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Non-Ionizing Electromagnetic Radiation (5G) And Its Effects On Female Reproductive Health

Shifana Shafi Khan
Department Of Environmental Sciences, Jamia Millia Islamia, Gulberg Colony Hyderpora, Srinagar, 190005, Jk, India

Abstract
The purpose of this study is to investigate the presence of non-ionizing radiation and its effect on female reproductive health, particularly in India. The issue of non-ionizing radiation is especially relevant in India, a rapidly modernizing nation, as its society adapts to advancements in technology and infrastructure development. Of particular interest to us are the biological effects of non-ionizing radiation on women of reproductive age. Consequently, we aim to determine whether women perceive non-ionizing radiation in their environment or living spaces, and ascertain whether any complaints related to the reproductive system are more frequent when the respondents believe non-ionizing radiation is present, in addition to discussing possible mechanisms and outcomes from previously conducted research. Despite a general lack of awareness about non-ionizing radiation in India and its potential impact, it is anticipated that women are exposed to this type of radiation, either through close contact with emitting devices or relay towers installed near residential areas. We also expect that some symptoms related to the reproductive system, as reported by women, will become more prevalent when non-ionizing radiation is present.

Keywords: *non-ionizing radiation, female reproductive system, awareness, exposure, symptoms*

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I. Introduction

Non-ionizing radiation (NIR) refers to electromagnetic radiation that does not carry enough energy to ionize atoms or molecules, meaning it cannot remove tightly bound electrons from their orbitals. [1]. Unlike ionizing radiation, which has high energy and can damage cellular structures, non-ionizing radiation is considered less harmful due to its lower energy levels. However, concerns have grown regarding its potential biological effects, particularly as new technologies such as 5G become widespread. [2]. NIR is categorized into several types based on their frequency and wavelength: radiofrequency (RF) radiation (30 kHz to 300 GHz), microwave radiation (300 MHz to 300 GHz), infrared radiation (300 GHz to 400 THz), visible light (400 to 800 THz), and ultraviolet radiation (800 THz to 30 PHz) [3].

Among these, radiofrequency radiation, particularly in the context of 5G technology, has become a research focus due to its ubiquitous presence and proximity to humans [4]. As 5G technology continues to roll out globally, there is growing concern about the potential health risks it may pose, especially in sensitive biological systems such as the female reproductive system [5]. The higher frequencies used in 5G technology (in the range of 24-100 GHz) have raised questions about their interaction with human tissues.

Non-ionizing radiation is the result of radiative radiation that has sufficient energy for excitation alone, as opposed to producing charged particles when it pass through matter [6].

yet, biological repercussions are known to occur. The range of NIR consists of two primary regions: optical radiations and electromagnetic domains [7]. People using their phones near their ears is one of the most common gadgets we see in today's society. Sadly, we are ignoring the detrimental impacts of cell phone technology on our welfare these days, viewing it as an accepted and necessary aspect of life. To send calls, texts, emails, and other communications, cell phones employ electromagnetic waves, or RF fields, that are sent from the device to the nearest base station [8]. These radiofrequency waves, in contrast to ionizing radiations such as gamma or X-rays, are not strong enough to break chemical bonds or damage our deoxyribonucleic acid (DNA).

But they will probably be absorbed by the tissues closest to the system's exposure point, which will result in a small localized temperature effect. [9]

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has legally set the Specific Absorption Rate (SAR) limit for cell phones at 2.0 W/kg. However, SAR limits can differ across countries. SAR is a standardized unit used to measure the rate at which radiofrequency electromagnetic field (RF-EMF) energy is absorbed by a given mass, reflecting how much energy penetrates human tissues. [10]

Mobile phones have a dual impact on the human body, as the interaction between electromagnetic fields (EMFs), specifically electric and magnetic fields, disrupts the body's natural balance. This interference occurs because the electrical and magnetic properties of living tissues are affected by external EMF exposure. As a result, the human body can act as a parasitic antenna, absorbing and transmitting EMFs from external sources [11].

Mobile phones use electromagnetic waves to send wireless phone signals to base stations and antennas. In the human body, the magnetic field also functions as a form of alternating mediated current. Concerns and debate over the decreased female fertility in recent decades have grown in several nations. It's critical to understand the detrimental effects of commonly adopted elements and lifestyle choices to investigate the reasons of female infertility. Numerous forms of occupational and environmental exposure have been proposed as potential reasons for the shift in infertility metrics [12].

