



SCHIZOPHRENIA PREDICTION USING MACHINE LEARNING TECHNIQUES

M. R. Meshram¹, A. D. Sakhare²

¹ R. T. M. Nagpur University, Nagpur, India. mihir25_2010@rediffmail.com

² Department of Electronics and Computer Science, R. T. M. Nagpur University, Nagpur, India. adsakhare616@gmail.com

Corresponding Author: M. R. Meshram (mihir25_2010@rediffmail.com)

Abstract: Schizophrenia is a mental health problem that affects how a person thinks, feels and behaves. It has symptoms like hearing things that're not there having false beliefs and thinking in a confused way. These symptoms can really affect a persons life. Diagnosing schizophrenia on is not easy because there are no simple tests for it. Doctors usually have to look at how a person behaves and their medical history to make a diagnosis. New developments in imaging and computer technology are giving us new ways to detect schizophrenia. Using a kind of scan called Magnetic Resonance Imaging or MRI along with machine learning is showing promise in finding the differences in the brain that are linked to schizophrenia. Machine learning is a way for computers to learn from amounts of data, which can help doctors make more accurate diagnoses. Researchers are trying approaches, like special algorithms and learning models to tell the difference between people with schizophrenia and those without it. Some methods, like Multiple Kernel Learning are working well. This research is about using machine learning to detect schizophrenia and classify it using MRI of the brain. The goal is to help doctors make decisions and diagnose people correctly.

Schizophrenia detection is getting better with the help of machine learning and MRI scans. Schizophrenia is a problem and doctors need all the help they can get to diagnose it. Machine learning is good at finding patterns in data, which can help doctors understand what is going on in the brain of a person with schizophrenia. This can lead to treatment and care for people, with schizophrenia. Schizophrenia research is important and using machine learning and MRI scans is a part of it.

Keywords: Schizophrenia (SZ), Machine Learning (ML), Magnetic resonance imaging (MRI)

1. INTRODUCTION

Schizophrenia is a severe mental disorder in which people interact reality abnormally(Samanta et al., 2004). Although psychotic symptoms such as hallucination and delusions are frequently present, impaired information processing is probably the common symptoms(Santos Febles et al., 2022). According to report of World Health Organization, around 1% of the worlds population is suffer from Schizophrenia disease. Researcher are challenged to predict SZ from subtle signs. Magnetic resonance imaging(MRI) is another ML resource used to detect SZ (Suri et al., 2021). Schizophrenia or SZ is a major psychiatric disorder related to structural and functional brain anomalies that gradually ended up with impairments in cognition, emotion, and behavior(Noor et al., 2020). Recently a lot of people who do research have been working on making tools that can help doctors figure out if someone has SZ. These tools use something called Deep Learning. Look at pictures of the brain from something called MRI. Many researchers have been trying to make these tools better so they can help with the diagnosis of SZ. They are using Deep Learning and MRI data to do this.

Machine learning techniques have potential value for assisting the diagnosis of brain disorders(Santos Febles et al., 2022).Machine learning is a set of artificial intelligence tools used to construct data models representing the knowledge hidden in huge data sets(Ruiz de Miras et al., 2023).Recent several studies have shown that machine learning can also be a very useful tool in classifying Schizophrenia. The causes of SZ are not known, however, it is



believed to be contributed by a combination of genetic, chemical and environmental factors (Agarwal & Singhal, 2023). Cognitive symptoms are symptoms related to disturbances in memory and difficulty in concentrating. All these symptoms of Schizophrenia can affect the quality of life and productivity significantly (Rampisela & Rustam, 2018). It appears in young age, and the brain damage increases, if left untreated (Agarwal & Singhal, 2023). It is a chronic disease that requires lifelong treatment. Schizophrenics' life expectancy are 2-3 times lower than the general population (Rampisela & Rustam, 2018) as 10% committed suicide. Furthermore, 20-40% Schizophrenic attempted suicide at least once (Raju, 2022).

