The Relationship between Proximity to Television Transmission Towers and the Health Conditions of Secondary School Students in the Bangkok Metropolitan Area

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Abstract

Exposure to radiofrequency electromagnetic fields (RF-EMF) emitted from television transmission towers has raised public health concerns, particularly among vulnerable groups such as children and adolescents. This study examined the relationship between residential proximity to television transmission towers and various dimensions of well-being physical health, emotional health, sleep quality, and chronic illnesses and assessed the role of personal factors. The sample comprised 260 upper secondary school students in the Bangkok Metropolitan Region. Data were collected through questionnaires and analyzed using descriptive statistics, chi-square tests, and multiple logistic regression. The findings revealed that living near a television transmission tower (≤ 500 meters) was significantly associated with emotional symptoms. Students residing closer to the towers were more likely to exhibit emotional disturbances than those living farther away (aOR = 2.22, 95% CI: 1.05–4.72, p = 0.037). A cumulative grade point average (GPA) above 3.00 was linked to a higher risk of sleep problems (aOR = 4.72, 95% CI: 1.42–15.66, p = 0.011), whereas a history of allergies appeared protective against chronic illnesses (aOR = 0.53, 95% CI: 0.31–0.91, p = 0.021). No other variables showed statistically significant associations. In conclusion, residing close to television transmission towers may be related to emotional disturbances among students, while academic performance and allergic history influence sleep and chronic health conditions. These findings highlight the need for health monitoring in educational settings and further research to confirm the observed associations.

Keywords: Television Transmission Tower, Electromagnetic Waves, Well-being, Secondary School Students

1. Introduction

1.1 Background and Significance

The continuous advancement of wireless communication technology over the past few decades including mobile phones, wireless internet, and modern electronic devices has led to increasing dependence on signal transmission through broadcasting towers that emit radiofrequency electromagnetic fields (RF-EMF). The propagation of these waves extends widely across communities, schools, and households, resulting in constant exposure among residents living nearby (Bodewein et al., 2022). Although no clear scientific conclusion has been reached regarding long-term health effects, children and adolescents are considered vulnerable populations requiring special attention. Their bodies are still developing, and the growth of the brain, nervous system, and immune system is not fully mature, causing differences in localized absorption compared to adults (Fernández-Rodríguez et al., 2015). The potential impacts of RF-EMF exposure among children and adolescents can be discussed in several aspects: (1) Physical health: studies have found correlations between mobile phone use and self-reported acute physical symptoms, such as headaches and insomnia, among students (Durusoy et al., 2017). Research using personal dosimeters have also shown that adolescents with higher evening exposure levels experience stronger daytime headaches and sleep disturbances (Heinrich et al., 2010). (2) Emotional and mental health: systematic reviews have identified partial evidence suggesting that wireless device use may be associated with increased anxiety, depression, and behavioral problems among adolescents (Girela-Serrano et al., 2024), as well as cognitive and behavioral development issues (Lim et al., 2023). (3) Cognitive development: review studies have proposed that RF-EMF exposure might affect brain and neural functions related to intelligence and memory in children and adolescents (Ishihara et al., 2020). (4) Chronic diseases: the International Agency for Research on Cancer (IARC) has classified radiofrequency radiation as a possible human carcinogen (Group 2B), representing one of the major health concerns related to children's exposure to electromagnetic fields (Moon, 2020).

Television is one of the most influential mass communication technologies in modern society. Broadcasting requires high-power transmission towers to deliver signals over wide geographic areas (SCENIHR, 2009), which results in continuous exposure to RF-EMF for large populations. Several international studies have directly investigated the health impacts of these transmission towers on children. For instance, an ecological study in South Korea found significantly higher mortality rates from overall cancers and leukemia among residents living near high-power AM radio towers (Park et al., 2004). Similarly, an Australian study reported that children with leukemia who lived within 3.5 to 10.0 kilometers of television transmission towers had lower survival rates compared to those who lived farther away (Hocking and Gordon, 2003). However, the evidence remains inconsistent. A large case control study conducted in Germany that assessed exposure one year before diagnosis found no significant increase in childhood leukemia risk among those residing near television or radio transmitters (Merzenich et al., 2008). Likewise, a cohort study in Switzerland reported no overall association between RF-EMF exposure from transmission towers and the risk of childhood cancer (Hauri et al., 2014). Regarding radiation dose assessment, several studies have emphasized that standard exposure models may underestimate actual risks due to physiological differences in children (Gandhi et al., 2012). Simulation studies have shown that the peak spatial specific absorption rate (psSAR) in children's brains can be nearly twice that of adults (Fernández-Rodríguez et al., 2015), while modern devices such as tablets also demonstrate relatively high RF absorption levels in children (Siervo et al., 2019). Moreover, advanced

imaging methods such as nuclear magnetic resonance (NMR) have been developed to precisely identify high-energy “hot spots” in brain tissue, helping to establish more reliable safety standards (Gültekin and Moeller, 2012; Fernández et al., 2018).