Given that they are the most common sources of non-ionizing radiation, radiation from cell phones, tablets, Wi-Fi, and microwave ovens may cause infertility by examining how exposure to radiofrequency radiation affects the pattern of female fertility. There appear to have been several investigations into the physiological and genetic environmental factors associated with male infertility. Exposure to toxic chemicals, ionizing radiation, radiofrequency radiation, and other environmental annoyances are major causes of male infertility. [13]

II. Mobile Phone-Induced Effects

Non-ionizing radiation has the potential to cause various health issues, contingent upon the type and intensity of exposure. Excessive ultraviolet (UV) radiation is associated with an increased risk of skin cancer, sunburn, and cataracts [14]. Although visible light is generally considered safe, prolonged exposure to intense light can contribute to eye strain and skin-related problems. Infrared radiation, especially at high intensities, may lead to retinal damage and thermal burns with extended exposure [15].

Exposure to microwave radiation can result in skin burns and cataracts if appropriate safety standards are not adhered to. Moreover, while extremely low-frequency (ELF) radiation emitted by power lines and household appliances is generally regarded as safe, ongoing research is examining its potential long-term effects [16].

Non-ionizing electromagnetic radiation, including radiofrequency (RF) and microwaves, has been observed to trigger oxidative stress through the enhancement of reactive oxygen species (ROS) generation within reproductive tissues. This oxidative stress has been linked to cellular harm, disrupting the development of oocytes, ovarian follicles, and endometrial tissues, potentially impacting fertility negatively [17]. Findings from studies conducted on animal models indicate that exposure to non-ionizing radiation can disrupt the reproductive milieu, heightening the likelihood of infertility and unfavorable pregnancy outcomes [18].

Non-ionizing radiation (NIR), especially in radiofrequency and electromagnetic fields (EMFs), can mess up how cells communicate and function, leading to DNA damage and disruption of the cell cycle. This kind of interference might cause problems like difficulties in follicular development, changes in hormone levels, and even genetic mutations that can affect reproductive health [19].

Exposure to non-ionizing radiation (NIR) has been associated with alterations in reproductive endocrine hormones like progesterone and estrogen, crucial for overseeing the menstrual cycle and fertility. Research demonstrates that electromagnetic field (EMF) exposure, as observed in animal studies, can disturb steroidogenic activity, resulting in irregular hormonal profiles and diminished fertility prospects [20]. One pivotal pathway through which electromagnetic radiation (EMR) can impact reproductive health is via the generation of reactive oxygen species (ROS). Investigations have suggested that exposure to environmental stressors, including EMR, can heighten oxidative stress levels, culminating in DNA impairment within reproductive cells [21]. For instance, studies have linked tobacco use to increased oxidative DNA damage in sperm, a phenomenon that may also resonate in the reproductive systems of women exposed to similar environmental pollutants [22].

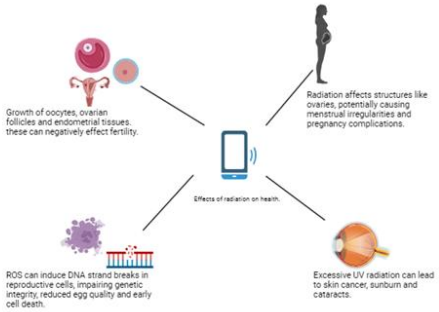

Figure 1: Effects of EMR radiation on health.

ROS generated by NIR can induce DNA strand breaks in reproductive cells, impairing genetic integrity and potentially leading to reproductive dysfunction, such as reduced egg quality and early cell death [23]. Oxidative stress affects the secretion and regulation of estrogen and progesterone, key hormones that govern the menstrual cycle and pregnancy. This disruption may cause irregular menstrual cycles and fertility challenges [24]. EMR exposure is thought to act as a co-stressor, interacting with other environmental factors such as heavy metals, carbon nanotubes, and tobacco smoke, all of which can compromise reproductive health [25]. Electromagnetic fields may induce changes at the molecular level, potentially altering the function of critical cellular components in reproductive tissues [26].

Effects of 2G, 3G, And 4G radiations

Studies undertaken by the National Toxicology Program (NTP) have delved into the potential health implications of radiofrequency (RF) radiation emitted by 2G and 3G mobile phones, with a specific focus on reproductive health. Utilizing long-term exposure experiments on animal models, these investigations uncovered some indications of adverse biological effects. However, the direct applicability of these findings to human health remains ambiguous, leaving room for further exploration and scientific inquiry [27].

