer novel approaches for diabetes treatment, though further research is needed to standardize protocols and confirm clinical efficacy.

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Table 1: Summary of the positive effects of EMWs on diabetes

EMF form	Frequency	Intensity	Exposure protocol (Time Scale)	Population	Effects	Ref.
PEMF			Participants underwent 10 to 22 treatments with a Diapause PEMF device	Individuals aged 54 to 65 with diabetes mellitus Type 2	Significant increases in microvascular red blood cell (RBC) perfusion (volume concentration of moving RBCs) and decreases in RBC speed were observed, with implications for preventing diabetic ulcers.	(28)
Static magnetic and electric fields (sBE)			Exposed to sBE (B field, 3 mT, and vertically oriented E field, 7 kV/m) for 30 days	Adult Mice of T2D	Exposure to magnetic fields aimed at the south adversely affected the regulation of blood sugar levels, while those directed towards the east showed no effect. It was only in the scenario where both magnetic fields existed simultaneously that an improvement in glucose tolerance was observed.	(29)
Electromagnetic radiation (WER) generated by He-Ne laser		2 MW power, of 632.8 nm wavelength	Exposed to 30-min WER sessions daily for 4 days	Adult male Wistar rats induced diabetes mellitus (DM)	Exposure of diabetic rats to wide-spectrum electromagnetic radiation, modulated by pancreatic and splenic signals, demonstrated potential as a novel therapeutic approach. This method showed promise in extending lifespan, normalizing blood glucose levels, and stimulating pancreatic regeneration	(30)
Pulsed electromagnetic field (PEMF)	50 Hz	5 mT	Exposed to four times daily for 30 min at 15-min intervals repeated daily for 30 days	Male Wistar rats induced diabetes mellitus	Effects of PEMF on the mechanical and electrical properties of aortic rings from diabetic rats, demonstrating that PEMF can improve aortic function in diabetes.	(31)
PEMF	15 Hz		Exposure (20 Gs, 15 Hz) for 12 weeks	T2DM db/db mice	PEMFs can effectively improve mandibular bone quality in diabetic mice by stimulating bone formation through the Wnt/β-catenin signaling pathway.	(32)
Static magnetic and electric fields (sBE)				Diabetic mice	sBE can rapidly and effectively improve insulin sensitivity in diabetic mice by modulating redox homeostasis, primarily through mitochondrial superoxide.	(33)
Low-intensity electromagnetic			Daily 10-minute-long sessions for 14 days	Mice induced diabetes mellitus	Low-intensity electromagnetic millimeter wave therapy demonstrated efficacy in ameliorating diabetes in mice. Treatment increased lifespan, reduced blood sugar levels, and enhanced physical activity.	(34)

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While pulsed electric field (PEF) did not significantly affect blood sugar levels, the results suggest its potential as a complementary treatment for diabetes (35). In a study, 15 Hz PEMF treatment ameliorated diabetic peripheral neuropathy in streptozotocin STZ-induced rats by reducing demyelination, increasing axon diameter, and enhancing vascular endothelial growth factor (VEGF) expression in the sciatic nerve without affecting hyperglycemia or weight loss [36]. PEMF are low-frequency magnetic fields characterized by a specific pattern and intensity [37]. Biao Yu et.al investigated the effects of different static magnetic fields (SMFs) on T2D in mice. Results showed that a downward SMF of a specific strength could effectively reduce blood sugar levels, fatty liver, weight gain, and tissue damage associated with T2D. The findings suggest that this simple and non-invasive method could potentially be used to prevent or treat T2D in the future[38]. Recent investigations into the impact of SMFs on diabetes and its associated complications have yielded inconsistent results, particularly regarding glycemic control [39]. The research found that PEF could modify the structure of damaged SOD, enhancing its enzymatic activity both in vitro and in vivo. This improvement led to a reduction in oxidative stress markers and inflammation in diabetic mice. EMFs can also be used as adjuvant therapy for certain diabetes-related complications. Some studies have shown that pulsed electromagnetic fields (PEMF) at 25 Hz can accelerate the wound healing [40, 41]. In contrast to the studies that have shown the therapeutic effects of the EMF, more studies have explored the influence of electromagnetic or electric fields on insulin secretion and the key pathways regulating insulin release and glucose metabolism. A review of studies showed that almost all types of electromagnetic fields can lead to an increase in blood glucose levels and cause a pre-diabetic condition (Table 2). However, exposure time can be an important factor.