Schizophrenia is a disorder that comes in forms. There are different types of schizophrenia. These types are: Paranoid Schizophrenia, Hebephrenic Schizophrenia, Catatonic Schizophrenia, Undifferentiated Schizophrenia, Residual Schizophrenia, Simple Schizophrenia, Cereasthopathic Schizophrenia, Unspecified Schizophrenia. Schizophrenia disorder can be very confusing. The different types of Schizophrenia disorder are what doctors look at when they try to figure out what is going on with someone who has schizophrenia. Schizophrenia is a disorder and the different types of Schizophrenia are important to know about. In most parts of the world paranoid Schizophrenia is the common type of type of Schizophrenia. The major problem in detecting Schizophrenia is that so far neither diagnostic tests nor biomarkers are available (Buettner et al., 2020). Clinical diagnosis is instead made based on a patient's history and their overall mental condition (Owen et al., 2016).

Schizophrenia disease facts:

- Schizophrenia causes psychosis. It affects areas of life. This includes family, educational, social and job life.
- People with schizophrenia often face discrimination and stigma. Their human rights are often not respected (Saher et al., 2024).
- Most people with psychosis do not get proper mental health care.
- There are effective ways to care for people with schizophrenia. One in three people with Schizophrenia can fully recover.

It Is a Biological Illness, Not "Split Personality".

Positive, Negative and Disorganized symptoms are three types of Schizophrenia.

Positive symptoms are also called "symptoms". They include delusions and hallucinations. This happens when a patient loses touch, with reality in some ways. Delusions can be very scary for a patient. They might think that people are reading their thoughts or that someone is plotting against them. Sometimes the patient will think that others are watching them and want to hurt them. The patient may even think that they have the power to control what other people are thinking.

Hallucinations are different, from delusions. They make people hear things or see things that're not really there. The patient might hear voices. See things that nobody else can see.. These symptoms are called "positive" because they are obvious and should not be present. The term "positive" here does not mean "good". It simply means that these symptoms are noticeable and not normal. Delusions and hallucinations are examples of symptoms. They are a sign that a patient has lost touch with reality.

Disorganized symptoms are confusing. They include speech and thinking and strange behavior. People, with schizophrenia get these symptoms. For example they have trouble talking in a way. They also struggle to have conversations. Some people move slowly. They repeat movements. Make ritualistic actions. An example is walking in circles. They also struggle to understand things. This includes sights, sounds and feelings.

Negative Symptoms are things like not being able to show emotions or feeling empty inside. People with Symptoms have a hard time starting things and seeing them through. They might not talk much. What they do say does not have much meaning. They also do not get excited about things that most people enjoy. The word "Negative" in Symptoms does not mean someone has a bad attitude. It means they are missing some things that normal people usually have. Negative Symptoms are basically a lack of things that should be there in a person's life like feelings and interest in things. Negative Symptoms can make life pretty dull, for people who have them.

To be diagnosed with schizophrenia a patient must have symptoms and a loss of reality for at least six months. This means the patient with schizophrenia will have a lot of trouble functioning like a person. The patient with

schizophrenia will get worse at doing things over time. The symptoms of schizophrenia must be present, for a time at least six months for a doctor to say that someone has schizophrenia.

Things that can increase the chance of getting schizophrenia include:

- Having a family member with schizophrenia is a risk factor for schizophrenia.
- What happens to you in life can also affect your chances of getting schizophrenia like living in a neighborhood with a lot of stress or danger these life experiences can be very hard on people with schizophrenia.
- Some things that happen when a woman is pregnant or when a baby is born can also affect the chances of getting schizophrenia, such as the baby not getting food before or after birth being really small when born or being around bad things like toxins or viruses, before birth that can hurt the development of the brain and lead to schizophrenia.

2. RELATED WORKS

Elsa Santos Febles and her team (Santos Febles et al., 2022) looked at how kernel learning or MKL can help tell Schizophrenic patients and healthy people apart. They used something called event-related measures to do this. The team also found that using the Boruta algorithm made their results more accurate and did not take long to get. The main goal of the study was to see how well the MKL classifier and Boruta feature selection method worked for telling Schizophrenia patients and healthy controls one person at a time. They wanted to know if this method could really help with Schizophrenia patients and healthy controls.