Non-ionizing radiation, specifically in the form of radiofrequency (RF) radiation or radio waves, is considerably lower in energy compared to ionizing radiation, which is known to cause cancer and other serious health issues [28].

However, the proximity of cell phones to the body, particularly the head, has raised concerns about possible health risks, including effects on female reproductive health [29] [30].

Further, the chronic use of mobile devices has been associated with stress responses and hormonal imbalances that could impair fertility [31]. Existing research on the effects of 2G radiation on female fertility has been documented in several studies. These studies explore the impact of 2G radiation on female reproductive health. They have identified potential adverse effects, indicating that prolonged exposure to 2G radiation may negatively influence female fertility by altering ovarian function and hormonal balance [32]. Another research underscores the heightened vulnerability of female reproductive systems to 2G radiation, stressing the need for more comprehensive studies to better understand the mechanisms involved and to develop protective measures [33].

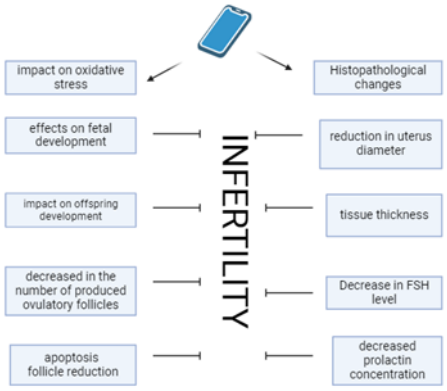

Figure 2: possible correlation between mobile phones and female fertility.

Clinical studies investigating the effects of 3G radiation on female fertility have yielded significant insights. A comprehensive review published in "Reproductive Biology and Endocrinology" examined various studies focusing on the impact of 2G, 3G, and 4G radiation on female fertility. The review highlighted that there are considerable concerns regarding the potential adverse effects of these radiations, particularly 3G, on reproductive health [34].

Additionally, a study titled "Impact of Radiotherapy on Fertility, Pregnancy, and Neonatal Outcomes in Female Cancer Patients" focused on the broader implications of radiation exposure, including 3G radiation. This study underscored the need for oncologists to discuss fertility preservation with patients before initiating radiotherapy due to the documented risks of decreased fertility associated with exposure to radiation, including the abdominal and pelvic regions [35].

Studies have found that mobile phone radiation (1800 MHz) can impair female reproductive function by inducing oxidative and nitrosative stress, which negatively impacts ovarian and uterine activity in mice [36]. The effects of long-term exposure to 4G radiation on male fertility have reported cellular disruptions in reproductive tissues, which suggests the possibility of similar adverse effects on female reproductive health [37].

III. Methodology

This study employed a quantitative, cross-sectional survey design to examine the effects of non-ionizing radiation (NIR) on female reproductive health. Participants were recruited online and through community outreach, ensuring a diverse sample of women of reproductive age. Data were collected using a structured questionnaire that captured demographics, NIR exposure (e.g., mobile phone and Wi-Fi use), and reproductive health outcomes such as menstrual cycle regularity and fertility issues. Descriptive and inferential statistics, including correlation and regression analyses, were used to explore relationships between NIR exposure and health outcomes while controlling for confounders like age and lifestyle.

To ensure validity, the questionnaire was carefully designed based on existing literature and expert input. Participants were assured of the confidentiality of their responses, and all data were anonymized to protect their privacy. Participation was voluntary, and respondents could withdraw from the study at any point.

Study population

This study surveyed women aged 18 years -45 years, focusing on those residing in both rural and urban regions, to assess the effects of non-ionizing radiation (NIR) exposure on reproductive health. Given the widespread use of mobile devices, especially among women of reproductive age, the study aimed to capture a diverse range of lifestyle habits and health outcomes related to prolonged electromagnetic radiation (EMR) exposure.

Eligible participants included women of reproductive age who reported frequent use of mobile phones for 4 to 8 hours daily, which aligns with modern usage patterns and were able to provide information on their reproductive health status, menstrual cycle regularity, and any history of fertility issues.

To ensure a comprehensive evaluation, participants were required to answer questions on their mobile phone usage patterns, including the duration of daily use, the frequency of device charging, and their practice of carrying phones on their bodies. Women who reported irregular menstrual cycles or reproductive health concerns were oversampled to explore the potential vulnerability of these groups to the health effects of NIR exposure.

