**Applied Psychology Review (APR)**
**Volume 2 Issue 2, Fall 2023**
ISSN$_{(P)}$: 2959-1597 ISSN$_{(E)}$: 2959-1600
Homepage: https://journals.umt.edu.pk/index.php/apr

**Article QR**


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**DOI:** https://doi.org/10.32350/apr.22.04

**History:** Received: June 07, 2023, Revised: November 07, 2023, Accepted: November 23, 2023, Published: December 29, 2023

**Citation:** Fatima,K., Ali, B., Khan, A., Khan, A. A., & Mahnoor. (2023). Application of logistic regression model in mental health evaluation: A case study of farmers working under high voltage transmission line (HVTL). *Applied Psychology Review*, *2* (2), 66–83. https://doi.org/10.32350/apr.22.04



**Conflict of Interest:** Author(s) declared no conflict of interest

A publication of
Department of Knowledge & Research Support Services
University of Management and Technology, Lahore, Pakistan

# Application of Logistic Regression Model in Mental Health Evaluation: A Case Study of Farmers Working Under High Voltage Transmission Line (HVTL)

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## Abstract

The current study examined the environmental impact of High Voltage Transmission Lines (HVTL) on human health, specifically the psychological health of farmers in Pakistan. The electric and magnetic fields that emanate from HVTL may have adverse effects on human health including psychological disorders. To investigate the probability of psychological disorders among farmers working under HVTL, the current study employed a logistic regression model considering the variables of gender, age, transmission line type, work duration, and prior health conditions. The results showed that women working under HVTL are more vulnerable to psychological disorders than men. Additionally, the probability of psychological disorders increases with age of the farmers, voltage magnitude, and duration of work under HVTL. The Female farmers aged between 46 to 69 years, working under a 220 KV HVTL for up to six hours daily, were at a significantly higher risk of experiencing psychological disorders. These findings highlighted the environmental impact of HVTL on psychological health of the farmers. Moreover, it also highlighted the need for adopting measures to mitigate the risk and protect both the environment and human health.

***Keywords*:** electromagnetic field, High Voltage Transmission Line (HVTL), logistic regression, psychological disorder

## Introduction

Extreme climatic conditions impact human life and society greatly (Dong et al., 2021). Nowadays, modern society is so reliant on electricity that it is

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practically difficult to survive without it in the times to come as well. Over the previous two decades developed countries have become more concerned about a rise in electromagnetic fields which poses health hazards (Yadav et al., 2022). In view of town development, High Voltage Transmission Lines (HVTL) along with huge thermal power plants that were once a long way from populated regions are currently planted near private houses and fields (Zou et al., 2021). A low and weak electric current would travel through our bodies as a result of these electromagnetic fields created by HVTL's and electrical equipment (Sun et al., 2011).

In order to fulfill the rising demand for electricity in this evolutionary world, overhead HVTLs are installed that provide electricity worldwide. The transmission lines are an ultimate resource to distribute electricity to consumers. The generation of electric and magnetic fields from HVTL produces electromagnetic waves due to which electricity supply is made possible covering long distances (Khawaja et al., 2019). HVTL produced by electromagnetic fields are one of the crucial concerns of designers and power distribution companies. This is because working near HVTL may cause severe damage to multiple components of human life (Salari et al., 2009). Electromagnetic fields, produced by HVTL, are exceptionally significant components that are altogether considered by power utilities during the lines' plan and maintenance. The essential impacts of EMF are related to health issues due to short-term, midterm, and long-term exposure to transmission lines and causing a safety risk for groups working close to HVTLs (Ali & Siddique, 2017) In Pakistan, since population is increasing day by day (Ali et al., 2018), the electricity demand is also at its peak. Therefore, the installation of more HVTLs is required. However, the radiation emitted from HVTLs is quite harmful for human body which may also lead to the development of psychological disorders (Ali et al., 2022).

