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Electromagnetic Field Exposure During the Use of New-Generation and Conventional Household Appliances and Health Indicators in Women: A Comparative Cross-Sectional Study

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Abstract

Objective

This study aimed to compare magnetic flux density (μT) measured during the use of new-generation and conventional household and personal-care appliances among women and to examine the associations of magnetic flux density and appliance-use characteristics with headache impact, fatigue, anxiety, and sleep quality.

Methods

This comparative cross-sectional study included 56 women aged 18–55 years living in Istanbul, Türkiye. Comparisons were conducted separately according to appliance type, including hair styling devices and cooking appliances. Appliance-use duration, frequency of use, total years of use, and magnetic flux density were recorded. Magnetic flux density was measured in microtesla (μT) using a portable Benetech GM3120 Electromagnetic Field Radiation Detector during appliance operation. Measurements were performed under real-life household conditions, with the measurement device held approximately 10–15 cm from the operating appliance. The appliances included in the study were newly purchased and had not been routinely used before the measurements. Health indicators were assessed using the Chalder Fatigue Scale, the anxiety subscale of the Depression Anxiety Stress Scale-21 (DASS-21), the Richards-Campbell Sleep Questionnaire, and the Headache Impact Test-6 (HIT-6).

Results

Mean magnetic flux density was significantly higher for conventional hair styling devices than for new-generation hair stylers (38.24 ± 20.39 μT vs. 14.89 ± 11.28 μT; $p < 0.001$). In contrast, magnetic flux density was significantly higher during air fryer use than during conventional oven use (29.95 ± 19.88 μT vs. 5.20 ± 1.95 μT; $p = 0.003$). No significant differences were found between appliance types in HIT-6, fatigue, anxiety, or sleep quality scores (all $p > 0.05$). Mean magnetic flux density was not significantly associated with any health scale score. However, longer weekly appliance-use duration was associated with lower sleep quality ($r = -0.27$; $p < 0.05$) and higher anxiety scores ($r = 0.28$; $p < 0.05$).

Conclusion

New-generation household appliances did not show a consistent pattern of lower magnetic flux density compared with conventional appliances. Magnetic flux density varied according to appliance type. Although measured magnetic flux density was not directly associated with headache impact, fatigue, anxiety, or sleep quality, longer weekly appliance-use duration was associated with poorer sleep quality and higher anxiety. These findings suggest that appliance type and patterns of use should be considered when evaluating magnetic field exposure in household settings.

1. Introduction

The widespread integration of electrical and electronic devices into everyday life has resulted in continuous exposure to electromagnetic fields (EMFs) of varying frequencies and intensities in both domestic and occupational environments (Bonato et al. 2023; Gajšek et al. 2016). Household EMF exposure may vary according not only to the technical characteristics of a device, but also to its operating principle, electrical power, frequency profile, duration and frequency of use, and the distance between the user and the device (Bonato et al., 2023). Although the potential health effects of electromagnetic fields have been investigated for decades, the evidence regarding the clinical consequences of low-level and intermittent exposures encountered in daily life remains (Bosch-Capblanch et al., 2024).

Rapid technological developments in household electronics have led to the widespread use of new-generation appliances with motor systems, heating mechanisms, airflow technologies, and electronic control systems that differ from those of conventional devices. Countertop cooking appliances such as air fryers and advanced hair styling devices are among the most visible examples of this transition. Research has demonstrated that energy-based personal-care devices generate electromagnetic fields whose intensity and frequency characteristics differ substantially depending on device type and operating mode (Stam, 2024). Similarly, assessments of cooking appliances such as induction hobs have shown that their electromagnetic emission profiles are fundamentally determined by the underlying electrical principle rather than by the product generation alone (Gryz et al., 2020). Although these devices may offer advantages in terms of convenience, energy efficiency, speed, and user experience, it remains unclear whether their EMF exposure profiles differ from those of their conventional counterparts. Measurements conducted in everyday environments have shown that EMF levels may vary considerably depending on device type, measurement location, and conditions of use (Bonato et al., 2023). However, field-based studies directly comparing new-generation devices with conventional alternatives under real-life conditions remain limited, representing an important gap in the current literature.

Potential associations between EMF exposure and non-specific health complaints such as headache, fatigue, sleep disturbances, and anxiety have attracted considerable public health interest (Bagheri Hosseinabadi et al., 2019; Belyaev et al., 2016). Occupational and field-based studies have documented that chronic or repeated ELF-EMF exposure is associated with poorer sleep quality, elevated stress, depression, and anxiety in exposed groups (Bagheri Hosseinabadi et al., 2019). However, these outcomes are multifactorial and may be influenced by age, educational level, occupational conditions, psychosocial stress, lifestyle, pre-existing health conditions, sleep patterns, and other environmental exposures. Therefore, evaluating EMF exposure solely on the basis of measured field strength may provide an incomplete picture. Simultaneous assessment of exposure duration and frequency together with health indicators may offer a more comprehensive approach. In particular, combining objective EMF measurements with validated self-report instruments may enable a more integrated evaluation of the relationship between environmental exposure and perceived health status.

This issue is also relevant from a women's health perspective. Patterns of household appliance and personal-care device use may result in regular interaction with multiple potential sources of EMF exposure (Gryz et al., 2020; Stam, 2024)). Personal monitoring studies have shown that women's daily MF exposure is temporally variable and closely linked to appliance-use behavior, making use patterns an important determinant of total personal exposure (Lewis et al., 2016). Nevertheless, studies specifically examining women's everyday use of

new-generation and conventional household appliances while simultaneously evaluating headache impact, fatigue, anxiety, and sleep quality remain scarce. Accordingly, investigating device-related exposure together with user characteristics and health indicators may provide a broader perspective on environmental exposure in women.

Another important limitation of the existing literature is that many EMF studies have focused on general environmental exposure, communication technologies, or individual devices considered in isolation (Bonato et al., 2023; Gajšek et al., 2016). In contrast, studies comparing technologically different generations of commonly used household appliances within the same research framework are relatively uncommon. Moreover, it cannot be assumed that a technologically more advanced device necessarily produces either lower or higher EMF exposure, as device-specific physical characteristics are the primary determinants of emitted field levels (Bonato et al., 2023). For this reason, device-specific measurements obtained under actual conditions of use are needed rather than assumptions based solely on whether a device is categorized as new-generation or conventional.