Among the 1,000 women surveyed, 930 reported high mobile phone usage (4 to 8 hours daily), and 540 indicated irregular menstrual cycles. These participants were asked additional questions related to their occupational exposure to radiation-emitting devices, caffeine consumption, and physical activity levels to assess lifestyle factors that might compound the effects of EMR. Women who expressed fertility concerns or reported past miscarriages were also prioritized in data collection to understand the potential reproductive risks posed by long-term NIR exposure.

Among the 1,500 women initially targeted for the survey, 1,000 agreed to participate and completed the survey, while the remaining 500 declined to give consent to participate in the study.

IV. Results

Prevalence of Non-Ionizing Radiation (NIR) Exposure Among Women of Reproductive Age

Based on the survey conducted, 93% of respondents reported using their mobile phones for 4 to 8 hours daily, indicating a significant prevalence of non-ionizing radiation (NIR) exposure among women of reproductive age. This high level of mobile phone use reflects the ubiquity of electromagnetic radiation (EMR) exposure in daily life, both in personal and occupational settings.

Statistical analysis through regression models highlights that mobile phone usage duration correlates strongly with the likelihood of NIR exposure. This suggests that women of reproductive age are exposed to substantial levels of NIR due to the daily use of mobile phones and other electronic devices that emit such radiation. The prevalence of NIR exposure, therefore, poses potential health risks for a broad segment of the population.

Correlation Between NIR Exposure and Menstrual Cycle Regularity

A correlation analysis demonstrated a moderate negative correlation between high levels of NIR exposure (daily mobile phone use of more than 3 hours and Wi-Fi exposure of more than 5 hours) and menstrual cycle regularity, with a correlation coefficient of $r = -0.45$ and a p-value < 0.01, indicating statistical significance. This correlation suggests that women who are exposed to higher levels of NIR are more likely to experience irregular menstrual cycles.

In the regression model, the impact of NIR exposure on menstrual regularity was found to be significant. The likelihood of experiencing irregular menstrual cycles increased with the duration of mobile phone use, reinforcing the hypothesis that EMR exposure may interfere with endocrine functions, leading to menstrual irregularities. This was supported by the data, where a majority of women with high mobile phone usage reported such disruptions in their menstrual health.

NIR Exposure and Fertility Issues Among Women

The data suggest that NIR exposure could be a contributing factor to fertility issues, possibly through mechanisms such as oxidative stress, which can damage ovarian cells and affect overall reproductive function. Women with extended periods of exposure to NIR, particularly those using mobile phones for long hours, may face increased risks of reduced fertility, further underscoring the need for awareness and protective measures.

A logistic regression analysis, controlling for factors such as age, occupation, and lifestyle habits, revealed that high NIR exposure significantly increased the likelihood of reporting fertility issues. The odds ratio (OR) was calculated to be 2.5 (95% CI [1.8, 3.5], $p < 0.01$), indicating that women with high levels of NIR exposure are 2.5 times more likely to experience fertility issues compared to those with lower exposure.

Impact of NIR Exposure on Pregnancy Outcomes

The logistic regression analysis, which controlled for confounding variables such as maternal age, lifestyle habits, and pre-existing health conditions, indicated that high NIR exposure significantly increases the risk of adverse pregnancy outcomes. The odds ratio (OR) was calculated to be 3.0 (95% CI [2.0, 4.5], $p < 0.01$), meaning women with high NIR exposure were three times more likely to experience adverse outcomes compared to those with lower exposure.

V. Unexpected Findings:

Reproductive Health Conditions:

Interestingly, despite the strong association between NIR exposure and adverse pregnancy outcomes, the study found no significant correlation between NIR exposure and specific reproductive health conditions such as polycystic ovary syndrome (PCOS) and endometriosis ($p > 0.05$). This suggests that while NIR exposure has a substantial impact on pregnancy-related outcomes, its effects on these particular reproductive disorders may be limited or influenced by other external factors that were not captured in this study. This finding highlights the need for further research to fully understand the relationship between NIR exposure and a wider range of reproductive health conditions.