Based on the existing scientific evidence, while several studies have reported correlations between RF-EMF exposure and certain health outcomes among children and adolescents, the overall findings remain inconsistent and insufficient to confirm an increased cancer risk in the general population (Karipidis et al., 2024). Such inconsistency may result from various complex factors, including sample characteristics, distance from transmission towers, and measurement methods of exposure (Lim et al., 2023). Furthermore, although childhood leukemia has been strongly linked to extremely low-frequency magnetic fields and X-ray radiation, the evidence for radiofrequency and microwave exposure remains uncertain (Onyije et al., 2022). In some cases, methodological controversies have arisen, such as debates over data analysis approaches used to identify anomalies in statistically valid models (Hocking et al., 1997). Altogether, this context highlights the need for continued research focusing on children a population particularly sensitive to environmental changes. In Thailand, research in this field remains limited. Therefore, this study holds particular importance as it investigates factors related to the well-being of students attending schools located near television transmission towers in the Bangkok Metropolitan Region. The findings aim to fill existing knowledge gaps and support future environmental and health policy development in educational settings

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2. Research Objectives

2.1 To examine the relationship between proximity to television transmission towers (within 500 meters) and various dimensions of student well-being, including physical health, emotional health, sleep quality, and chronic illnesses among secondary school students.

2.2 To investigate the correlations between personal factors such as gender, presence of chronic diseases, history of allergies, family history of cancer, academic performance (GPA), and behavioral use of mobile phones, computers, and Wi-Fi, and the well-being of students.

3. Research Methodology

3.1 Study Design

This research employed a cross-sectional survey design, which involved collecting data from the target population at a single point in time. The primary objective of this design was to explore and analyze factors associated with the well-being symptoms of students attending schools located near a television transmission tower in the suburban area of Bangkok. Such a design is particularly appropriate for examining the prevalence of symptoms and co-occurring variables within a specific population, thereby enabling the identification of potential correlations between exposure to electromagnetic fields and students’ well-being.

3.2 Population and Sampling

The study population consisted of approximately 800 upper secondary school students from two schools located in close proximity to a television transmission tower. The sample size was determined using the Krejcie and Morgan (1970) table, which indicated that a minimum of 260 participants was required to adequately represent the target population. A simple random sampling technique was employed to ensure that every student within the population had an equal chance of being selected. To implement this, a list of enrolled students from both schools was obtained, and participants were randomly selected until the required sample size was achieved. The inclusion criteria specified that eligible participants must be current students aged 15–18 years who were attending one of the two schools within the designated study area. Exclusion criteria were applied to maintain data quality; questionnaires

that were incomplete or contained more than 20% missing responses were discarded and not included in the final analysis.

3.3 Exposure Assessment and Study Outcomes

Exposure to electromagnetic fields (EMF) in this study was determined based on the distance from the source of emission. Students were classified into two groups according to their school's location: (1) those situated within 500 meters of the television transmission tower, and (2) those located 500–1000 meters away. This distance-based classification is a common approach in epidemiological studies and serves as a preliminary indicator of exposure level. Field measurements of electromagnetic intensity were conducted in both school areas. For average frequencies specific to the television tower, the measured intensity ranged from 0.0002–0.6730 W/m² within 500 meters and 2.790–4060.650 µW/m² between 500–1000 meters. For integrated frequencies, the intensity ranged from 0.0001–0.6730 W/m² within 500 meters and 17.84–1365.60 µW/m² between 500–1000 meters. These results confirmed that actual exposure levels in both school areas were within the ICNIRP safety limits. The primary outcomes of interest were well-being symptoms, self-reported by students using a structured questionnaire. Symptoms were classified into four categories: Physical symptoms (e.g., back pain, neck pain, muscle fatigue, weakness, and muscle twitching), Emotional/mental symptoms (e.g., blurred vision, poor concentration, depression, and irritability), Sleep-related symptoms (e.g., difficulty falling asleep, frequent awakenings, or insufficient sleep), and Chronic symptoms (e.g., unexplained allergies, memory problems, bloating, and irregular heartbeat). The severity or frequency of each symptom was assessed on a scale ranging from "rarely experienced" to "experience several days per week." Additional personal factors that may influence students' well-being were also collected, including gender, presence of chronic diseases, history of allergies, family history of cancer, grade point average (GPA), and daily use of mobile phones, computers, and Wi-Fi. These variables were included to control for confounding factors and to identify other potential influences on students' well-being.