A 'psychological disorder' is a condition marked by disturbing and unusual thoughts, feelings, or activities. In the current era, majority of psychologists concur that psychological disorders are defined by both psychological discomfort and impairment in various facets of life (Spinhoven et al., 2016). According to literature, one of the major reasons of a psychological disorder is daily exposure to HVTL (Zhang et al., 2013). The fluid present in human body is a good conductor of electricity. The charges in human body move to its surface under the effect of electric force in HVTL. Electromagnetic waves, which are the building blocks of

electromagnetic radiation, produce both electric and magnetic field. Figure 1 shows HVTL in Pakistan.

**Figure 1**

*High Voltage Transmission Line (HVTL) Passing through Fields in Pakistan*

Free electric charges are present in the human body that react after the exertion of charges and current flowing in nearby transmission lines (Gupta, 2012).

Electromagnetic fields can destroy cells and affect the human body's sensory system (Kulkarni & Gandhare, 2014). Electrical cables emit high levels of electromagnetic radiation which may also damage DNA components. The discharge current from an electromagnetic field of 50-60 Hz is weaker than the natural current in the body, such as the current generated by electrical activity of the brain or heart (Beale et al., 1997). Human health may get affected by multiple factors including unsteadiness, fatigue, migraine, illness, restlessness, insomnia, irritation, devouring skin, rashes, muscle pain, and stomach problems. These harmful effects on human body may also lead towards the development of psychological disorders. They frequently cause more severe issues in women who are young, pregnant, or of advanced age. A significant linear relationship is present between exposure to HVTL and some psychological disorders. The higher time-integrated exposure to HVTL is associated with worsening psychiatric symptoms (Hossain & Abdelgawad, 2019). In neuropsychological disorders, the psychological behavior of affected person may change to some extent, leading to many transient disorders,

some of which may last a lifetime, depending on the level of exposure to HVTL (McRobbie, 2011). International Commission on Non-Ionizing Radiation Protection (ICNIRP) has set limits to rules dependent on two classes to be specific for the overall population and work-related exposure line. The overall population, on the other hand, includes people of all ages and health status updates as well as susceptible individuals. Table 1 shows the exposure limits set by ICNIRP (Gowland & Glover, 2014; Walterscheid et al., 2002).

**Table 1**

*International Commission on Non-Ionizing Radiation Protection (ICNIRP) Level of Exposure Limits for General Public (Walterscheid et al., 2002)*

| S. No | Ranges | MF strengths ($Am^{-1}$) | Magnetic flux density | EF strengths ($KV\ m^{-1}$) |
|---|---|---|---|---|
| 1 | 3-10000 KHz | 21 | 2.7*105 | 8.3*102 |
| 2 | 0.4 – 3 KHz | 6.4*104 /f | 8*102 /f | 2.5*102 /f |
| 3 | 50 – 400 Hz | 1.6*102 | 2*102 | 2.5*102 /f |
| 4 | 25 – 50 Hz | 1.6*102 | 2*104 | 5 |
| 5 | 25 – 50 Hz | 4*103 /f | 5*103 /f | 5 |
| 6 | 1-8Hz | 3.2*104/f | 4*102/f | 5 |

Literature above depicts a need to conduct a study in order to estimate the impact of high voltage on rural population in Pakistan. The current study attempted to determine the probability of a psychological disorder among 200 farmers working under HVTL. In order to investigate the impact of several variables, a logistic regression model was employed which included gender, age, transmission line type, length of time the farmers worked, and whether they had any prior health problems or not.

## Method

### Analytical Approach

Electric fields and electric currents can be induced in various organs of the human body when a high voltage power line of 50-60 HZ interacts with the human body (Khwaja et al., 2023). In the presence of accurate directions and magnitudes, their interaction with cellular mechanisms can be observed analytically. An overhead HVTL is installed, where conductors are arranged in a triangular pattern. The transmission line is assumed as a line charge near a plane conductor. The electric field produced by the

transmission line on a human body standing near it can be calculated by considering the image of the line charge as "–λ". The line charge λ and its image – λ are parallel to each other, in the x-y plane at points (0, b, 0) and (0,-b, 0) respectively. The voltage V at any arbitrary position P(x,y) in the x-y plane can be shown as (Klieštik et al., 2015).