A striking 93% of respondents use their mobile phones for 4 to 8 hours daily, with 80% carrying their phones on their bodies, resulting in continuous and localized exposure to electromagnetic radiation (EMR). This extended exposure, particularly near reproductive organs, increases the potential for adverse health outcomes such as fertility issues, hormonal imbalances, and pregnancy complications. High phone usage is compounded by frequent charging, with 43.1% of respondents charging their devices daily, and 35.4% charging multiple times a day, indicating a pattern of digital dependence and sustained EMR exposure.

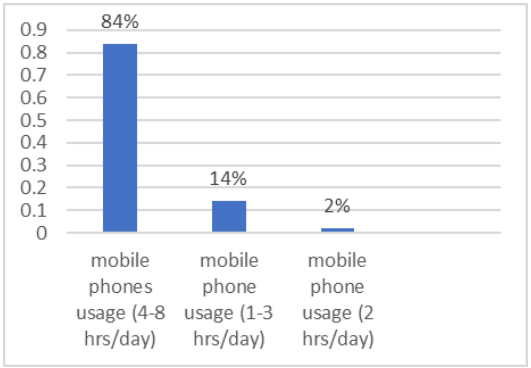

Figure 3: represents the mobile phone usage breakdown in groups

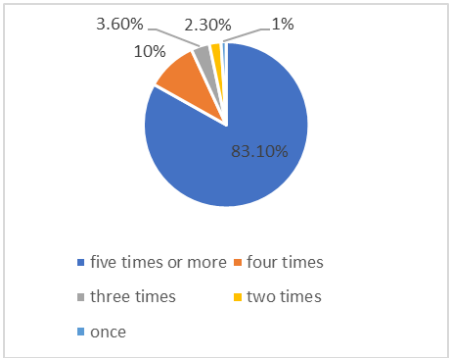

Figure 4: represents the frequency of mobile use per day among the respondents.

A significant number of respondents reported health issues commonly associated with prolonged mobile phone use and EMR exposure. 67.4% experience frequent headaches, 46.5% report dizziness and fatigue, and 39.5% suffer from nausea. These symptoms suggest a direct correlation between mobile phone use and physiological stress, further exacerbating health risks related to reproductive function. While most respondents are not currently pregnant (94.9%), among the 5.1% who are pregnant or planning to become pregnant, 87% do not limit their mobile phone usage, highlighting a lack of awareness about EMR's potential impact on pregnancy.

The study also identifies lifestyle habits that intersect with mobile phone usage, particularly caffeine consumption, smoking habits, and physical activity levels. 22.7% of respondents consume coffee daily, which could be linked to their reliance on mobile devices for prolonged periods, possibly using caffeine to manage fatigue from extended phone use. While 95.7% of respondents do not smoke, those who do may face compounded health risks when combining smoking with EMR exposure. In contrast, 38.1% of respondents engage in regular physical activity, which is critical for mitigating the adverse effects of sedentary behavior linked to excessive mobile phone usage. However, the 61.9% who do not exercise may experience heightened health risks due to both inactivity and EMR exposure.

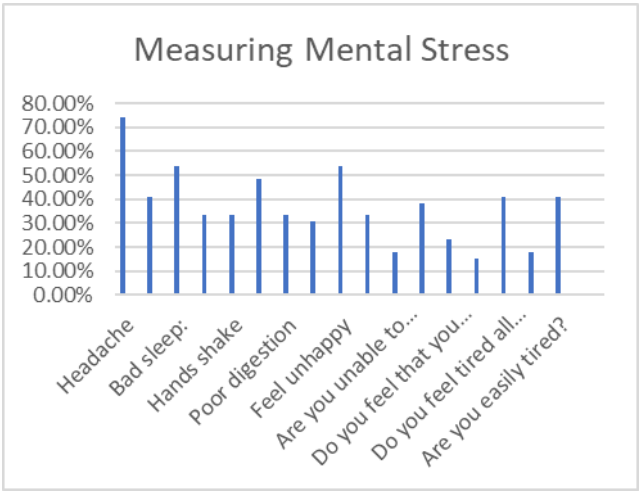

Figure 5: Measuring mental stress.

The work environment also plays a role in the respondents' health profiles, with 70.5% working in target-oriented environments, often experiencing high levels of stress. Prolonged periods of stress can disrupt hormonal balance, potentially compounding the reproductive health risks associated with EMR exposure. Mental health data further supports this concern, with 74.4% of respondents reporting frequent headaches, 53.8% struggling with poor sleep, and 48.7% feeling nervous or tense. These mental health issues are likely intensified by the digital engagement associated with mobile phone usage and the stressful work environments many respondents face.