The present study was designed to address this gap by comparing magnetic flux density measured in microtesla (μT) during the real-life use of new-generation and conventional household and personal-care appliances and by examining these measurements in relation to headache impact, fatigue, anxiety, and sleep quality among women. A key strength of the study is that it separately compares new-generation and conventional technologies across two appliance categories, relates individual magnetic field measurements to duration and frequency of use, and evaluates objective exposure indicators together with validated health measures within the same analytical framework. Thus, rather than assuming that new-generation appliances systematically generate higher or lower magnetic field exposure, the study empirically evaluates whether exposure varies according to appliance type and patterns of use.

Accordingly, the primary aim of this study was to compare magnetic flux density measured during the use of new-generation and conventional electronic household and personal-care appliances among women and to investigate its relationships with headache impact, fatigue, anxiety, and sleep quality. A secondary aim was to examine the associations between appliance-use duration and frequency and these health indicators.

2. Materials and Methods

2.1. Study Design

This study was conducted as a controlled, cross-sectional comparative study to compare magnetic field exposure and health indicators among women using new-generation and conventional electronic household and personal-care appliances. No experimental exposure was administered to the participants. Instead, magnetic flux density was measured under real-life conditions while participants were using appliances that were already part of their daily routines.

Magnetic field exposure was evaluated not only according to appliance type but also in relation to individual usage characteristics, including duration of use, frequency of use, and total years of appliance use. In addition, objectively measured magnetic flux density was assessed together with validated self-report measures of headache impact, fatigue, anxiety, and sleep quality.

2.2. Population and Sample

The study population consisted of women living in Istanbul who actively used either new-generation or conventional electronic household appliances. A total of 56 women participated in the study, with ages ranging from 18 to 55 years. Participants were recruited using purposive and snowball sampling methods.

Participants were evaluated separately according to appliance category. Among the 36 women who used hair styling devices, 20 used new-generation hair stylers and 16 used conventional hair styling devices. Among the 20 women included in the cooking-appliance category, 10 used air fryers and 10 used conventional electric ovens. Participants were not randomized; instead, they were classified according to the appliances they routinely used in their daily lives.

This device-specific classification allowed new-generation and conventional technologies to be compared separately within each appliance category, thereby avoiding the potential loss of appliance-specific exposure differences that could occur if all devices were combined into a single general classification.

2.3. Inclusion and Exclusion Criteria

Women were eligible for inclusion if they lived in Istanbul, were able to read and write in Turkish, actively used at least one of the appliances evaluated in the study, and agreed to complete the data collection forms and use the portable EMF measurement device.

Women who were pregnant or breastfeeding; those occupationally exposed to relatively high levels of electromagnetic fields, such as radiology technicians; and those with a diagnosis of chronic migraine, clinically diagnosed sleep disorder, major psychiatric disorder, multiple sclerosis, or electromagnetic hypersensitivity were excluded from the study. These criteria were applied to reduce the potential confounding effects of pre-existing clinical conditions that could independently influence the main health outcomes of the study, including headache, sleep quality, fatigue, and anxiety.

2.4. Data Collection Instruments

Data were collected using the Descriptive Information and Appliance Use Form, Electromagnetic Field Measurement and Recording Form, Chalder Fatigue Scale, anxiety subscale of the Depression Anxiety Stress Scale-21 (DASS-21), Richards-Campbell Sleep Questionnaire, and Headache Impact Test-6 (HIT-6).

2.4.1. Descriptive Information and Appliance Use Form

The form was developed by the researchers based on the relevant literature to assess participants' sociodemographic characteristics and patterns of electronic appliance use. It included information on age, educational level, and occupation, as well as appliance type, total years of appliance use, weekly frequency of use, and weekly duration of use. These variables were used to characterize participants' appliance-use patterns and to examine their relationships with EMF measurements and health indicators.

2.4.2. Electromagnetic Field Measurement and Recording Form

Magnetic field exposure was measured using a portable Benetech GM3120 Electromagnetic Field Radiation Detector (Benetech, GM3120). In this study, magnetic field measurements were recorded in microtesla (μT). Participants received standardized instructions from the researchers regarding the use of the measurement device, and measurements were performed under real-life conditions while participants were using their household or personal-care appliances.

Measurements were obtained during the use of both new-generation and conventional hair styling devices. The same procedure was applied to participants using air fryers and conventional electric ovens. During appliance operation, the measurement device was held at a distance of approximately 10–15 cm from the appliance, corresponding to the typical distance between the appliance and the user during routine use. The magnetic flux density measured during appliance operation was recorded on a standardized form prepared by the researchers, together with appliance-use characteristics.

The new-generation and conventional appliances included in the study were newly purchased and had not been routinely used before the measurements. Each appliance was used no more than twice during the measurement procedures.

2.4.3. Chalder Fatigue Scale

The Chalder Fatigue Scale was developed by Chalder et al. to assess physical and mental fatigue (Chalder et al., 1993). The scale consists of 11 items, including seven items assessing physical fatigue and four assessing mental fatigue. Using the 0–3 scoring method, the total score ranges from 0 to 33, with higher scores indicating greater fatigue severity. The psychometric properties of the Turkish version were evaluated by Adın et al. (Adın et al., 2022).

In the present study, the total scale score was used, with higher scores interpreted as indicating greater fatigue.

2.4.4. DASS-21 Anxiety Subscale

The Depression Anxiety Stress Scale-21 (DASS-21) is a self-report instrument comprising three seven-item subscales assessing symptoms of depression, anxiety, and stress (Lovibond & Lovibond, 1995).. Only the seven-item anxiety subscale was used in the present study. Each item was scored from 0 to 3, resulting in a raw anxiety score ranging from 0 to 21, with higher scores indicating greater anxiety symptoms. The validity and reliability of the Turkish short form were established by Yılmaz et al. (Yılmaz et al., 2017).

The raw anxiety subscale score (0–21) was used in the statistical analyses.

2.4.5. Richards-Campbell Sleep Questionnaire

The Richards-Campbell Sleep Questionnaire (RCSQ) is a six-item visual analogue instrument developed to assess perceived sleep quality (Richards, 1987). The questionnaire evaluates sleep depth, sleep latency, frequency of awakenings, time spent awake after awakening, overall sleep quality, and perceived environmental noise. Each item is scored on a 0–100 scale. The sixth item, which assesses environmental noise, is not included in the overall sleep quality score; the overall assessment is based on the first five items. Higher scores indicate better perceived sleep quality. The validity and reliability of the Turkish version were established by Özlü and Özer (Özlü and Özer 2015)

In this study, RCSQ scores were evaluated on a 0–100 scale, with higher scores representing better sleep quality. Sleep quality was also examined according to categorical classifications ranging from very poor to very good sleep.