$$V = -2k\lambda \ln\left(\frac{R_1}{R_2}\right) \tag{1}$$

The value of k is $9\text{x}10^9$ $\text{Nm}^2$ /$\text{C}^2$. In the Cartesian coordinates system, $R_1$ and $R_2$ can be written as

$$R_1 = \sqrt{x^2 + (y-b)^2} \tag{2}$$

$$R_2 = \sqrt{x^2 + (y+b)^2} \tag{3}$$

Hence, the voltage V becomes

$$V = -2k\lambda\left[\ln\sqrt{x^2 + (y-b)^2} - \ln\sqrt{x^2 + (y+b)^2}\right] \tag{4}$$

To calculate electric field $\vec{E}$, use the relationship between potential and electric field

$$\vec{E} = -\nabla V \tag{5}$$

The total electric field strength can be written as

$$\vec{E} = \sqrt{\vec{E}_x{}^2 + \vec{E}_y{}^2}$$

$$\vec{E} = \sqrt{\left(2k\lambda\left[\frac{4xyb}{[x^2 + (y-b)^2]\ [x^2 + (y+b)^2]}\right]\right)^2 + \left(2k\lambda\left[\frac{2y^2b - 2bx^2 - 2b^3}{[x^2 + (y-b)^2]\ [x^2 + (y+b)^2]}\right]\right)^2}$$

$$\overrightarrow{E} = \frac{8k\lambda b^2}{[x^2+(y-b)^2]\ [x^2+(y+b)^2]} \tag{6}$$

Equation 6 shows that the electric field on a human body standing beneath the HVTL can be calculated through this expression. The equation is helpful to calculate the impact of electric field on farmers working under different transmission lines.

## Statistical Model and Analysis

Binary logistic regression analysis presents the relationship between a

dichotomous dependent variable and one or more independent categorical variables. This method provides odds, odds ratio, and probability data, which may help to express the research purpose effectively. For decades, logistic regression model has been widely used statistical method (Buchari & Darmawan, 2020). It is generally used when the dependent variable being discussed is binary, dichotomous, or alternative, rather than continuous (Farooq et al., 2021; Hayes & Matthes, 2009). Therefore, it can only accept two values.

The current study surveyed about 200 farmers including 180 men and 20 women, who worked near HVTL to determine the impact of electric and magnetic fields on their mental health. A number of farmers were reported to be suffering from psychiatric symptoms, such as depression, anxiety, obsessive-compulsive disorder, post-traumatic stress disorder, and others. Therefore, *N*= 200 farmers were screened out using basic terminologies of symptoms through which disorders were identified during preliminary consent by asking absence or presence of these symptoms. If any farmer had a psychological disorder, the value would be 1 and if the farmer had no psychological disorder, the value would be 0. This technique would be helpful to estimate the probability of psychological disorder of the farmers working near HVTL. This dichotomous variable would be used as a dependent variable which depends on gender, age, type of transmission line, duration of their work, and any health issue (such as, headaches, fatigue, anxiety, insomnia. and muscle pain)

The SPSS software was used to determine the relationship between psychological disorders with the explanatory variables of gender, age, type of transmission line, duration of their work, and any health issue. In the survey of 200 farmers working near HVTL, 180 men and 20 women were included with different age groups ranging from 18-69 years. Two types of transmission lines of 132 KV and 220 KV were seen in the fields. The duration of farmers working in the fields near HVTL was around six hours. After executing the logistic regression in IBM SPSS, some information was obtained that helped to estimate the impact of transmission lines on farmers.

### *Model Diagnosis*

An analysis of model execution was provided by the model diagnosis. Using Table 2, the rate of number of expectations can be determined in total predictions. This is also known as a "Goodness of Fit test". An exact number

of expectations within a total prediction was determined using this formula. The significant value was less than 0.05 which reflects that the model was significant. The chi-square statistic was 79.217 with 5 degrees of freedom. Therefore, the overall model was statistically significant, $\chi^2$ (5) = 79.217, p < 0.05. The Hosmer and Lemeshow tests were also used in the support model but their interpretation was completely different from the omnibus test. In this test, the significance value should be higher than 0.05 so that the model fits the data. Table 2 shows that the chi-square value for Hosmer and Lemeshow test was 8.835 with a significance level of 0.356. This value is larger than 0.05, therefore indicating adequacy for the model.