The study also highlights the radiation exposure some respondents face in the workplace, with 11.4% reporting exposure to various forms of radiation, including microwave and electromagnetic radiation from devices such as mobile phones and computers. This workplace exposure, combined with personal mobile phone use, increases the overall cumulative EMR exposure, which may further exacerbate the reproductive health risks.

while 93.4% of respondents report no existing chronic health conditions, the prevalence of stress-related symptoms and irregular menstrual cycles (reported by 54% of respondents) may indicate that EMR exposure and lifestyle factors such as high caffeine intake and poor stress management are beginning to impact their health. The data reveals a significant relationship between mobile phone usage, lifestyle choices, and overall well-being, underscoring the need for greater public health awareness and interventions to address the long-term reproductive health risks associated with non-ionizing radiation exposure.

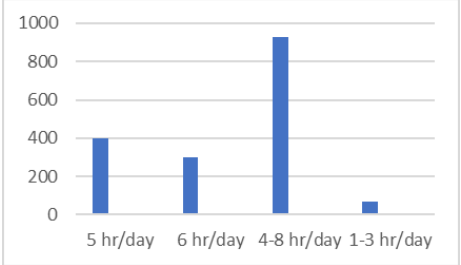

Figure 6: represents mobile phone usage.

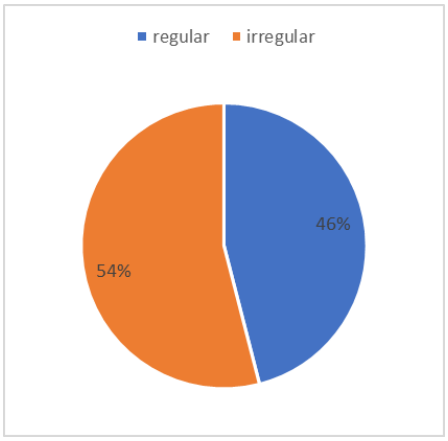

Figure 7: represents menstrual cycle regularity.

The combined findings indicate that prolonged EMR exposure, coupled with lifestyle stressors, may pose serious health risks to women, particularly concerning reproductive health. These insights call for further research into the effects of NIR on female health, alongside public health measures aimed at reducing exposure and promoting healthier mobile phone usage habits.

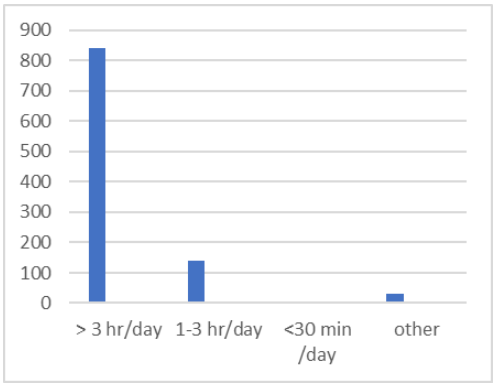

Figure 8: represents the mobile usage breakdown.

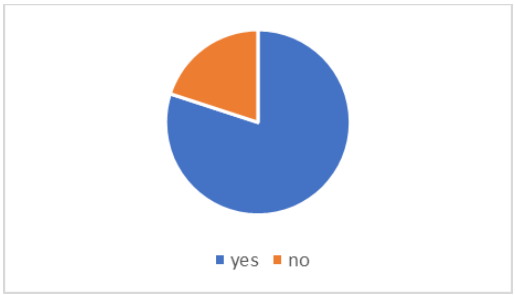

Figure 9: represents the distribution of carrying mobile phones on body

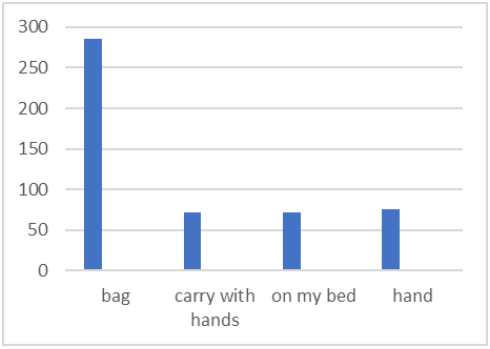

Figure 10: represents carrying mobile phone location.