3.4 Statistical Analysis

The data analysis followed a systematic sequence. Initially, descriptive statistics were used to compare the two group's students residing within 500 meters and those ≥500 meters from the tower. The frequencies and percentages of personal, health, academic, and technology-use variables were calculated and presented using bar charts (Figure 1) to illustrate proportional differences between groups. Next, well-being data were analyzed across four dimensions: physical, emotional, sleep-related, and chronic symptoms. The frequency of each symptom type was counted to identify common health trends among all participants. These results were presented in Table 1 as counts and percentages. In the third stage, cross-tabulation (Crosstabs) was used to explore relationships between independent variables and well-being outcomes. The odds ratio (OR) and 95% confidence interval (95% CI) were calculated to indicate the strength of association. Findings from this preliminary analysis were reported in Table 2. Finally, to assess multivariate relationships and control for confounding variables, binary logistic regression was performed. Variables showing statistically significant differences in earlier analyses such as gender, chronic illness, and allergy, family history of cancer, GPA, and technology use were entered into the model. Results were presented as adjusted odds ratios (aOR) with 95% CI and p-values (Table 3) to illustrate adjusted correlations. Model adequacy was evaluated using the Hosmer–Lemeshow goodness-of-fit test, and potential multicollinearity was examined through the Variance Inflation Factor (VIF), ensuring the validity and reliability of the statistical analysis.

4. Research Results

To provide a clear understanding of the basic characteristics of the study participants and to examine the differences between students living near and far from the television transmission tower, comparative analyses were conducted on demographic factors, health history, grade point average (GPA), and technology use behaviors between the two groups. The results of these comparisons of fundamental characteristics are presented in Figure 1.

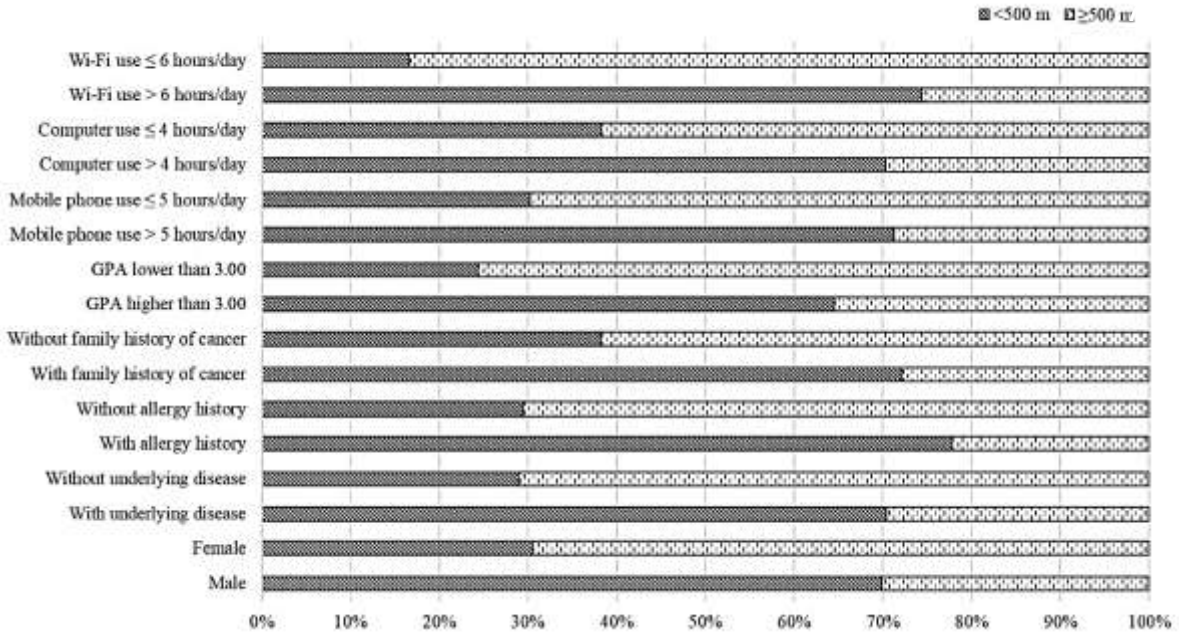

Figure 1. Distribution of students' basic characteristics by distance from the television transmission tower (<500 m and ≥500 m), presented as a 100% stacked bar chart.