Table 2 reviews studies on the potential adverse or neutral effects of EMF exposure on diabetes. Findings showed that prolonged exposure to static and radio frequency (RF) EMFs can elevate blood glucose levels, impair insulin secretion, and disrupt glucose metabolism. These results raise concerns about the health risks of chronic EMF exposure, highlighting the need for further investigation into its long-term effects.

Table 2: A review of studies exploring the relationship between EMFs and diabetes

EMF form	Frequency	Intensity	Exposure (Time Scale)	Population	Effects	Ref.
Mobile phone	-	-	Group (1): less than 2 h, Group (2): 2–3 h, and Group (3): more than 3 h	Male Saudi Arabian mobile phone users	Mobile phone usage does not affect HbA1c and body composition parameters	(42)
EMP	2000 pulses	400 kV.m^{-1}	-	Type I diabetes model mice	EMP exposure significantly decreased the bioactivity of insulin to reduce the blood glucose levels	(43)
Transient EMFs (radio frequencies)	kHz ranges	-	-	Type 1 and Type 2 diabetic men	Plasma glucose levels, in Type 1 and Type 2 diabetic Cases was associated with electromagnetic pollution	(26)
SMF	-	128 mT or 0 mT	1 h/day during 15 consecutive days	Zucker rat and Wistar rat	128 mT SMFs exposure might favour the development of a pre-diabetic state	(44)
RF electromagnetic field radiation (RF-EMFR)	925 MHz	1.909 and 9.601 nW/cm^2	6 h daily, five days in a week	Male students in elementary schools	Exposure to high RF-EMFR emitted by MPBS is linked to increased HbA1c levels and a higher risk of developing T2D mellitus	(45)
radio frequency (RF) WIFI signals	2.45 GHz	-	1 h/day during 21 consecutive days	Adult male Wistar rats,	RF radiation induced glucose metabolism disorders.	(46)
Static magnetic field	-	128 mT	1 h/day during 5 or 15 consecutive days	Male rats	SMF exposition elevated blood glucose level and decreased insulin concentration. The effect is time-dependent.	(27)
ELFMF	60 Hz	5 mT	-	RIN-m cells in vitro	Exposure to ELFMF significantly attenuated insulin release from RIN-m cells	(47)
PEF	50 Hz	0.7 V/m	Duration of PEF exposure was 40 min	Human hepatocytes (HL7702 cell) in vitro	PEF induced a conformational change in the insulin molecule. Following PEF treatment, the insulin's binding capacity to its receptors decreased to 87% of the control level.	(48)
SMF	-	128mT	1hour/day from day 6 to day 19 of pregnancy	Wistar female rats	Exposure to SMF elevated blood glucose levels and reduced insulin secretion, resulting in a diabetic-like condition in pregnant rats.	(49)
Low-frequency pulsed magnetic field	4-kHz	-	18 h	Rabbit islet cells	Electrical gradients have altered membrane charge which, in turn, may have altered the Ca^{2+} flux and insulin release	(50)
Mobile phone	-	-	3 months	Wistar Albino male rats	Long-term exposure to activated mobile phones is associated with an increase in fasting blood glucose levels and serum insulin in albino rats.	(19)

EMF form	Frequency	Intensity	Exposure (Time Scale)	Population	Effects	Ref.
ELF magnetic field	50 Hz	0.4 mT	6 hours a day for 5-10 days	Wistar Albino female rats	A significant increase in glucose, HbA1c, and HbA1 IFCC values was observed in the experimental groups compared to the control group.	(51)
Pulse-modulated microwave (RF) radiation	-	-	-	A type 1 diabetic male	Increases blood glucose levels and body temperature in individual's diabetic male.	(52)
Constant magnetic fields	-	103 T and 10~2 T	1 hour each day, for a period of ten days	Rats	Compared to the control group, blood glucose levels showed a slight increase, insulin release decreased, and glucagon content was elevated.	(53)
SMFs	-	5-T	for 24 h and 48 h	Mice	Blood glucose levels in the exposed group were higher than in the sham-exposed group.	(54)
Physiologically patterned magnetic fields	-	30 – 50 nT and medium 90 – 580 nT	Prenatal exposure	Adult rats	Peak elevations of glucose	(55)
High frequency electromagnetic field	1,9 GHz	4,79 V/m	7 hours per day and 5 days per week, for thirty days	Adult male Wistar rat	The concentration of glucose and insulin has increased with the exposed group	(56)
ELF-EMFs	60-Hz	3.8 mT	15 min-single exposure	Male rats	Increases in blood glucose level an attenuated second serum insulin peak	(57)

The impact of daily environmental exposure to EMF was investigated in Havas et al. and Beale et al. studies [26, 58]. Havas et al. demonstrated that plasma glucose levels in both T1D and T2D cases were associated with electromagnetic pollution, specifically radio frequencies in the kHz range, linked to indoor wiring (dirty electricity). The studies showed that in addition to insufficient and ineffective insulin production being identified with type 1 and type 2 diabetes, respectively, environmental exposure to EMFs can lead to the development of type 3 diabetes[26]. A linear association has been observed between the incidence of type 2 diabetes in adults living near power lines and exposure to 50 Hz magnetic fields [58].