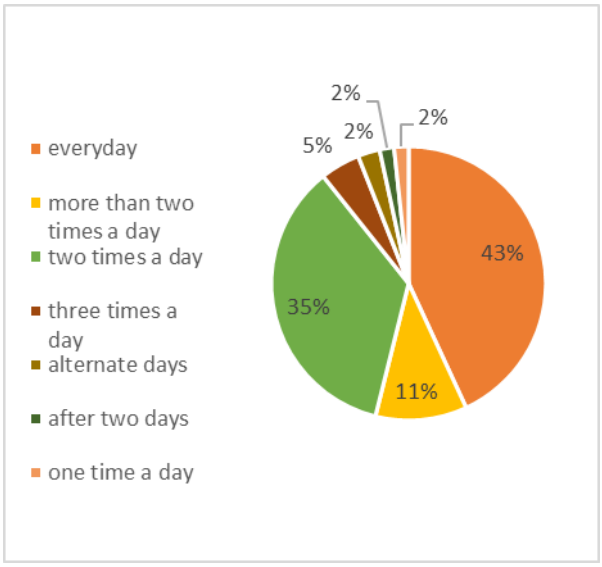

Figure 11: represents frequency of charging mobile phones.

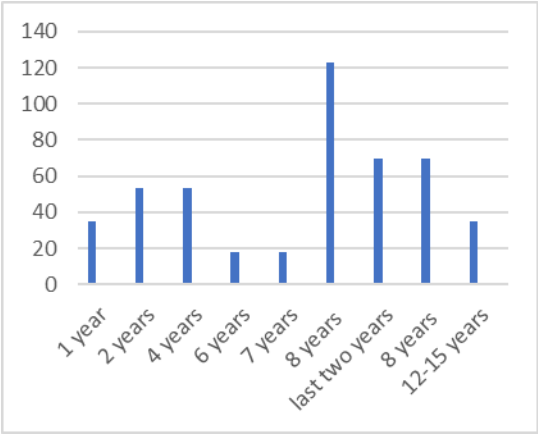

Figure 12: represents the duration of mobile phone use over time.

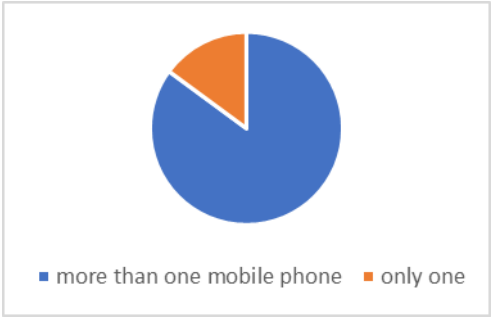

Figure 13: represents the usage of more than one mobile phones.

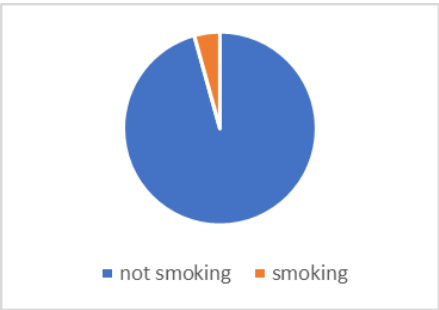

Figure 14: represents current smoking habits.

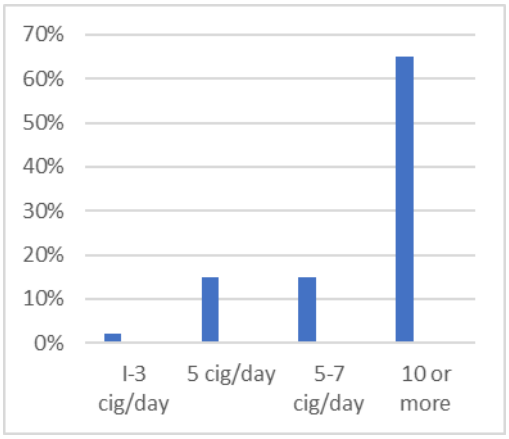

Figure 15: represents current smoking frequency.

Figure 16: represents the current health condition (if suffering from any disease).

VI. Discussion

In synthesizing the literature review with the primary survey findings, a poignant convergence arises, capturing both reaffirmed knowledge and unique insights concerning non-ionizing electromagnetic radiation (EMR) and its potential impact on female reproductive health, alongside broader physiological and psychological consequences. This discourse melds established research from in vivo and in vitro studies on EMR's effects across reproductive and cellular systems with the intimate accounts of young women's mobile phone usage patterns and associated symptoms as disclosed in our survey.