From a total of 260 upper secondary school students who participated in the study, 120 students (46.2%) resided within 500 meters of the television transmission tower, while 140 students (53.8%) lived more than 500 meters away. The distribution of basic characteristics among participants, illustrated in the 100% stacked bar chart (Figure 1), revealed notable differences across several dimensions. Students living closer to the transmission tower had a higher proportion of males, whereas females were more prevalent in the group residing farther away. In terms of health characteristics, those in the near-tower group exhibited higher proportions of students with chronic illnesses, allergic conditions, and a family history of cancer, indicating a greater burden of potential health risk factors. Regarding academic performance, students with a cumulative grade point average (GPA) of 3.0 or higher were more common among those living near the tower, while lower GPAs were more frequent in the group farther away. For technology-use behaviors, the near-tower group showed significantly higher proportions of students using mobile phones for more than five hours per day, computers for over four hours per day, and Wi-Fi for more than six hours per day. These distributions suggest that students living closer to the tower have distinct lifestyle and baseline characteristics compared to those living farther away. Presenting these findings in a stacked bar chart facilitates a clear visual comparison between groups and highlights the importance of these variables as potential confounding factors to be controlled in subsequent statistical analyses.

This study aimed to compare the well-being of students living near the television transmission tower with those residing farther away. The assessment of well-being was categorized into four main dimensions: physical symptoms, emotional and cognitive symptoms, sleep-related symptoms, and chronic health symptoms. Each category consisted of several specific sub-symptoms that were evaluated through the self-reported questionnaire. The

most frequently reported and notable symptoms within each dimension are summarized in Table 1.

Table 1. Frequency of Health-related Well-being Problems among Secondary School Students

Groups	Symptom	No symptom	Rarely	Monthly	Weekly	Several times per week
Physical	Back pain	119 (45.77%)	21 (8.08%)	27 (10.38%)	31 (11.92%)	62 (23.85%)
	Neck pain	119 (45.77%)	21 (8.08%)	28 (10.77%)	30 (11.54%)	62 (23.85%)
	Muscle pain	127 (48.85%)	26 (10.00%)	27 (10.38%)	26 (10.00%)	54 (20.77%)
	Fatigue	141 (54.23%)	30 (11.54%)	21 (8.08%)	29 (11.15%)	39 (15.00%)
	Muscle twitching	157 (60.38%)	26 (10.00%)	18 (6.92%)	26 (10.00%)	33 (12.69%)
Emotional	Blurred vision	157 (60.38%)	21 (8.08%)	13 (5.00%)	12 (4.62%)	57 (21.92%)
	Poor concentration	165 (63.46%)	20 (7.69%)	14 (5.38%)	12 (4.62%)	49 (18.58%)
	Depression	179 (68.85%)	17 (6.54%)	15 (5.77%)	13 (5.00%)	36 (13.85%)
	Irritability	210 (80.77%)	11 (4.23%)	12 (4.62%)	3 (1.15%)	24 (9.23%)
Sleep	Falling asleep in class	165 (63.46%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	95 (36.54%)
	Difficulty falling asleep but sleep well	169 (65.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	91 (35.00%)
	Difficulty falling asleep and frequent awakening	230 (88.46%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	30 (11.54%)
	Sleep <5 hours/day	227 (87.31%)	0 (0.00%)	1 (0.38%)	0 (0.00%)	32 (12.31%)
Chronic	Frequent allergy of unknown cause	152 (58.46%)	19 (7.31%)	14 (5.38%)	12 (4.62%)	63 (24.23%)
	Memory problems	148 (56.92%)	23 (8.85%)	16 (6.15%)	10 (3.85%)	63 (24.23%)
	Indigestion/bloating	165 (63.46%)	24 (9.23%)	14 (5.38%)	9 (3.46%)	48 (18.46%)
	Palpitations	176 (67.69%)	19 (7.31%)	13 (5.00%)	9 (3.46%)	43 (16.54%)