On the other hand, even in frequencies mainly used in the treatment of diabetes, pre-diabetes effects have been seen. Litovitz et al. reported that exposure of diabetic patients to 60 Hz magnetic fields increased the blood glucose levels[59]. Similarly, Navakatikyan et al. (1994) reported that serum insulin levels were reduced at medium and high flux densities in rats exposed to 50 Hz magnetic fields [60]. Gorczynska and Wegrzynowicz (1991) and Chater et al. (2006) reported that exposure of rats to a constant magnetic field leads to the development of a pseudo-diabetes with increased blood glucose [61, 62]. In vitro studies have also confirmed these effects. Li et al. (2005) found a significant time-dependent Exposure to 50 Hz PEF resulted in alterations in insulin binding to its hepatocyte receptors. Additionally, conformational changes were observed in the insulin molecule, leading to an 87% reduction in its binding capacity to receptors compared to the control groups[63]. Jolley et al. [64] showed that the rate of insulin release in rabbits exposed to low-frequency pulsed magnetic fields was significantly reduced compared to the control group. Similarly, Sakurai *et al.* [65] reported that insulin secretion from hamster islet cells exposed to low-frequency magnetic fields (60 Hz) was reduced by about 30% compared to the control group. Also, stimulation of rat islets with a low-frequency pulsed magnetic field resulted in a reduction of calcium efflux, which consequently led to a decrease in insulin release compared to the control islet [66]. Khaki et al. reported that the EMF decreased insulin level, which was associated with decreased area and perimeter of pancreatic islets in EMF-exposed rats[67]. Martiñón et al. showed that a single 60Hz EMF exposure induced hyperglycemia in rats. This effect was linked to altered glucose metabolism, oxidative stress, and insulin/glucagon imbalance. Chronic EMF exposure did not modify these acute responses [68]. Furthermore, Storch et al. documented the influence of low-frequency EMFs on both glycolytic and tricarboxylic acid cycle processes [69]. Preliminary analysis suggests a potential correlation between electromagnetic exposure and an increased prevalence of diabetes. Sedentary behaviors associated with television consumption may contribute to obesity and insulin resistance. While the carcinogenic effects of mobile phones remain a topic of ongoing research, the potential for these devices to adversely affect health, possibly through impaired glucose metabolism, warrants further investigation. Notably, the elevated iron levels observed in diabetic patients, combined with the role of iron in both glucose metabolism and carcinogenesis, necessitate further exploration of the potential influence of electromagnetic stimulation on these processes [70-72].

Mechanisms causing diabetes by EMFs

The increase in blood glucose because of exposure to EMFs was confirmed in studies. However, the underlying diabetic mechanism of EMFs remains unclear. Several mechanisms of diabetes have been proposed. One major mechanism contributing to the development of diabetic complications is oxidative stress [15-17]. Increasing evidence suggests that oxidative stress plays a crucial role in both the development and progression of diabetes. Many well-known risk factors for diabetes, like obesity, rising age, and poor diet, all create an environment within the body with high levels of oxidative stress. This stressful environment can change insulin