2.4.6. Headache Impact Test-6 (HIT-6)

The Headache Impact Test-6 (HIT-6) is a six-item instrument designed to assess the impact of headache on daily functioning. It evaluates several domains affected by headache, including pain, vitality, psychological distress, social functioning, role functioning, and cognitive functioning. Items are scored using five response categories, producing a total score ranging from 36 to 78, with higher scores indicating a greater impact of headache on daily life.

Scores of ≤ 49 indicate little or no impact, scores of 50–55 indicate some impact, scores of 56–59 indicate substantial impact, and scores of ≥ 60 indicate severe impact (Kosinski et al., 2003). The reliability and validity of the Turkish version were demonstrated by Dikmen et al. (Yalinay Dikmen et al., 2021).

2.6. Data Collection Procedure

Women who met the eligibility criteria were informed about the aim, scope, and data collection procedures of the study, and written informed consent was obtained from all participants. The Descriptive Information and Appliance Use Form and the study scales were completed by participants with guidance from the researchers when needed.

Participants received practical instruction on the use of the Benetech GM3120 Electromagnetic Field Radiation Detector. Magnetic field measurements were performed under normal real-life conditions while participants used appliances that were already part of their daily routines. Measurements were obtained during the use of air fryers or new-generation hair styling devices in the new-generation appliance group and conventional electric ovens or conventional hair styling devices in the conventional appliance group. Magnetic flux density was recorded in microtesla (μT). Weekly duration of appliance use, weekly frequency of use, and total years of appliance use were also recorded.

After collection, the measurement and data collection forms were reviewed by the researchers for missing or inconsistent data. The eligibility of the recorded measurements for inclusion in the statistical analysis was evaluated according to the study protocol.

2.7. Study Variables

The primary exposure variable was magnetic flux density (μT) measured during appliance use. Weekly duration of use, weekly frequency of use, and total years of appliance use were evaluated as additional appliance-use variables.

The primary grouping variable was whether the appliance was classified as new-generation or conventional. Comparisons were performed separately for hair styling devices and cooking appliances.

Health outcome variables included total scores from the Headache Impact Test-6 (HIT-6), Chalder Fatigue Scale, DASS-21 Anxiety Subscale, and Richards-Campbell Sleep Questionnaire. Sociodemographic characteristics, including age, educational level, and occupation, were evaluated as descriptive variables.

2.8. Statistical Analysis

Data were analyzed using statistical software (IBM SPSS Statistics-26). Continuous variables were summarized using means, standard deviations, minimum values, and maximum values, whereas categorical variables were presented as frequencies and percentages. Independent-samples t tests were used to compare continuous variables between users of new-generation and conventional appliances. Pearson's chi-square test was used for comparisons of categorical variables between groups. Hair styling devices and cooking appliances were analyzed as separate appliance categories. Relationships among magnetic flux density, appliance-use characteristics, and health scale scores were evaluated using Pearson correlation analysis. Correlation coefficients were interpreted according to their direction and magnitude. To quantify the magnitude of between-group differences, Cohen's d effect sizes and 95% confidence intervals were calculated. All statistical tests were two-sided, and a p value < 0.05 was considered statistically significant.

2.9. Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Maltepe University Non-Interventional Scientific Research Ethics Committee (meeting date: May 15, 2025; meeting no: 2025/09; decision no: 2025/09–10). Written informed consent was obtained from all participants before data collection. Participant data were anonymized and kept confidential throughout the study.

3. Results

3.1. Descriptive Characteristics of the Participants

A total of 56 women participated in the study. The mean age of the participants was 36.88 ± 9.07 years, with an age range of 18–55 years. Regarding educational attainment, 39.3% of the participants had postgraduate education, 35.7% had an undergraduate degree, 21.4% had completed high school, and 3.6% had eight years or less of formal education.

Teachers/academics constituted the largest occupational group (39.3%). Students and homemakers each accounted for 17.9% of the sample, followed by healthcare professionals (10.7%), self-employed participants (7.1%), engineers/architects (3.6%), and those working in finance/accounting (3.6%) (Table 1).

Table 1
Descriptive characteristics of the women

Characteristics	n	%
Education		
≤ 8 years	2	3.60
High school	12	21.40
Undergraduate	20	35.70
Postgraduate	22	39.30
Occupation		
Teacher/academic	22	39.30
Student	10	17.90
Homemaker	10	17.90
Healthcare professional	6	10.70
Self-employed	4	7.10
Engineer/architect	2	3.60
Finance/accounting	2	3.60
Age, years	36.88 ± 9.07	18.00–55.00

Note. n: number; %: percentage. Age is presented as mean ± SD and range (min–max). SD: standard deviation.

3.2. Comparison of Appliance-Use Characteristics and Magnetic Flux Density

Among the 36 women using hair styling devices, 20 (55.6%) used new-generation hair stylers and 16 (44.4%) used conventional hair styling devices. Weekly duration of use was significantly longer among users of new-generation hair stylers than among users of conventional devices (15.40 ± 7.44 vs. 9.19 ± 6.46 min/week; t = 2.64, p = 0.013; Cohen's d = 0.89, 95% CI: 0.19–1.57). Weekly frequency of use was also higher among users of new-generation devices, although the difference did not reach statistical significance (4.05 ± 2.21 vs. 2.88 ± 1.36 times/week; t = 1.96, p = 0.059).

Total years of appliance use were significantly greater among conventional hair styler users than among new-generation hair styler users (4.31 ± 2.96 vs. 1.70 ± 0.80 years; t = -3.43, p = 0.003; Cohen's d = -1.27). Mean magnetic flux density was significantly lower for new-generation hair stylers than for conventional hair styling devices (14.89 ± 11.28 vs. 38.24 ± 20.39 μT; t = -4.11, p < 0.001; Cohen's d = -1.46, 95% CI: -2.20 to -0.71).

Among the 20 women using cooking appliances, 10 (50.0%) used air fryers and 10 (50.0%) used conventional electric ovens. Weekly duration of use was significantly longer among conventional oven users than among air fryer users (96.00 ± 30.98 vs. 48.30 ± 49.58 min/week; t = -2.58, p = 0.021; Cohen's d = -1.15). In contrast,

weekly frequency of use was significantly higher among air fryer users (2.50 ± 0.85 vs. 1.50 ± 0.53 times/week; t = 3.16, p = 0.005; Cohen's d = 1.41).