Jihoon oh et al.(Oh et al., 2020) approached to detect schizophrenia in structural MRI data set using a trained deep learning algorithm. The author found that the deep learning algorithm performed well in detecting Schizophrenia and found relevant structural features from structural brain MRI data.They discovered that the deep learning algorithm was heavily reliant on data from the right temporal region when classifying Schizophrenia. When trained on multicenter structural MRI datasets, deep neural networks demonstrated high sensitivity and specificity in identifying Schizophrenia.

Guruprasad singh suri et al. (Suri et al., 2021) presented a systematic an overview on machine learning in detecting SchizophreniaHis studies suggests that support vector machine ,deep neural network and random forest can predict SZ with high accuracy of 70-90% .Finally, the results obtained show that the ML methods give reliable answers for clinicians in the decision-making process of SZ patients.

Guruprasad singh suri and other people presented an overview of how machine learning can help detect Schizophrenia. They looked at machine learning. Found that it is really good at detecting Schizophrenia. Machine learning things like SVM and random forest and deep learning can predict Schizophrenia with an accuracy of 70 to 90 percent.

The results that Guruprasad singh suri and other people collected show that machine learning methods give doctors information to make decisions about Schizophrenia patients. Machine learning is helpful for doctors when they are making decisions about people, with Schizophrenia.

Manan Bintah Taj Noor et al.(Noor et al., 2020) presented a survey, about finding out if people have Schizophrenia. The author found out that people are using Deep Neural Networks a lot to detect Schizophrenia. They are using Deep Neural Networks more and more for Schizophrenia detection.

The studies, in Table 1.1 looked at how Machine Learning algorithms can help detect Schizophrenia disorders.

Author Name	Number of Samples	ML Method	Validation Method	Accuracy
Elsa Santos Febles et al.(Santos Febles et al., 2022)	54 SZ 54 HC	Multiple Kernel Learning	10-fold cross validation	86%
Jihoon oh et al.(Oh et al., 2020)	443 HC 423 SZ	3DCNN	10-fold cross validation	97%

Carlos Cabral et al.(Cabral et al., 2016)	71 SZ 74 HC	SVM	20-fold validation	cross	75%
ZhiHong Chen et al.(Chen et al., 2020)	34 SZ 34 HC	SVM	LOOC		85%
Organisciak et al.(Organisciak et al., 2022)	97 SZ 54 HC	DNN	10-fold validation	cross	98%
Jo et al.(Jo et al., 2020)	48 SZ 25 HC	SVM	10-fold validation	cross	66.3%

Classification Algorithms:

Classification algorithms are a kind of machine learning technique that we use to put data into classes or groups. We use classification algorithms to learn patterns from the data we already have. Then we use those patterns to figure out the class of new data that we get. Classification algorithms are used in lots of areas like diagnosis and image recognition and spam detection and customer analysis.

Some common classification algorithms are the k-Nearest Neighbour algorithm, Random Forest algorithm, Decision Tree algorithm, the Naïve Bayes Classifier algorithm and the Support Vector Machine algorithm. Classification algorithms like these are really useful for helping us make sense of our data. Classification algorithms are very good, at learning patterns from the data we give them.

1. k-Nearest Neighbour (kNN)

The kNN algorithm is really simple. It is also very powerful when it comes to classifying things. The kNN algorithm gets its name from the idea that people who are similar usually stick together. For example people who live in the neighborhood are often similar in some ways. The kNN algorithm works in a way. When the kNN algorithm has to make a prediction about some data it looks at the training data to find similar things. The kNN algorithm then assigns a class label to the data based on the class labels of the similar training data. So the kNN algorithm is basically trying to find the neighbors to the unknown data in the training data set and use that to make a prediction. The kNN algorithm is using the training data set elements that're similar to the unknown element to make this prediction. The class label of the element is assigned based on the class labels of the similar training data set elements, in the kNN algorithm.

1.1 Strengths of the kNN algorithm

- The kNN algorithm is really easy to get.
- It works great in some cases like when designing a recommender system.
- The training phase takes no time.