**Table 2**

*Omnibus and Hosmer Tests of Model Coefficients*

| Test | $\chi^2$ | *df* | *p* |
|---|---|---|---|
| Omnibus | 79.217 | 5 | .000 |
| Hosmer and Lemeshow | 8.835 | 8 | .356 |

To calculate the variations in dependent variable, the method of Cox and Snell $R^2$ and Nagelkerke $R^2$ is very supportive. According to these methods, Table 3 shows that around 32.7%-47.3% variance in psychological disorders was considered by all the independent variables.

**Table 3**

*Model Summary*

| -2 Log likelihood | Cox & Snell $R^2$ | Nagelkerke $R^2$ |
|---|---|---|
| 156.051 | .327 | .473 |

The classification table depicted in Table 4, obtained after the execution of logistic regression in IBM SPSS, provides an explanation of how well the model is going to predict the correct category (facing psychological problem/no psychological problem) for each case. Logistic regression approximates the probability of the occurrence of an event (in this case, having a psychological problem). If the estimated probability of an event occurring is 0.5 or greater, SPSS statistics classifies it as having occurred (for instance, psychological problem being present). If the probability is less than 0.5, SPSS statistics classifies it as not causing an event. (for instance, no psychological problem). Logistic regression is used to forecast whether the cases of dependent variables are correctly categorized or not.

**Table 4**

*Classification Table*

| Observed | | Predicted | | |
|---|---|---|---|---|
| | | Are you facing any psychological problems? | | Percentage Correct |
| | | no | yes | |
| Are you facing any psychological problems? | no | 134 | 11 | 92.4 |
| | yes | 22 | 33 | 60.0 |
| Overall Percentage | | | | 83.5 |

***Model Characteristics***

The sensitivity of the model is the percentage of the farmers having a psychological problem that has been truly identified by the model in Table 4 which is 60%. It means that 60% farmers are facing a psychological problem. The model's specificity refers to the fraction of farmers who do not have a true psychological condition. In this model, the specificity was 92.4% which means farmers who did not have a psychological problem were correctly predicted by the model not to have a psychological problem. Positive predictive value, which is 75%, is the percentage of accurately predicted cases with the observed characteristic against the total number of predicted cases with the observed characteristic. Therefore, 75% of the farmers who were predicted to be suffering from psychological problems were correctly predicted by the model. Based on the negative predictive value, 85.89% of the cases accurately predicted without the observed characteristic were correctly predicted in comparison to the total number of cases forecasted without that characteristic. This means 85.89% of the farmers were predicted as not having psychological problems and they were correctly predicted.

## Results

The model shows a complete picture of all the parameters assessed in the current study. Table 5 provides detailed data about the contributions of every independent variable.

**Table 5**

*Assessed Coefficients of Logistic Regression Model for Different Psychological Parameters*

| Independent variables | *B* | *SE* | Wald | Sig. | Exp(*B*) | 95% *C.I.* Exp (*B*) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower | Upper |
| Gender of farmers | -3.2 | .714 | 20.183 | .000 | .040 | 0.01 | 0.16 |
| Age of farmers | .08 | .021 | 13.131 | .000 | 1.080 | 1.04 | 1.12 |
| Type of Transmission line nearby farmers are working | .83 | .518 | 2.589 | .108 | 2.303 | 0.83 | 6.36 |
| Are Farmers suffering any health disorders, working near HVTL? | .99 | .471 | 4.429 | .035 | 2.694 | 1.07 | 6.78 |
| Duration of work of farmers near HVTL more than 6 hours | 1.38 | .436 | 9.931 | .002 | 3.953 | 1.68 | 9.30 |
| Constant | -3.35 | 1.169 | 8.234 | .004 | .035 | - | - |

***Note.*** Gender (0= Female, 1= Male). Age (in years). Type of transmission line (0=132 KV, 1= 220 KV). Farmers with health disorders working near HVTL (0= No, 1= Yes). Work duration > 6 hours near HVTL (0= No, 1= Yes).