Total years of appliance use were significantly greater for conventional ovens than for air fryers (5.00 ± 3.37 vs. 1.70 ± 0.67 years; t = -3.04, p = 0.013). Mean magnetic flux density was significantly higher during air fryer use than during conventional oven use (29.95 ± 19.88 vs. 5.20 ± 1.95 μT; t = 3.92, p = 0.003; Cohen's d = 1.75, 95% CI: 0.69–2.78) (Table 2).

Table 2
Appliance-use characteristics and magnetic flux density measurements

Characteristic	New-generation	Conventional	t; p	Cohen's d	95% CI
Hair styling devices (n = 36)	**Dyson (n = 20; 55.6%)**	**Other brands (n = 16; 44.4%)**	Group distribution p = 0.618		
Weekly duration of use, min	15.40 ± 7.44 (5.00–30.00)	9.19 ± 6.46 (1.00–25.00)	2.64; 0.013	0.89	0.19 to 1.57
Weekly frequency of use, times	4.05 ± 2.21 (1.00–7.00)	2.88 ± 1.36 (1.00–5.00)	1.96; 0.059	0.62	-0.06 to 1.29
Total duration of use, years	1.70 ± 0.80 (1.00–3.00)	4.31 ± 2.96 (1.00–10.00)	-3.43; 0.003	-1.27	-1.99 to -0.54
Magnetic flux density, μT	14.89 ± 11.28 (1.90–42.00)	38.24 ± 20.39 (2.00–73.35)	-4.11; <0.001	-1.46	-2.20 to -0.71
Cooking appliances (n = 20)	**Air fryer (n = 10; 50.0%)**	**Conventional electric oven (n = 10; 50.0%)**	Group distribution p = 1.00		
Weekly duration of use, min	48.30 ± 49.58 (10.00–120.00)	96.00 ± 30.98 (60.00–120.00)	-2.58; 0.021	-1.15	-2.09 to -0.19
Weekly frequency of use, times	2.50 ± 0.85 (1.00–4.00)	1.50 ± 0.53 (1.00–2.00)	3.16; 0.005	1.41	0.41 to 2.39
Total duration of use, years	1.70 ± 0.67 (1.00–3.00)	5.00 ± 3.37 (1.00–10.00)	-3.04; 0.013	-1.36	-2.33 to -0.36
Magnetic flux density, μT	29.95 ± 19.88 (1.50–61.50)	5.20 ± 1.95 (2.06–7.96)	3.92; 0.003	1.75	0.69 to 2.78

Note. Values are presented as mean ± SD (min–max), unless otherwise indicated. Independent-samples t tests were used for continuous variables, and effect sizes were calculated using Cohen's d. CI: confidence interval; SD: standard deviation; μT: microtesla

3.3. Comparison of Health Indicators According to Appliance Type

No statistically significant differences were observed between users of new-generation and conventional hair styling devices in HIT-6, Chalder Fatigue Scale, DASS-21 Anxiety Subscale, or Richards-Campbell Sleep Questionnaire scores (all $p > 0.05$).

The mean HIT-6 score was 52.70 ± 8.49 among users of new-generation hair stylers and 51.75 ± 9.86 among users of conventional devices ($p = 0.76$). Corresponding Chalder Fatigue Scale scores were 12.60 ± 6.85 and 12.69 ± 5.62 ($p = 0.97$), anxiety scores were 2.90 ± 2.63 and 1.88 ± 3.10 ($p = 0.29$), and Richards-Campbell Sleep Questionnaire scores were 65.30 ± 20.41 and 65.00 ± 19.89 ($p = 0.96$), respectively. The distribution of sleep quality categories also did not differ significantly according to hair styling device type ($\chi^2 = 3.578$, $p = 0.311$).

Similarly, no statistically significant differences were found between air fryer and conventional oven users in HIT-6 (53.30 ± 6.67 vs. 57.60 ± 11.69; $p = 0.33$), Chalder Fatigue Scale (11.60 ± 4.22 vs. 13.50 ± 9.59; $p = 0.57$), anxiety (3.30 ± 3.59 vs. 3.90 ± 4.58; $p = 0.75$), or Richards-Campbell Sleep Questionnaire scores (67.10 ± 26.69 vs. 56.20 ± 35.10; $p = 0.44$). The distribution of sleep quality categories was also similar between the two cooking-appliance groups ($\chi^2 = 3.133$, $p = 0.372$) (Table 3).

Table 3
Comparison of health scale scores according to appliance type

Measure	New-generation	Conventional	t; p	Cohen's d	95% CI
Hair styling devices (n = 36)	**Dyson (n = 20)**	**Other brands (n = 16)**			
HIT-6	52.70 ± 8.49 (38.00–67.00)	51.75 ± 9.86 (36.00–68.00)	0.31; 0.76	0.10	-0.55 to 0.76
Chalder Fatigue Scale	12.60 ± 6.85 (4.00–30.00)	12.69 ± 5.62 (3.00–22.00)	-0.04; 0.97	-0.01	-0.67 to 0.64
DASS-21 Anxiety	2.90 ± 2.63 (0.00–8.00)	1.88 ± 3.10 (0.00–12.00)	1.07; 0.29	0.36	-0.31 to 1.02
Richards-Campbell Sleep Questionnaire	65.30 ± 20.41 (32.00–100.00)	65.00 ± 19.89 (20.00–95.00)	-0.44; 0.96	0.15	-0.64 to 0.67
Sleep quality classification	**n (%)**	**n (%)**	**χ^2 = 3.578; p = 0.311**		
Very poor sleep	0 (0.0)	1 (6.25)			
Poor sleep	6 (30.0)	2 (12.50)			
Good sleep	6 (30.0)	8 (50.00)			
Very good sleep	8 (40.0)	5 (31.25)			
Cooking appliances (n = 20)	**Air fryer (n = 10)**	**Conventional electric oven (n = 10)**			
HIT-6	53.30 ± 6.67 (44.00–61.00)	57.60 ± 11.69 (42.00–76.00)	-1.01; 0.33	-0.45	-1.33 to 0.44
Chalder Fatigue Scale	11.60 ± 4.22 (5.00–20.00)	13.50 ± 9.59 (0.00–33.00)	-0.57; 0.57	-0.26	-1.13 to 0.63
DASS-21 Anxiety	3.30 ± 3.59 (0.00–12.00)	3.90 ± 4.58 (0.00–13.00)	-0.33; 0.75	-0.15	-1.02 to 0.73
Richards-Campbell Sleep Questionnaire	67.10 ± 26.69 (10.00–96.00)	56.20 ± 35.10 (8.00–98.00)	0.78; 0.44	0.35	-0.54 to 1.23
Sleep quality classification	**n (%)**	**n (%)**	**χ^2 = 3.133; p = 0.372**		
Very poor sleep	1 (10.0)	2 (20.0)			
Poor sleep	1 (10.0)	3 (30.0)			