1.2 Weaknesses of the kNN algorithm

- The kNN algorithm does not really learn from the data. It makes classifications based on the training data. So it relies heavily on the training data. If the data does not cover the problem well the kNN algorithm will not classify things efficiently.
- The classification process is slow because it uses the training data directly. There is no model to make things faster.
- The kNN algorithm needs a lot of space to store the training data for classification. This can be a problem.

2. Decision tree

Decision tree learning is one of the popular ways to classify things. The name says it all. It makes a model that looks like a tree. It groups things together using methods and it works really well. A decision tree is great for looking at lots of things with many classes. It is fast and easy to understand the rules. Using the input variables in the feature vector, decision tree learning aims to create a model that can forecast the output. Decision tree learning is about making

a model that can predict the output variable based on the input variables in the feature vector. Decision tree is used for this purpose.

2.1 Strengths of decision tree

- Decision tree produces simple rules that are easy to understand. For decision trees you do not need to know a lot of math or computer stuff to get it.

- Decision tree works well for problems.
- It can handle numbers and categories.
- Decision tree can work well with large sets of training data.

- Decision tree gives us an idea of which features are more important for classification. Decision tree is good at showing us which features are useful for classification.

2.2 Weaknesses of decision tree

- Decision tree models can be biased towards features, with levels.
- Decision tree models can be. Underfitted easily.
- Decision trees can make mistakes when there are classes and not many examples to train with.

Training a decision tree can be slow.

- Big decision trees are hard to understand. Large decision trees are complex to understand.

3. Random forest model

The random forest model is a type of classifier that combines decision tree classifiers. This is what we call a classifier. It uses decision trees and combines them to get a better result. We use a method called bagging to combine these decision trees. We use different feature sets to do this. The reason we use a lot of trees in the forest model is so that we can train the trees enough to get a good contribution from each feature in many models. After we combine all the trees to make the forest model we use something called majority vote to combine the output of all the different trees. The result we get from the forest model is usually better than the result we get from individual decision tree models. We get a result from the random forest model because it uses many decision trees and this makes the random forest model more accurate, than individual decision tree models.

3.1 Strengths of Random Forest

- It works well with data sets.
- It handles missing data and stays accurate even when most of the data is missing.
- It corrects errors in data sets where some classes have more data than others.
- It shows which features are most important for the classification.
- It gives an estimate of how it will do, on new data as it is being created.
- The forest it creates can be. Used on other data later.
- Random Forest can be used for both classification and regression problems.

3.2 Weaknesses of the random forest

- The forest model is not as easy to understand as a decision tree model because the random forest model combines a lot of decision tree models.

- The random forest model is also a lot more expensive to run on a computer than a model, like a decision tree model.

4. Support Vector Machine

A Support Vector Machine is a model. It can do linear classification and regression. The model works by finding a line called a hyperplane. This line separates data points in a n -dimensional space. The line acts as a boundary between the data points. The Support Vector Machine predicts one of two classes. These classes are defined in the training

data. The model is like a tool that helps make predictions. It uses a hyperplane to decide which class new data points belong to. In short the Support Vector Machine algorithm builds a model. This model assigns new data points to one of two classes. The model is based on a hyperplane that separates the data points. The hyperplane is like a divider, in a n -dimensional space. It helps the model make predictions. The model is a Support Vector Machine.

4.1 Strengths of SVM

- SVM is good for classification and regression tasks.
- It works well with noisy data or outliers.
- The results, from this model are really good.

4.2 Weaknesses of SVM

- SVM is only good for problems with two classes. It does not work well when there are than two classes.
- The SVM model can be very hard to understand when dealing with data that has many features. It becomes like a box making it difficult to interpret the results.
- SVM can be slow when working with datasets. This includes datasets with features or a huge number of instances.
- SVM requires a lot of memory to run which can be a problem, for datasets.

5. Naive Bayes classifier

The Bayes classifier is simple. It thinks that the attribute values do not depend on each other when we know the class of the instance. This simple idea makes the calculations a lot easier. We do not lose much by making this assumption. The Naive Bayes classifier gives us the classification. The Naive Bayes classifier is very useful, in real life situations. The Naive Bayes classifier is one of the ways to learn. When the attribute values do depend on each other the Naive Bayes classifier is still very good. It gives us a standard to compare the learning methods to the Naive Bayes classifier.