Column *B* represents the direction and quality of the relationship between dependent and independent variables. Negative value *B* indicates that as the score of the independent variable increases, the situation is less likely to record a score of 1 in the dependent variable. In the model, the *B* value of gender is negative which means that men have less probability of having a psychological disorder than women. The other *B* values are positive which reflect that if the age of farmers increased, the chances of having psychological disorders increases as well. Furthermore, 220 KV is more harmful than 132 KV transmission line for human beings. Similarly, as the exposure duration near HVTL increases, the risks of psychological disorders increase. The farmers already facing any diseases are more prone to develop psychological disorders.

These values of *B* can be utilized in an equation to determine the likelihood of farmers having psychological disorders. These values are in log-odds units which can be converted into probabilities. The following is the expression for the binary logistic regression model considering the

aforementioned variables:

$$\log\left(\frac{p}{1-p}\right) = b_0 + b_1\, x_{\text{gender}} + b_2\, x_{\text{age}} + b_3\, x_{\text{type of HVTL}} + b_4\, x_{\text{duration}} + b_5\, x_{\text{health disorder}} \quad (7)$$

Where $p$, is the probability of being in a psychological problem for farmers working near HVTL, $\log\left(\frac{p}{1-p}\right)$ in equation (7) is considered as a log of odds or link logit function, while $\frac{p}{1-p}$ is taken as the odds ratio. Odds ratio values explain how certain independent variables can cause certain dependent variables to increase or decrease in value. The logistic regression equation in variables form is:

$$\log\left(\frac{p}{1-p}\right) = -3.353 - 3.208\, x_{\text{gender}} + 0.077\, x_{\text{age}} + 0.834\, x_{\text{type of HVTL}} + 1.375\, x_{\text{duration}} + 0.991\, x_{\text{health disorder}} \quad (8)$$

Applying antilog on both sides, the odds ratio would be equal to,

$$\left(\frac{p}{1-p}\right) = e^{-3.353 - 3.208\, x_{\text{gender}} + 0.077\, x_{\text{age}} + 0.834\, x_{\text{type of HVTL}} + 1.375\, x_{\text{duration}} + 0.991\, x_{\text{health disorder}}} \quad (9)$$

The probability of each psychological problem parameter with different covariates can be easily depicted. Equation 10 represents the probability equation generated from the model.

$$p = \frac{e^{-3.353 - 3.208\, x_{\text{gender}} + 0.077\, x_{\text{age}} + 0.834\, x_{\text{type of HVTL}} + 1.375\, x_{\text{duration}} + 0.991\, x_{\text{health disorder}}}}{1 + e^{-3.353 - 3.208\, x_{\text{gender}} + 0.077\, x_{\text{age}} + 0.834\, x_{\text{type of HVTL}} + 1.375\, x_{\text{duration}} + 0.991\, x_{\text{health disorder}}}} \quad (10)$$

The column Exp($B$) is the value of the odd ratio for each independent variable. It is the ratio of two different odd values of independent variable that are separated by one unit. It shows how many times the odds of occurrence rise when the independent variable is increased by one unit. In the model, the odds of a farmer having psychological disorders is 2.303 times higher for the farmers who work in near 220KV than the farmers who work in near 132 KV of transmission lines, if all other factors are presumably constant. Similarly, the odds of having psychological disorders is 3.953 times higher for the farmers whose duration of work near HVTL is more than 6 hours than those with work duration of less than 6 hours. Same is the case of farmers who have any health conditions and work near HVTL. The probability of psychological disorders in these farmers is 2.694 times

higher than those without any health conditions, taking all other factors constant.

The odd ratio of gender is less than 1 which represents that mostly female farmers report psychological disorders as compared to men. The odds of psychological disorders in male farmers decrease by a factor of 0.040 than the female farmers when all other factors are kept constant. In the model, one continuous variable, that is, age was also included. The odd ratio of age is increased by a factor of 1.080 for one-year increase in age. In Table 5, the confidence interval of 95% gives a lower limit and upper limit linked with the corresponding odds ratio. These are the limits that would cover the true value of the odds ratio.