From the survey on the prevalence of well-being symptoms among students, it was found that the most frequent symptoms in the sleep category included sleepiness during class and difficulty falling asleep but sleeping well afterward, with more than 90 students reporting these symptoms several times per week. This reflects a widespread issue of sleep disturbance that may affect both academic performance and overall health. In addition, symptoms such as insufficient sleep (<5 hours per day) and difficulty sleeping with frequent awakenings were

also observed, though in smaller numbers, indicating poor sleep quality that aligns with daytime drowsiness. For physical symptoms, back pain and neck pain were the most common, with more than 60 students reporting them several times per week. These were followed by muscle pain and fatigue, which were also reported at high levels, suggesting a burden of physical discomfort possibly related to technology use and posture during study. Moreover, blurred vision and difficulty concentrating were reported by a large number of students, with 40–50 of them experiencing these symptoms repeatedly each week. In the emotional and psychological domain, depressive mood and irritability were found at lower frequencies compared to physical and sleep symptoms, yet a number of students still reported feeling depressed or irritated on a weekly basis. Meanwhile, memory problems, bloating or indigestion, and palpitations continued to appear among some students, possibly signaling underlying health issues that require further monitoring. In summary, the results presented in Table 1 indicate that sleep-related and physical symptoms were the most common well-being issues among students, followed by concentration and vision problems. Although emotional and other physiological symptoms appeared less frequently, they still reflected the students' vulnerability in overall well-being, which should be addressed through health promotion and preventive measures in the long term.

From the results shown in Figure 1, which illustrate the differences in basic characteristics between the two student groups, these factors appear to play a role as potential confounders in the studied relationship. Therefore, to preliminarily assess the association between independent factors and the well-being symptoms identified in Table 1, a Crude Odds Ratio analysis was conducted using binary logistic regression to explore these initial relationships. The results of this analysis are presented in Table 2.

Table 2. Preliminary correlations between independent factors and students' well-being symptoms, presented as Crude Odds Ratios (OR) with 95% Confidence Intervals (CI)

Predictor	Physical OR (95% CI)	Emotional OR (95% CI)	Sleep OR (95% CI)	Chronic OR (95% CI)
Distance <500 m (Yes vs No)	0.58 (0.35–0.95)*	0.39 (0.23–0.68)*	0.39 (0.22–0.68)*	0.52 (0.32–0.86)*
Gender (Male vs Female)	0.91 (0.55–1.51)	0.77 (0.45–1.31)	0.33 (0.18–0.61)*	0.92 (0.56–1.53)
Chronic illness (Yes vs No)	0.80 (0.49–1.32)	0.59 (0.35–1.01)	0.59 (0.34–1.03)	0.63 (0.38–1.04)
Allergy history (No vs Yes)	1.03 (0.62-1.70)	1.00 (0.58-1.71)	0.55 (0.32-0.93)*	1.59 (0.96-2.63)
Family history of cancer (Yes vs No)	0.88 (0.54–1.45)	0.65 (0.38–1.11)	0.36 (0.21–0.64)*	0.75 (0.46–1.23)
GPA <3.00 (Yes vs No)	0.58 (0.35–0.95)*	0.54 (0.31–0.94)*	0.24 (0.13–0.41)*	0.60 (0.37–1.00)*
Phone use >5 h/day (Yes vs No)	0.67 (0.41–1.10)	0.49 (0.28–0.84)*	0.43 (0.25–0.74)*	0.50 (0.30–0.83)*
PC use >4 h/day (Yes vs No)	0.71 (0.43–1.17)	0.41 (0.24–0.72)*	0.31 (0.18–0.55)*	0.54 (0.33–0.88)*
Wi-Fi use >6 h/day (Yes vs No)	0.76 (0.46–1.25)	0.52 (0.30–0.90)*	0.40 (0.23–0.69)*	0.65 (0.40–1.07)