Note. Values are presented as mean ± SD (min–max) for continuous variables and n (%) for categorical variables. Independent-samples t tests were used for continuous variables;

Pearson's chi-square test was used for sleep-quality categories. HIT-6: Headache Impact Test-6; DASS-21: Depression Anxiety Stress Scale-21; CI: confidence interval; SD: standard deviation.

Measure	New-generation	Conventional	t; p	Cohen's d	95% CI
Hair styling devices (n = 36)	**Dyson (n = 20)**	**Other brands (n = 16)**			
Good sleep	4 (40.0)	1 (10.0)			
Very good sleep	4 (40.0)	4 (40.0)			
Note. Values are presented as mean ± SD (min–max) for continuous variables and n (%) for categorical variables. Independent-samples t tests were used for continuous variables;					
Pearson's chi-square test was used for sleep-quality categories. HIT-6: Headache Impact Test-6; DASS-21: Depression Anxiety Stress Scale-21; CI: confidence interval; SD: standard deviation.					

3.4. Associations Between Magnetic Flux Density, Appliance-Use Characteristics, and Health Indicators

Correlation analysis showed a weak negative association between mean magnetic flux density and weekly appliance-use duration ($r = -0.34$, $p < 0.05$). Mean magnetic flux density was not significantly associated with HIT-6, Richards-Campbell Sleep Questionnaire, Chalder Fatigue Scale, or anxiety scores (all $p > 0.05$). No significant associations were observed between magnetic flux density and weekly frequency of use or total years of appliance use.

Weekly appliance-use duration was negatively associated with Richards-Campbell Sleep Questionnaire scores ($r = -0.27$, $p < 0.05$) and positively associated with anxiety scores ($r = 0.28$, $p < 0.05$). Thus, longer weekly appliance-use duration was associated with lower sleep quality scores and higher anxiety scores. No significant associations were found between weekly duration of use and HIT-6 or Chalder Fatigue Scale scores.

Age was positively associated with total years of appliance use ($r = 0.33$, $p < 0.05$) and negatively associated with Richards-Campbell Sleep Questionnaire scores ($r = -0.27$, $p < 0.05$). Higher educational level was associated with higher sleep quality scores ($r = 0.43$, $p < 0.001$) and lower HIT-6 ($r = -0.33$, $p < 0.05$) and anxiety scores ($r = -0.44$, $p < 0.001$). Educational level was also weakly positively associated with mean magnetic flux density ($r = 0.28$, $p < 0.05$) (Table 4).

Table 4
Correlations among study variables

Variables	1	2	3	4	5	6	7	8	9	10
1. Age	1	-0.27*	-0.23	0.23	-0.08	0.33*	0.03	-0.27*	0.08	-0.04
2. Educational level		1	0.28*	-0.62***	0.31*	-0.24	-0.33*	0.43***	-0.24	-0.44***
3. Mean magnetic flux density			1	-0.34*	0.11	0.01	-0.04	-0.06	-0.03	-0.19
4. Weekly duration of appliance use, min				1	-0.33*	0.26	0.21	-0.27*	0.06	0.28*
5. Weekly frequency of appliance use					1	-0.15	0.15	-0.01	0.03	0.10
6. Total duration of appliance use, years						1	0.26	-0.19	0.13	0.17
7. HIT-6							1	-0.53***	0.55***	0.64***
8. RCSQ								1	-0.39**	-0.53***
9. Chalder Fatigue Scale									1	0.55***
10. DASS-21 Anxiety										1

Note. Pearson correlation coefficients are presented. HIT-6: Headache Impact Test-6; RCSQ: Richards-Campbell Sleep Questionnaire; DASS-21 Anxiety: anxiety subscale of the Depression Anxiety Stress Scale-21. *p < 0.05, **p < 0.01, ***p < 0.001.

3.5. Associations Among Health Indicators

Several significant correlations were observed among the health-related measures. HIT-6 scores were negatively associated with sleep quality scores ($r = -0.53$, $p < 0.001$) and positively associated with fatigue ($r = 0.55$, $p < 0.001$) and anxiety scores ($r = 0.64$, $p < 0.001$).

Richards-Campbell Sleep Questionnaire scores were negatively associated with Chalder Fatigue Scale scores ($r = -0.39$, $p < 0.01$) and anxiety scores ($r = -0.53$, $p < 0.001$). Fatigue and anxiety scores were also positively correlated ($r = 0.55$, $p < 0.001$) (Table 4).

4. Discussion

The present study revealed a contrasting pattern of magnetic field exposure across appliance categories. New-generation hair styling devices showed substantially lower magnetic flux density than conventional hair styling devices, whereas air fryers showed significantly higher magnetic flux density than conventional electric ovens. This opposing pattern is the most important finding of the study and indicates that technological generation alone cannot be used to predict magnetic field exposure. Instead, exposure appears to vary according to the specific appliance type and its technical and operational characteristics. Research on cooking appliances has similarly demonstrated that even within the same appliance category, magnetic field strength is strongly determined by device-specific engineering features rather than generation alone (Xi et al., 2025), while environmental ELF measurements confirm substantial variability across different source types (Kiouvrekis et al., 2021).

The difference observed for hair styling devices was particularly pronounced. Mean magnetic flux density was 14.89 ± 11.28 μT for new-generation hair stylers compared with 38.24 ± 20.39 μT for conventional devices, with a large effect size. Thus, among the products evaluated in this study, new-generation hair styling devices resulted in markedly lower magnetic field exposure during use. This finding is relevant because hair styling and drying devices are generally operated close to the head and may be used repeatedly as part of personal-care routines. WHO data demonstrate that magnetic field levels around hair dryers can vary widely between models and that apparently similar appliances may generate very different magnetic fields because of differences in product design. Magnetic field strength also decreases rapidly as distance from the appliance increases. These observations support the interpretation that the lower values observed for newer hair styling devices may reflect device-specific engineering characteristics rather than technological generation alone. ELF-EMF exposure measurements in various settings have likewise demonstrated that field intensity is highly sensitive to source design and measurement distance, and that even structurally similar devices may produce markedly different field levels (Jafarimanesh et al., 2025; Kiouvrekis et al., 2021).