In the column of WALD of Table 5, the Wald test gives information about the statistical significance of each independent variable. If the significance value of the variable is less than 0.05, that variable would contribute significantly to the predictive capacity of the model. The *p*-value of independent variables of gender of farmers, age of farmers, duration of work, and health disorders was less than 0.05 which means these variables added a significant role in the prediction model. However, the type of transmission line did not add a significant part to the model. By using the probability equation obtained in equation (10), Table 6 shows that all probabilities of having a psychological disorder with the effect of all the independent variables were measured.

**Table 6**

*Probability Table of Having a Psychological Disorder with the Covariates*

| Transmission Type | | 132 KV | | | | 220 KV | | | |
|---|---|---|---|---|---|---|---|---|---|
| Duration | | Less than 6 Hours | | More than 6 Hours | | Less than 6 Hours | | More than 6 Hours | |
| Health Condition | | Good health | Bad health | Good health | Bad health | Good health | Bad health | Good health | Bad health |
| Women | 18 years | 0.12 | 0.27 | 0.36 | 0.60 | 0.24 | 0.46 | 0.56 | 0.77 |
| | <46 years | 0.55 | 0.76 | 0.83 | 0.93 | 0.74 | 0.88 | 0.92 | 0.97 |
| | <69 years | 0.88 | 0.95 | 0.96 | 0.99 | 0.94 | 0.98 | 0.98 | 0.99 |
| Men | 18 years | 0.01 | 0.02 | 0.02 | 0.06 | 0.01 | 0.03 | 0.05 | 0.12 |
| | <46 years | 0.05 | 0.12 | 0.16 | 0.34 | 0.54 | 0.23 | 0.31 | 0.54 |
| | <69 years | 0.22 | 0.44 | 0.53 | 0.75 | 0.88 | 0.64 | 0.72 | 0.88 |

As age is the continuous variable, therefore maximum, minimum, and average age was taken to estimate the probabilities. The lowest probability of having a psychological disorder is 0.0056, which depicts a male farmer of good health at the age of 18 years, working under the transmission line of 132 KV and his exposure duration is less than 6 hours. While, the maximum probability of having a psychological disorder is 0.9943, which represents a female farmer who is already facing health issues and with the age of approximately 69 years, working under the transmission line of 220 KV and her exposure duration is more than 6 hours. Figure 2 shows the probability of psychological disorders in men with the consideration of all the independent variables. While, Figure 3 shows the probability of psychological disorders in a woman with the consideration of all the independent variables.

**Figure 2**

*Probability of Psychological Disorders in Male Farmers*

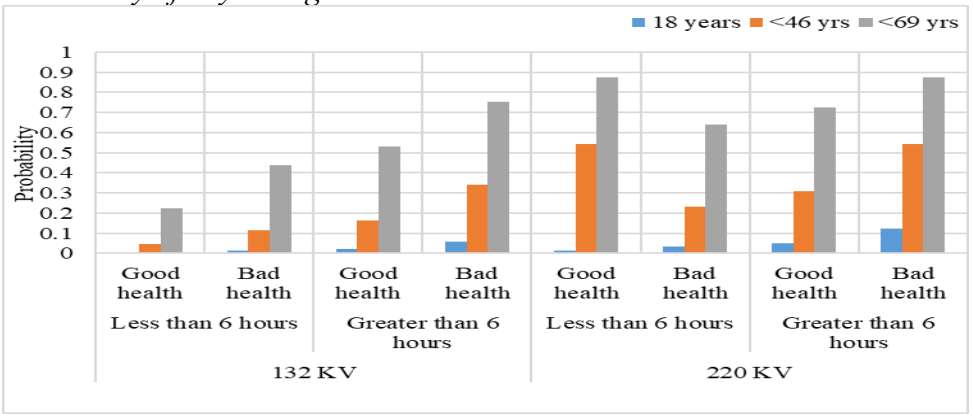
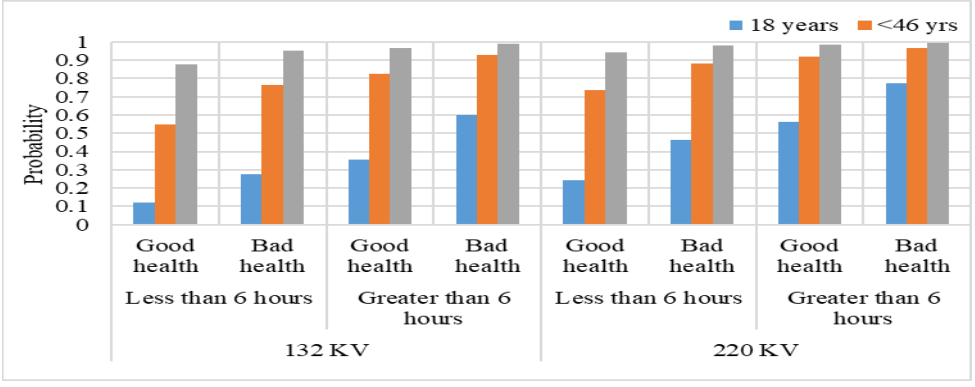