The preliminary analysis of correlations (Crude Odds Ratio) between independent factors and students' well-being symptoms revealed that residing within 500 meters of a television transmission tower was significantly associated with lower odds of experiencing all dimensions of symptoms studied. Students living closer to the tower showed a notably lower likelihood of reporting physical, emotional, sleep-related, and chronic symptoms compared to those living farther away (OR = 0.39–0.58, 95% CI not crossing 1). Regarding gender, male students were significantly less likely to experience sleep-related symptoms than females (OR = 0.33, 95% CI = 0.18–0.61), while no significant differences were found for other dimensions. Students with chronic diseases or a history of allergies also tend to report fewer well-being symptoms, with allergies showing a significant protective association against sleep disturbances (OR = 0.55, 95% CI = 0.32–0.93). In terms of family history of cancer, students with close relatives diagnosed with cancer were significantly less likely to experience sleep-related problems (OR = 0.36, 95% CI = 0.21–0.64). Academic performance (GPA) also played a role, as students with a GPA ≥ 3.0 had significantly lower odds of emotional, sleep-related, and chronic symptoms compared to those with a GPA < 3.0. For technology use behaviors, students who used mobile phones for more than 5 hours per day, computers for more than 4 hours per day, and Wi-Fi for more than 6 hours per day were significantly less likely to experience emotional and sleep-related symptoms (OR = 0.31–0.52, 95% CI not crossing 1). However, no significant correlations were observed for physical and chronic symptoms.

Although the preliminary results presented in Table 2 revealed correlations that differed from the initial hypothesis particularly the finding that living closer to the television transmission tower was associated with a lower likelihood of well-being symptoms these findings should be interpreted with great caution. This is because the analysis at this stage did not account for the influence of confounding factors that showed significant differences between groups, such as gender, underlying diseases, allergy history, and family history of cancer, academic performance, and patterns of technology use. Therefore, after adjusting for these potential confounders through multiple logistic regression analysis, the results demonstrated clearer and more consistent correlations aligned with the study hypothesis. The adjusted findings are presented in Table 3.

Table 3. Binary Logistic Regression Analysis of the Association between Distance from the Television Transmission Tower and Well-being Symptoms, Adjusted for Confounding Factors

Predictor	Physical aOR (95% CI)	Emotional aOR (95% CI)	Sleep aOR (95% CI)	Chronic aOR (95% CI)
Distance <500 m (Yes vs No)	1.78 (0.89–3.56), p=0.105	2.22 (1.05–4.72), p=0.037*	1.11 (0.51–2.45), p=0.791	1.77 (0.88–3.57), p=0.108
Gender (Male vs Female)	0.78 (0.43–1.44), p=0.429	0.82 (0.43–1.57), p=0.548	1.80 (0.88–3.72), p=0.110	0.71 (0.38–1.32), p=0.275
Chronic illness (Yes vs No)	1.00 (0.56–1.79), p=0.997	1.19 (0.64–2.21), p=0.577	0.84 (0.43–1.63), p=0.599	1.34 (0.75–2.39), p=0.329
Allergy history (No vs Yes)	0.84 (0.49–1.42), p=0.511	0.89 (0.50–1.57), p=0.679	1.64 (0.92–2.91), p=0.095	0.53 (0.31–0.91), p=0.021*
Family history of cancer (Yes vs No)	0.57 (0.26–1.26), p=0.164	0.64 (0.27–1.48), p=0.294	1.18 (0.45–3.06), p=0.737	0.64 (0.29–1.43), p=0.277

GPA <3.00 (Yes vs No)	2.51 (0.94–6.71), p=0.067	0.66 (0.20–2.18), p=0.494	4.72 (1.42–15.66), p=0.011*	1.04 (0.37–2.90), p=0.942
Phone use >5 h/day (Yes vs No)	1.21 (0.53–2.77), p=0.647	1.47 (0.59–3.67), p=0.412	0.61 (0.23–1.60), p=0.315	2.10 (0.91–4.82), p=0.082
PC use >4 h/day (Yes vs No)	0.86 (0.34–2.17), p=0.756	2.34 (0.84–6.51), p=0.103	1.43 (0.51–4.00), p=0.495	1.52 (0.60–3.84), p=0.380
Wi-Fi use >6 h/day (Yes vs No)	0.77 (0.30–1.99), p=0.590	0.94 (0.33–2.64), p=0.899	0.58 (0.18–1.84), p=0.354	0.68 (0.26–1.77), p=0.427