In contrast, the findings for cooking appliances showed the opposite direction. Magnetic flux density during air fryer use was 29.95 ± 19.88 μT, compared with 5.20 ± 1.95 μT during conventional electric oven use, again with a large effect size. This result is important because it demonstrates within the same study that a newer appliance technology does not necessarily produce lower magnetic field exposure. WHO reports that magnetic fields generated by household appliances differ greatly between appliance types and even between apparently similar products, while field strength is strongly influenced by appliance design and measurement distance. Research specifically examining cooking appliances has confirmed that devices relying on electromagnetic induction principles generate strong alternating magnetic fields, with stray fields remaining substantial even at distances beyond the cookware (Xi et al., 2025). ICNIRP likewise emphasizes that low-frequency magnetic fields arise from electric current and are expressed as magnetic flux density in tesla, with household electrical appliances representing common sources of such fields. Studies examining ELF-EMF at 50 Hz have confirmed that such fields can exert biological effects depending on flux density and exposure duration, further supporting the need for appliance-specific measurement (Tekam et al., 2025). Therefore, the higher magnetic flux density observed for air fryers may reflect their specific electrical configuration, component arrangement, or operating characteristics. These mechanisms, however, were not directly examined in the present study.

Taken together, these two appliance categories clearly show that broad generalizations regarding "new-generation" and "conventional" electronic appliances are inappropriate. The newer technology was associated

with lower magnetic flux density in hair styling devices but higher magnetic flux density in cooking appliances. This suggests that magnetic field exposure should be evaluated on a product- and appliance-specific basis, rather than assuming that technological advancement is systematically associated with either lower or higher exposure (Kiouvrekis et al., 2021; Xi et al., 2025). This device-specific perspective may also be important for future studies evaluating household electromagnetic exposure.

Despite the marked differences in magnetic flux density between appliance groups, no significant differences were found in headache impact, fatigue, anxiety, or sleep quality. Similarly, mean magnetic flux density was not significantly correlated with any of these health indicators. These results suggest that the differences in short-term magnetic field exposure detected between appliances were not accompanied by measurable differences in the evaluated health outcomes in this sample. This finding is broadly consistent with WHO assessments indicating that current evidence does not establish a consistent relationship between low-level electromagnetic field exposure and non-specific symptoms such as headache, fatigue, or anxiety. Provocation studies using controlled EMF exposure protocols have similarly reported that symptom attribution in individuals with idiopathic environmental intolerance is largely unrelated to actual exposure conditions (Ledent et al., 2025). Surveys of individuals reporting electromagnetic hypersensitivity have further documented that the relationship between self-reported symptoms and measured field exposure remains inconsistent and is influenced by psychological and contextual factors (Redmayne and Reddel, 2021; Tatoń et al., 2022). WHO's comprehensive review of extremely low-frequency fields also highlights continuing uncertainties and methodological challenges in assessing possible health effects of such exposures.

Nevertheless, the absence of significant associations should not be interpreted as evidence that magnetic field exposure is universally without health effects. The present study assessed magnetic flux density during individual appliance-use sessions rather than long-term cumulative exposure. In addition, magnetic field intensity may change considerably according to appliance model, operating mode, and distance from the source. WHO data show particularly large variations in magnetic flux density near household appliances and a rapid decline in field intensity with increasing distance. Experimental work has demonstrated that periodic ELF-EMF exposure at relevant flux densities can affect cellular viability and organ-level biological responses in animal models, indicating that dose, duration, and continuity of exposure are important determinants of biological effect (Tekam et al., 2025). Furthermore, recent mechanistic reviews have highlighted that ELF-EMF may induce oxidative stress and neurobiological changes under conditions of repeated or sustained exposure (Leković, 2026). Therefore, the measurements obtained in this study should be interpreted as indicators of appliance-specific short-term exposure rather than total daily exposure.

An additional finding was that longer weekly appliance-use duration was associated with poorer sleep quality and higher anxiety, although magnetic flux density itself was not associated with these outcomes. This distinction suggests that duration of appliance use and magnetic field intensity may represent different dimensions of exposure. Experimental and field-based studies have reported that ELF electromagnetic fields may induce anxiety-like behavioral responses through neurobiological pathways, with the relationship depending on field parameters, exposure duration, and individual characteristics (Hosseini, 2024; Sert et al., 2024). Reviews of EMF effects on mood and circadian rhythm have further suggested that prolonged or repeated exposure to electromagnetic fields may disrupt sleep-wake regulation and emotional processing, independently of acute field intensity (Zou et al., 2025). Consistent with this, research on expectations and

symptom attribution has shown that factors beyond measured field intensity—including behavioral and psychological variables—substantially influence reported fatigue and well-being outcomes in EMF exposure contexts (Yang et al., 2025). Longer appliance use may also reflect behavioral, occupational, domestic, or lifestyle characteristics that influence sleep and anxiety independently of magnetic field exposure. Because of the cross-sectional design, causal direction cannot be established.

The correlations among the health measures further support a multifactorial interpretation. Greater headache impact was associated with higher fatigue and anxiety and poorer sleep quality, while poorer sleep quality was also associated with greater fatigue and anxiety. These relationships indicate that the health indicators examined in this study are closely interconnected. Bibliometric analyses of EMF-related nervous system research similarly emphasize that neurological, psychological, and sleep-related outcomes cluster together in the EMF literature, reflecting the shared pathways through which electromagnetic exposures may exert influence (Liang et al., 2026). Studies examining community-level EMF exposure have also found concurrent elevations in anxiety and depression scores among exposed individuals, further illustrating the interrelated nature of these symptoms (Sert et al., 2024). Consequently, non-specific symptoms such as fatigue, headache, anxiety, and sleep problems should not be attributed solely to appliance-related magnetic field exposure without considering broader psychological and behavioral factors (Hosseini, 2024; Ledent et al., 2025; Yang et al., 2025).