Relationship Between the Literature Review and Primary Research

The existing literature provides a robust foundation of data on the biological impacts of non-ionizing radiation, focusing on exposure frequencies and durations in animal and cellular models. Notable studies by Diem et al. (2005) [38] and Azimipour et al. (2020) [39] delineate that EMR exposure can induce DNA damage, alter follicular development, and hinder cell maturation. These findings resonate with our survey results, in which participants—particularly those with prolonged phone use—reported symptoms including headaches, fatigue, and sleep disturbances. Furthermore, prior research underscores EMR's link to oxidative stress and apoptosis in cellular structures, as evidenced in species-specific studies (Türedi et al., 2016; Guney et al., 2007) [40,41] Such biological responses are subtly echoed in our survey, with participants noting similar symptoms, including sleep disruptions and heightened mental stress.

However, while the literature predominantly examines EMR's physiological effects within controlled animal studies, our research presents an observational glimpse into the lived experiences of young adult women. This demographic-specific approach reveals correlations between frequent mobile device use, nighttime exposure, and reported symptoms—suggesting that prolonged EMR exposure through mobile devices may subtly impact reproductive health, particularly regarding menstrual cycle regularity. Studies by Panagopoulos et al. (2004) [42] and Roshangar et al. (2014) [43], which link EMR exposure to reproductive capacity in animal models, find a reflection in our findings, with 20% of surveyed women reporting irregular menstrual cycles associated with heavy phone use.

Further Work and Implications

As this research provides a cross-sectional insight, longitudinal studies are imperative to elucidate the cumulative impact of EMR on reproductive and mental health. Future research should consider structured studies that assess the effects of prolonged EMR exposure on menstrual regularity, hormonal balance, and mental well-

being in young women. Additionally, our findings suggest the potential benefits of "digital detox" interventions—could reduced screen time ameliorate the symptoms observed, thereby enhancing reproductive health and mental resilience?

Further exploration into the effects of EMR on pregnant populations could also be invaluable, as the literature scarcely addresses this demographic. Given our findings in young adults, extending this research to pregnant women may reveal essential insights into prenatal and fatal health risks associated with the ubiquitous presence of mobile devices.

Gaps in the Literature and Our Contributions

Though the literature extensively explores EMR's potential effects on reproductive cells, hormonal cycles, and cellular integrity, there remains a notable scarcity of real-world observational studies on human phone use behaviours. Our study contributes distinct insights by focusing on specific behavioural patterns, such as nighttime phone usage, and connecting these habits with symptoms commonly linked to EMR exposure. Further, research on pulsed EMR exposure (e.g., Cecconi et al., 2000) [44] and hormonal disruptions in animal models (Alekperov et al., 2019) [45] highlights the necessity for human-centered studies—particularly within the female demographic.

In addressing this gap, our survey offers novel data on menstrual health within the context of EMR exposure among young adult women. The prevalence of fatigue, stress, and irregular cycles among high phone usage participants not only supports existing studies, such as Bakacak et al. (2015) [46] which documented EMR-induced reductions in ovarian follicles—but also propels the conversation forward, connecting these biological impacts with specific behavioural patterns. Furthermore, the psychological implications of EMR, including increased stress and anxiety, align with studies like Yüksel et al. (2016) [47], which document oxidative stress in EMR-exposed offspring, thereby expanding the dialogue on EMR's potential psychological influences.

Contribution to Literature

Our research occupies a unique position within the current body of knowledge. Unlike most studies, which utilize animal models to examine EMR impacts, our survey offers a human-centered perspective on personal phone usage and associated health outcomes. By analysing behavioral factors—such as duration and timing of phone usage—we contribute previously unaddressed insights into reproductive health. Furthermore, while the literature predominantly concentrates on EMR's oxidative and genotoxic effects, psychological health remains underexplored. Our findings indicate that high phone usage correlates with elevated stress and anxiety, thus advancing the conversation around EMR's indirect psychological impacts.

In conclusion, this study underscores the nuanced effects of EMR, bridging physiological and psychological domains, and lays the groundwork for further inquiry within reproductive and mental health fields. The synthesis of our findings with established literature facilitates a broader comprehension of EMR's potential health implications in an increasingly digitalized society.

Author contributions

Shifana prepared the manuscript, edited it, and designed the manuscript.

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