**Figure 3**

*Probability of Psychological Disorders in Female Farmers*



## Discussion

According to the assessment of evidence acquired through surveys conducted, examined current research, and guidelines provided by (International Commission on Nonionizing Radiation Protection), the study conducted shows that farmers working under high voltage transmission lines are affected by high electromagnetic radiation. The symptoms arise with the passage of long and short time exposures. This study's findings align with the guidelines discussed by (Gowland & Glover, 2014), who show different variables involved in affecting electromagnetic waves. Similarly, Gautam et al. (2021) discussed the impact of high electromagnetic non-ionized fields on male infertility. The study focused on low electromagnetic fields generated from different electronic devices. It also suggests numerous factors which contribute, but the electromagnetic effect has a more significant share in this problem. Moreover, growing urbanization affects the farmer's life in terms of high-power infrastructure development that has an impact on human health that leads to severe health disorders that include several types of cancers due to radiating electromagnetic fields from high voltage transmission lines, mobile towers, high voltage frequency resonators (Gupta et al., 2020). The latest research was conducted on rats to find the association between abnormal growth and electromagnetic effects. Significant traces of nonionizing radiation accelerated hyperplasia in an observational rodent model with and without estrogen administration in the presence of an electromagnetic field (Fadiloglu et al., 2019). A study was also conducted to find out the impact of electromagnetic waves on human health. It concludes that there are traces of evidence related to human health, and extreme exposure to high electric fields, which can trigger different biological complications (Saliev et al., 2019).

### Limitations and Suggestions

The present study also observed some limitations. Although formal procedures and standardized tools are essential in psychological assessment, our approach sought to bridge the gap between formal diagnosis and farmers' lived experiences. However, presently, basic terminologies regarding the symptoms of psychological disorders were used to screen out farmers instead of using formal psychological assessment. This method may not capture the full complexity of psychological disorders or account for comorbid conditions and confounding factors, but it helps

identify those who may need support. Future research could add measures and correlations to understand farming mental health better across genders.

## Conclusion

The current study employed logistic regression analysis to investigate the potential psychological health risks posed by HVTL to farmers. The study examined the effects of gender, age, type of transmission line, work duration, and pre-existing health issues on the probability of developing psychological disorders. Results indicated that the logistic regression model is a suitable tool for modeling psychological disorders among farmers exposed to HVTLs. Female farmers were found to be more vulnerable to psychological disorders than their male counterparts. Moreover, the likelihood of psychological disorders increases with age, voltage magnitude, and exposure duration.

## Implications

These findings have important environmental implications, as they highlight the potential risks associated with HVTLs and the need for measures to mitigate their adverse effects on the psychological well-being of farmers. Specifically, female farmers between the ages of 46 to 69 who regularly work under a 220 KV HVTL for up to six hours should be considered as a high-risk group and targeted with appropriate interventions. There is dire need to start a discussion about mental health awareness and support among farmers, acknowledging that formal assessments are necessary but may not be available in rural areas.

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