Based on the multiple logistic regression analysis examining the association between the distance from the television transmission tower and various well-being symptoms, while adjusting for confounding factors—including gender, underlying diseases, allergy history, family history of cancer, grade point average (GPA), and technology use behaviors—the results presented in Table 3 identified three variables that remained statistically significant ($p < 0.05$): distance from the transmission tower, allergy history, and GPA. For emotional symptoms, students living within 500 meters of the transmission tower were more than twice as likely to experience emotional symptoms compared to those living farther than 500 meters (aOR = 2.22, 95% CI: 1.05–4.72, p = 0.037). This finding suggests a clear association between exposure to electromagnetic fields from the transmission tower and students' emotional well-being. Although other variables were not statistically significant, students who used computers for more than four hours per day showed a trend toward increased emotional symptoms (aOR = 2.34, p = 0.103). Regarding sleep-related symptoms, GPA appeared to be an important factor. Students with a GPA ≥ 3.0 were approximately 4.7 times more likely to experience sleep problems compared to those with a GPA < 3.0 (aOR = 4.72, 95% CI: 1.42–15.66, p = 0.011), possibly reflecting academic stress or time management habits that affect sleep quality. Other variables were not statistically significant, although students with a history of allergies tend to have a higher likelihood of sleep problems (aOR = 1.64, p = 0.095). For chronic symptoms, allergy history showed a protective association. Students with allergies were nearly half as likely to experience chronic symptoms as those without allergies (aOR = 0.53, 95% CI: 0.31–0.91, p = 0.021). This result may reflect differences in symptom perception or reporting between student groups, or the influence of unmeasured confounders. At the same time, using mobile phones for more than five hours per day tend to increase the risk of chronic symptoms (aOR = 2.10, p = 0.082), although this did not reach statistical significance. In terms of physical symptoms, no variables showed statistically significant correlations after adjusting for confounders. However, students living within 500 meters of the transmission tower tend to have higher frequencies of physical symptoms (aOR = 1.78, p = 0.105), as did those with higher GPAs (aOR = 2.51, p = 0.067), though these trends did not reach the level of statistical significance.

In summary, the analysis of data from Tables 1 to 3 revealed that students living near the television transmission tower exhibited distinct baseline characteristics compared to those living farther away, particularly in terms of gender, health history, academic performance, and technology-use behaviors. These differences suggest that such variables may act as confounding factors influencing the relationship between proximity to the tower and well-being outcomes. The preliminary analysis (Crude Odds Ratios in Table 2) initially indicated a protective association that partially contradicted the study hypothesis. However, after adjusting for confounders through multiple logistic regression (Adjusted Odds Ratios in Table 3), the

relationships became clearer and more consistent with the original assumptions—especially regarding emotional symptoms, where students living closer to the tower had a significantly higher likelihood of experiencing emotional disturbances. Additionally, GPA and allergy history remained significantly associated with certain well-being dimensions, underscoring the multifactorial nature of students' well-being. These results collectively highlight that student well-being is influenced by both environmental and individual factors, and that adjusting for confounding variables is crucial for ensuring accurate and reliable interpretation of findings.

4. Conclusions

This study aimed to analyze the relationship between proximity to television transmission towers and the health symptoms of high school students in the Bangkok metropolitan area. It also examined the influence of personal factors on various dimensions of well-being. A cross-sectional survey design was employed with a sample of 260 upper secondary school students. Data were collected through questionnaires and analyzed using descriptive statistics, chi-square tests, and multiple logistic regression. The results showed that students living within 500 meters of a television transmission tower had a significantly higher risk of emotional problems compared to those living farther away (aOR = 2.22, 95% CI: 1.05–4.72, p = 0.037). However, no significant differences were found in physical health, sleep quality, or chronic conditions. These findings suggest that exposure to electromagnetic waves from television transmission towers may be more closely associated with students' emotional well-being than with other health aspects.

In addition, certain personal factors were found to play a clear role in students' well-being, particularly grade point average (GPA) and allergy history. Students with a GPA of 3.00 or higher were more likely to experience sleep problems than those with lower GPAs (aOR = 4.72, 95% CI: 1.42–15.66, p = 0.011). Conversely, students with a history of allergies were significantly less likely to experience chronic illnesses compared to those without allergies (aOR = 0.53, 95% CI: 0.31–0.91, p = 0.021). Other factors, such as gender, underlying diseases, family history of cancer, and technology usage, showed no significant correlations. Therefore, this study confirms that both environmental and personal factors influence students' well-being at different levels, especially the proximity to television transmission towers, which may significantly affect adolescents' emotional health.