The focus on women is also relevant to the exposure scenarios examined. Hair styling devices are commonly used during personal-care routines and typically operate close to the head, while cooking appliances may constitute repeated sources of exposure during household activities. These exposure contexts are particularly relevant for women in settings where personal-care practices and domestic food preparation may involve frequent use of such appliances. Reviews of non-ionizing electromagnetic radiation and women's health have highlighted that female biological systems, including reproductive tissues, may respond differently to EMF exposure, and have called for sex-disaggregated assessments of household electromagnetic exposure (Jangid et al., 2023). Furthermore, the potential for EMF to affect neurological and behavioral outcomes in women has been underscored in recent work documenting associations between long-term exposure and disrupted social and reproductive functioning (Leković, 2026). However, because only women were included and no comparison with men was performed, the findings should not be interpreted as evidence of sex-based differences in magnetic field exposure.

Overall, the findings indicate that new-generation appliances cannot be classified as uniformly producing either higher or lower magnetic field exposure than conventional appliances. New-generation hair styling devices were associated with considerably lower magnetic flux density, whereas air fryers were associated with higher magnetic flux density than conventional ovens (Kiouvrekis et al., 2021; Xi et al., 2025). At the same time, measured magnetic flux density was not directly associated with headache impact, fatigue, anxiety, or sleep quality (Ledent et al., 2025; Tatoń et al., 2022). These results support an appliance-specific approach to household magnetic field exposure assessment rather than broad classification according to technological generation.

Strengths and Limitations

A strength of this study is the use of direct magnetic flux density measurements during real-life appliance use together with validated health measures and separate comparisons across two appliance categories. However, the cross-sectional design prevents causal inference, and the relatively small sample, particularly within the cooking-appliance groups, limits generalizability. Magnetic flux density was measured during a single use session and may not represent cumulative exposure; measurements may also be influenced by appliance model, operating mode, and measurement distance. Future studies should therefore include larger samples, repeated measurements, standardized measurement conditions, and detailed model-specific exposure assessments.

5. Conclusion

The present study showed that magnetic field exposure from electronic household and personal-care appliances cannot be generalized solely according to whether a device is classified as new-generation or conventional. New-generation hair styling devices were associated with substantially lower magnetic flux density than conventional hair styling devices, whereas air fryers showed significantly higher magnetic flux density than conventional electric ovens. These contrasting findings indicate that magnetic field exposure is appliance-specific and may vary according to the technical and operational characteristics of individual products.

Despite the observed differences in magnetic flux density, no significant associations were found between magnetic flux density and headache impact, fatigue, anxiety, or sleep quality. However, longer weekly appliance-use duration was associated with poorer sleep quality and higher anxiety scores. Future studies should therefore include larger samples, repeated measurements under standardized conditions, and a wider range of appliance brands and models to better characterize cumulative and device-specific exposure. Longitudinal studies may also help clarify the possible relationships between long-term appliance-use patterns and health outcomes.

Declarations

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Authors' Contributions

Conceptualization: Ö.İ. and S.K.; Methodology: Ö.İ. and S.K.; Data Collection: Ö.İ. and S.K.; Formal Analysis: T.B.; Writing – Original Draft Preparation: Ö.İ.; Writing – Review and Editing: Ö.İ., S.K., and T.B. All authors read and approved the final manuscript.

Ethical Approval

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Maltepe University Non-Interventional Scientific Research Ethics Committee (meeting date: May 15, 2025; meeting no: 2025/09; decision no: 2025/09-10).

Consent to Participate

Written informed consent was obtained from all participants before participation in the study.

Consent to Publish

Not applicable. The manuscript does not contain identifiable personal data, images, or other information requiring individual consent for publication.

Human Ethics and Consent to Participate

This study involved human participants and was approved by the Maltepe University Non-Interventional Scientific Research Ethics Committee (meeting date: May 15, 2025; meeting no: 2025/09; decision no: 2025/09-10). Written informed consent was obtained from all participants.

Competing Interests

The authors declare no competing interests.

Data Availability Statement

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request, subject to ethical and confidentiality restrictions.

Clinical Trial Number

Clinical trial number: not applicable.

References

1. Adın RM, Ceren AN, Salcı Y, Fil Balkan A, Armutlu K, Ayhan Kuru Ç (2022) Dimensionality, psychometric properties, and population-based norms of the Turkish version of the Chalder Fatigue Scale among adults. Health Qual Life Outcomes 20:161. https://doi.org/10.1186/s12955-022-02074-x
2. Bagheri Hosseinabadi M, Khanjani N, Ebrahimi MH, Haji B, Abdolahfard M (2019) The effect of chronic exposure to extremely low-frequency electromagnetic fields on sleep quality, stress, depression and anxiety. Electromagn Biol Med 38:96–101. https://doi.org/10.1080/15368378.2018.1545665
3. Belyaev I, Dean A, Eger H, Hubmann G, Jandrisovits R, Kern M, Kundi M, Moshammer H, Lercher P, Müller K, Oberfeld G, Ohnsorge P, Pelzmann P, Scheingraber C, Thill R (2016) EUROPAEM EMF Guideline 2016 for the prevention, diagnosis and treatment of EMF-related health problems and illnesses. Rev Environ Health 31:363–397. https://doi.org/10.1515/reveh-2016-0011
4. Bonato M, Chiaramello E, Parazzini M, Gajšek P, Ravazzani P (2023) Extremely Low Frequency Electric and Magnetic Fields Exposure: Survey of Recent Findings. IEEE J Electromagn RF Microw Med Biol 7:216–