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sensitivity by reducing insulin resistance or decreasing glucose tolerance[73]. Antioxidant levels in diabetic individuals initially rise in response to ROS but subsequently decline due to consumption by free radicals. As the disease progresses, concurrent tissue and antioxidant system damage can lead to further reductions in antioxidant capacity[74]. Oxidative stress may directly lead to the onset of diabetes by reducing sensitivity to insulin and damaging the function of beta cells in the pancreas [75]. Oxidative stress is also believed to play a significant role in causing vascular complications in diabetes, especially T2D [76]. SMF increases the cellular concentration and lifetime of ROS. Therefore, the increased glucagon secretion and low insulin levels may be due to the glycogenolytic effect resulting from the sympathetic hyperactivity induced by SMF [77]. In addition to oxidative stress, after EMP exposure, a reduced amount of insulin was able to bind to its receptor on the membrane of HL-7702 cells, indicating a decreased binding affinity between insulin and its receptor. In the absence of receptor binding, insulin is unable to exert its biological effect. This finding may explain the diminished effect of EMP-exposed insulin on blood glucose levels in the mouse model [43]. The "stress response" to electromagnetic energy may offer another mechanism to explain T3DM. The process of producing stress proteins is influenced by low-frequency EMFs and non-thermal RF radiation [78]. Given that the stress hormone norepinephrine leads to inhibition of insulin secretion, blood glucose levels increase during stress. Therefore, this condition can be used to explain T3DM caused by EMF exposure. Because the capacity of insulin to bind to its receptors is reduced [51]. Some studies have identified a link between hyperlactatemia and changes in lactate exchange in the development of insulin resistance. Therefore, the hyperglycemia observed following SMF exposure may be explained by reduced glucose uptake due to elevated lactate levels[44, 79]. Moreover, hyperglycemia may also result from changes in other hormones involved in glucose homeostasis [80]. Gorczynska and Wegrzynowicz observed an increase in glucagon, cortisol, thyroid hormones, and growth hormone levels following magnetic field exposure, indicating the onset of a diabetic-like state [53]. When rat islets were exposed to a low-frequency pulsed magnetic field, they showed a decrease in the release of calcium ions and, as a result, a reduction in insulin secretion compared to islets that were not exposed to the magnetic field [81]. Cortisol is vital for transforming protein into sugar in the body. While it mainly affects liver glycogen, excessive cortisol can cause higher blood sugar levels. This happens because cortisol works against insulin, the hormone that regulates blood sugar. By blocking muscle and fat cells from taking in glucose, cortisol prompts the liver to produce more sugar. In essence, high cortisol levels can trigger diabetes and undermine the effectiveness of insulin. The pronounced effect of cortisol on blood sugar, fat metabolism, and ketone production is usually noticeable only when it is produced in large amounts due to stress [82]. Excessive sympathetic activity brought on by SMF might lead to the breakdown of glycogen, which is linked to an increase in glucagon release and a decrease in insulin levels [83]. An increase in calcium levels within cells can disrupt the balance of charges on the cell membrane. This makes it easier for insulin-containing granules to merge with the cell membrane and release their insulin into the bloodstream [84].

Conclusion

The relationship between EMFs and all diabetes is multifaceted, encompassing both therapeutic potentials and health risks. This literature review synthesizes findings from various studies, revealing that while certain types of EMF exposure, particularly PEMFs, may offer beneficial effects in diabetes management, other forms of exposure can lead to detrimental health outcomes. Studies have indicated that PEMF therapy is effective in enhancing insulin sensitivity, promoting wound healing, and improving microvascular blood flow in diabetic patients. Many studies are characterized by

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significant variability in methodologies, including differences in exposure duration, intensity, and frequency of EMF. Many studies rely on animal models, which may not accurately reflect human responses to EMF exposure. Furthermore, the heterogeneity in study populations complicates the generalizability of results, making it challenging to establish definitive causal relationships. Future investigations should prioritize large-scale, longitudinal studies that encompass diverse populations to elucidate the long-term effects of EMF exposure on diabetes. A focus on mechanistic studies is essential to unraveling the biological pathways through which EMFs affect glucose metabolism and insulin sensitivity. Establishing clear safety guidelines based on comprehensive evidence will be crucial in mitigating potential risks associated with EMF exposure while harnessing their therapeutic benefits. While the potential therapeutic applications of EMFs in diabetes management are encouraging, the associated risks necessitate a cautious approach. A balanced understanding of both the benefits and hazards is essential for advancing diabetes research and improving clinical practices. Continued exploration of this complex relationship will ultimately contribute to more effective strategies for diabetes prevention and management.

Abbreviations

EMFs: Electromagnetic Fields
PEMF: Pulsed Electromagnetic Fields
ELF-EMF: Extremely Low-Frequency Electromagnetic Field
PEF: Pulsed Electric Field
RF-EMF: Radiofrequencies Electromagnetic Field
BE: Biological Effects
SBE: Static Magnetic and Electric Fields
ROS: Reactive Oxygen Species
VEGF: Vascular Endothelial Growth Factor
EMWs: Electromagnetic Waves
WHO: World Health Organization

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Conflict of Interest

The authors declare that there is no conflict of interest.

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Ethical Approval

This study does not involve human or animal subjects, and thus no ethical approval was required.

Code of Ethics

This study was done without receiving ethical code.

Authors contributions

All authors equally contributed to the preparation of this article.

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