5. Discussion

The present study examined the relationship between living near television transmission towers and the well-being of upper secondary school students in the Bangkok metropolitan area. Both descriptive analysis and multiple logistic regression were used to control for potential confounding factors. The key finding was that, although preliminary analysis suggested a protective relationship between living within 500 meters of a television transmission tower and several well-being dimensions, the direction of the association changed after adjusting for confounders. Students living near the towers were found to have a significantly higher likelihood of emotional problems (aOR = 2.22, 95% CI: 1.05–4.72, p = 0.037). This finding highlights the importance of controlling for confounding variables in observational studies to ensure valid interpretation and reduce external bias. The results were partly consistent with the study hypothesis and supported international evidence suggesting that exposure to radiofrequency electromagnetic fields (RF-EMF) may affect emotional and mental well-being among children and adolescents, particularly in relation to anxiety and depression. Girela-Serrano et al. (2024) found that nighttime wireless device use was associated with higher anxiety and depression levels, while Heinrich et al. (2010) reported that daily RF-EMF exposure was linked to insomnia and headaches among adolescents. Moreover, experimental studies by Jing et al. (2024) and Zhang et al. (2017) demonstrated that prolonged

exposure to multiple RF-EMF frequencies over four weeks led to anxiety-like behaviors in laboratory animals, along with changes in neurotransmitters such as γ-Aminobutyric Acid (GABA) and Aspartate, as well as increased expression of neuroinflammatory proteins. These mechanisms suggest that continuous RF-EMF exposure may disrupt the balance of the autonomic nervous system and the brain's electrochemical stability, which are essential for emotion regulation and stress response. Therefore, this study supports the hypothesis that living near high-intensity RF-EMF sources, such as television transmission towers, could be a potential risk factor for emotional well-being among students in large urban areas.

However, some findings were not consistent with the original hypothesis, particularly in terms of physical health, sleep, and chronic symptoms, which showed no significant differences between students living near and far from transmission towers. One possible reason is that RF-EMF intensity levels in the study area were within the safety limits established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), which may not have immediate physical effects. Environmental characteristics such as building structures, tree density, and terrain could also reduce wave propagation. Furthermore, the cross-sectional design of this study limits causal interpretation, which may explain inconsistencies with the initial hypothesis. Similar findings were reported by Merzenich et al. (2008) and Hauri et al. (2014), who found no association between tower proximity and increased cancer risk or general health problems in children and adolescents. Behavioral confounders—such as prolonged use of mobile phones, computers, and Wi-Fi, or stress from academic workload—might have a greater influence on students' health than direct RF-EMF exposure (Lim et al., 2023).

In the analysis of personal factors, two variables showed noteworthy results: grade point average (GPA) and allergy history. Students with a GPA of 3.00 or higher were significantly more likely to experience sleep problems than those with lower GPAs. This may reflect stress from heavy academic demands, long study hours, and excessive use of technology before bedtime. This result is consistent with Thapa et al. (2025), who found that academic pressure and insufficient rest were strongly associated with sleep problems among high school students. Regarding chronic symptoms, students with allergies were less likely to report chronic illnesses than those without allergies. This could be because allergic individuals tend to receive regular medical care and adopt better health management behaviors, thereby reducing the risk of chronic conditions.

Nevertheless, all interpretations should be considered within the study's limitations. First, as this was a cross-sectional study, it cannot establish causal relationships. Second, students' well-being was assessed through self-reported questionnaires, which may be subject to recall or reporting bias. Third, the level of RF-EMF exposure was estimated using the distance from television towers as a proxy indicator and averaged field intensity data by area, which might not reflect actual individual exposure. Finally, the sample was drawn from specific areas within the Bangkok metropolitan region, limiting the generalizability of the findings to other environments with different characteristics.

6. Recommendations

This study highlights the complex relationship between technological environments, personal factors, and lifestyle behaviors that influence students' well-being. The results confirm that proximity to television transmission towers may be associated with emotional health problems, while individual factors such as GPA and allergy history also play roles in sleep and chronic health dimensions. Future research should adopt a longitudinal design to monitor health changes over time in relation to continuous RF-EMF exposure, together with direct physical measurements to improve accuracy. Additionally, integrating qualitative data, such as in-depth interviews, would help capture students' perceptions and experiences regarding the effects of transmission towers. Health monitoring measures and guidelines for

appropriate technology use particularly limiting electronic device use before bedtime should also be promoted to reduce emotional impacts and improve long-term sleep quality effectively.

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