228. https://doi.org/10.1109/JERM.2023.3268555

5. Bosch-Capblanch X, Esu E, Oringanje CM, Dongus S, Jalilian H, Eyers J, Auer C, Meremikwu M, Röösli M (2024) The effects of radiofrequency electromagnetic fields exposure on human self-reported symptoms: A systematic review of human experimental studies. Environ Int 187:108612. https://doi.org/10.1016/j.envint.2024.108612
6. Chalder T, Berelowitz G, Pawlikowska T, Watts L, Wessely S, Wright D, Wallace EP (1993) Development of a fatigue scale. J Psychosom Res 37:147–153. https://doi.org/10.1016/0022-3999(93)90081-p
7. Gajšek P, Ravazzani P, Grellier J, Samaras T, Bakos J, Thuróczy G (2016) Review of Studies Concerning Electromagnetic Field (EMF) Exposure Assessment in Europe: Low Frequency Fields (50 Hz–100 kHz). Int J Environ Res Public Health 13:875. https://doi.org/10.3390/ijerph13090875
8. Gryz K, Karpowicz J, Zradziński P (2020) Evaluation of the Influence of Magnetic Field on Female Users of an Induction Hob in Ergonomically Sound Exposure Situations. Bioelectromagnetics 41:500–510. https://doi.org/10.1002/bem.22283
9. Hosseini E (2024) Ubiquitous extremely low frequency electromagnetic fields induces anxiety-like behavior: mechanistic perspectives. Electromagn Biol Med 43:220–235. https://doi.org/10.1080/15368378.2024.2380305
10. Jafarimanesh S, Ehsani H, Shaki F, Moosazadeh M, Samaei SE (2025) Investigating the Effects of Occupational Noise and Extremely Low-Frequency Electromagnetic Field Exposure on Oxidative Response in Power Plant Workers. Bioelectromagnetics 46:e70027. https://doi.org/10.1002/bem.70027
11. Jangid P, Rai U, Sharma RS, Singh R (2023) The role of non-ionizing electromagnetic radiation on female fertility: A review. Int J Environ Health Res 33:358–373. https://doi.org/10.1080/09603123.2022.2030676
12. Kiouvrekis Y, Alexias A, Softa V, Alkhorayef M, Sulieman A, Tyrakis C, Kappas C (2021) Extremely Low Frequency Electromagnetic Exposure Assessment In Schools: A Statistical Analysis Of Urban And Semi-Urban Areas. Radiat Prot Dosimetry 194:76–81. https://doi.org/10.1093/rpd/ncab076
13. Kosinski M, Bayliss MS, Bjorner JB, Ware JE, Garber WH, Batenhorst A, Cady R, Dahlöf CGH, Dowson A, Tepper S (2003) A six-item short-form survey for measuring headache impact: the HIT-6. Qual Life Res 12:963–974. https://doi.org/10.1023/A:1026119331193
14. Ledent M, Bordarie J, Vatovez B, Dieudonné M, Prignot N, Vanderstraeten J, Bouland C, De Clercq EM (2025) Exposure Perception and Symptom Reporting in Idiopathic Environmental Intolerance Attributed to Electromagnetic Fields Using a Co-Designed Provocation Test. Bioelectromagnetics 46:e70006. https://doi.org/10.1002/bem.70006
15. Leković Ž (2026) Electromagnetic fields and oxidative stress: The link to the development of cancer, neurological diseases, and behavioral disorders. Electromagn Biol Med 45:94–118. https://doi.org/10.1080/15368378.2025.2567872
16. Lewis RC, Hauser R, Wang L, Kavet R, Meeker JD (2016) Personal power-frequency magnetic field exposure in women recruited at an infertility clinic: association with physical activity and temporal variability. Radiat Prot Dosimetry 168:478–488. https://doi.org/10.1093/rpd/ncv365
17. Liang K, Zhou W, Li X, Wu J, Li D, Xie Y, Wei X (2026) Quantitative analysis and trends in the study of the effects of electromagnetic radiation on the nervous system from a bibliometric perspective. Electromagn Biol Med 45:123–136. https://doi.org/10.1080/15368378.2025.2568667

18. Lovibond PF, Lovibond SH (1995) The structure of negative emotional states: Comparison of the Depression Anxiety Stress Scales (DASS) with the Beck Depression and Anxiety Inventories. Behav Res Ther 33:335–343. https://doi.org/10.1016/0005-7967(94)00075-U
19. Özlü ZK, Özer N (2015) Richard-Campbell Sleep Questionnaire Validity and Reliability Study. Turk J Sleep Med 2:29–32. https://doi.org/10.4274/jtsm.02.008
20. Redmayne M, Reddel S (2021) Redefining electrosensitivity: A new literature-supported model. Electromagn Biol Med 40:227–235. https://doi.org/10.1080/15368378.2021.1874971
21. Sert C, Başak N, Koruk İ (2024) Electric and magnetic field pollution in near substations and investigation of anxiety and depressive effects on adult individuals living in this area. Electromagn Biol Med 43:145–155. https://doi.org/10.1080/15368378.2024.2348574
22. Stam R (2024) New developments in cosmetic applications of electromagnetic fields: Client and occupational hazard assessment. Bioelectromagnetics 45:251–259. https://doi.org/10.1002/bem.22503
23. Tatoń G, Kacprzyk A, Rok T, Pytlarz M, Pawlak R, Rokita E (2022) A survey on electromagnetic hypersensitivity: the example from Poland. Electromagn Biol Med 41:52–59. https://doi.org/10.1080/15368378.2021.1995873
24. Tekam CKS, Majumdar S, Kumari P, Prajapati SK, Sahi AK, Singh R, Krishnamurthy S, Mahto SK (2025) Effects of extremely low-frequency (50 Hz) electromagnetic fields on vital organs of adult Wistar rats and viability of mouse fibroblast cells. Radiat Prot Dosimetry 201:88–104. https://doi.org/10.1093/rpd/ncae220
25. Xi J, Kühn S, Fortunato C, Ofli E, Kuster N (2025) Evaluation of Exposure Assessment Methods and Procedures for Induction Hobs. Bioelectromagnetics 46:e70024. https://doi.org/10.1002/bem.70024
26. Yalinay Dikmen P, Bozdag M, Gunes M, Kosak S, Tasdelen B, Uluduz D, Ozge A (2021) Reliability and validity of Turkish version of Headache Impact Test (HIT-6) in patients with migraine. Noro Psikiyatr Ars 58:300–307. https://doi.org/10.29399/npa.24956
27. Yang L, Ding X, Zhang S, Wu T (2025) Impact of expectancy on fatigue by exposure to the fifth generation of mobile communication signals. Electromagn Biol Med 44:267–278. https://doi.org/10.1080/15368378.2025.2496151
28. Yılmaz Ö, Boz H, Arslan A (2017) The validity and reliability of the Turkish short form of the Depression Anxiety Stress Scale-21 (DASS-21). Finans Ekon Sos Araşt Derg 2:78–91 (in Turkish). https://dergipark.org.tr/en/pub/fesa/article/323190
29. Zou D-F, Li Z-H, Liu Y-B, Wang C-Z (2025) Progress in the study of the effects of electromagnetic radiation on the mood and rhythm. Electromagn Biol Med 44:212–227. https://doi.org/10.1080/15368378.2025.2460971