5.1 Strengths of Naïve Bayes classifier

- It is simple and easy to implement.
- It actually works well with small datasets.
- One of its advantages is handling dimensional data efficiently.
- Naïve Bayes classifier is effective for text classification tasks.
- It is less sensitive to features that're not relevant.
- This classifier supports n -class classification, which is really useful.
- Naïve Bayes classifier is good, at dealing with types of data.

5.2 Weaknesses of Naïve Bayes Classifier

- The problem with thinking that features are independent of each other is that this is not always the case with Feature Independence.
- When features are related to each other, which is known as Correlated Features the system does not work well and this results in Poor Performance with Correlated Features.
- Sometimes a feature has Zero Probability which means it never happens. This causes a problem.
- The system is not very smart. Has Limited Learning Ability to deal with new things.
- To work properly the system Requires Good Quality Data. This is very important for the system to be accurate and work well with Feature Independence and avoid Poor Performance, with Correlated Features and the Zero Probability Problem.

3. CONCLUSION

In this research, our objective was to create a Schizophrenia disease prediction system obtained for all implemented techniques. In this we have studied different classification of Schizophrenia disease database also we have different techniques of machine learning. So, far at the completion of the Schizophrenia disease prediction model survey, we have evaluated the popular and effective Schizophrenia prediction methods from the literature survey and finally, select the most efficient algorithm for their performance analysis on the Schizophrenia disease prediction. I hope this survey is helpful to research scholars, students and practitioners.

Schizophrenia is a complex mental disorder that affects cognitive functions, emotions, and daily activities. Due to the absence of specific biomarkers and diagnostic tests, early and accurate detection of schizophrenia remains a major challenge. The integration of Magnetic Resonance Imaging (MRI) with machine learning techniques provides an effective approach for identifying brain abnormalities and distinguishing schizophrenia patients from healthy individuals. Machine learning algorithms can analyze hidden patterns in large medical datasets, improving diagnostic accuracy and supporting clinicians in decision-making.

Various classification and feature selection methods have shown promising results in Schizophrenia prediction. Techniques such as Multiple Kernel Learning (MKL), deep learning, and other machine learning approaches help in extracting meaningful features from brain imaging data. Although these methods have significant potential, challenges such as limited datasets, feature complexity, and model interpretability still need to be addressed. Future research focusing on larger datasets, advanced algorithms, and improved validation methods can lead to more reliable automated systems for early diagnosis and treatment planning of Schizophrenia.

References:

1. Agarwal, M., & Singhal, A. (2023). Fusion of pattern-based and statistical features for Schizophrenia detection from EEG signals. *Medical Engineering and Physics*, 112(February), 1–7. <https://doi.org/10.1016/j.medengphy.2023.103949>
2. Buettner, R., Beil, D., Scholtz, S., & Djemai, A. (2020). Development of a machine learning based algorithm to accurately detect schizophrenia based on one-minute EEG recordings. *Proceedings of the Annual Hawaii International Conference on System Sciences*, 2020-Janua, 3216–3225. <https://doi.org/10.24251/hicss.2020.393>
3. Cabral, C., Kambeitz-Ilankovic, L., Kambeitz, J., Calhoun, V. D., Dwyer, D. B., Von Saldern, S., Urquijo, M. F., Falkai, P., & Koutsouleris, N. (2016). Classifying Schizophrenia Using Multimodal Multivariate Pattern Recognition Analysis: Evaluating the Impact of Individual Clinical Profiles on the Neurodiagnostic Performance. *Schizophrenia Bulletin*, 42(1), S110–S117. <https://doi.org/10.1093/schbul/sbw053>
4. Chen, Z. H., Yan, T., Wang, E. L., Jiang, H., Tang, Y. Q., Yu, X., Zhang, J., Liu, C., & Rostro-Gonzalez, H. (2020). Detecting Abnormal Brain Regions in Schizophrenia Using Structural MRI via Machine Learning. *Computational Intelligence and Neuroscience*, 2020. <https://doi.org/10.1155/2020/6405930>
5. Jo, Y. T., Joo, S. W., Shon, S. H., Kim, H., Kim, Y., & Lee, J. (2020). Diagnosing schizophrenia with network analysis and a machine learning method. *International Journal of Methods in Psychiatric Research*, 29(1), 1–11. <https://doi.org/10.1002/mpr.1818>
6. Noor, M. B. T., Zenia, N. Z., Kaiser, M. S., Mamun, S. Al, & Mahmud, M. (2020). Application of deep learning in detecting neurological disorders from magnetic resonance images: a survey on the detection of Alzheimer's disease, Parkinson's disease and schizophrenia. *Brain Informatics*, 7(1). <https://doi.org/10.1186/s40708-020-00112-2>
7. Oh, J., Oh, B. L., Lee, K. U., Chae, J. H., & Yun, K. (2020). Identifying Schizophrenia Using Structural MRI With a Deep Learning Algorithm. *Frontiers in Psychiatry*, 11. <https://doi.org/10.3389/fpsy.2020.00016>
8. Organisciak, D., Shum, H. P. H., Nwoye, E., & Woo, W. L. (2022). RobIn: A robust interpretable deep network for schizophrenia diagnosis. *Expert Systems with Applications*, 201, 1–39. <https://doi.org/10.1016/j.eswa.2022.117158>
9. Owen, M. J., Sawa, A., & Mortensen, P. B. (2016). Schizophrenia. *The Lancet*, 388(10039), 86–97. [https://doi.org/10.1016/S0140-6736\(15\)01121-6](https://doi.org/10.1016/S0140-6736(15)01121-6)
10. Raju, N. N. (2022). Psychiatry training in India. *Indian Journal of Psychiatry*, 64(5), 433–439. https://doi.org/10.4103/indianjpsychiatry.indianjpsychiatry_649_22
11. Rampisela, T. V., & Rustam, Z. (2018). Classification of Schizophrenia Data Using Support Vector Machine (SVM). *Journal of Physics: Conference Series*, 1108(1). <https://doi.org/10.1088/1742-6596/1108/1/012044>
12. Ruiz de Miras, J., Ibáñez-Molina, A. J., Soriano, M. F., & Iglesias-Parro, S. (2023). Schizophrenia classification using machine learning on resting state EEG signal. *Biomedical Signal Processing and Control*, 79(April 2022). <https://doi.org/10.1016/j.bspc.2022.104233>
13. Saher, A., Gilanie, G., Cheema, S., Latif, A., Batool, S. N., & Ullah, H. (2024). A Deep Learning-Based Automated Approach of Schizophrenia Detection from Facial Micro-Expressions. *Intelligent Automation and Soft Computing*, 39(6), 1053–1071. <https://doi.org/10.32604/iasc.2024.057047>
14. Samanta, M. K., Wesley, N. E. S., Manikandan, S. R., & Suresh, B. (2004). An overview of schizophrenia. *Indian Journal of Pharmaceutical Sciences*, 66(2), 148–157.

15. Santos Febles, E., Ontivero Ortega, M., Valdés Sosa, M., & Sahli, H. (2022). Machine Learning Techniques for the Diagnosis of Schizophrenia Based on Event-Related Potentials. *Frontiers in Neuroinformatics*, 16(July), 1–11. <https://doi.org/10.3389/fninf.2022.893788>
16. Suri, G. S., Kaur, G., & Moein, S. (2021). Machine learning in detecting schizophrenia: An overview. *Intelligent Automation and Soft Computing*, 27(3), 723–735. <https://doi.org/10.32604/IASC.2021.015049>
17. Bae, Y. J., Shim, M., & Lee, W. H. (2021). Schizophrenia detection using machine learning approach from social media content. *Sensors*, 21(17). <https://doi.org/10.3390/s21175924>
18. Ruiz de Miras, J., Ibáñez-Molina, A. J., Soriano, M. F., & Iglesias-Parro, S. (2023). Schizophrenia classification using machine learning on resting state EEG signal. *Biomedical Signal Processing and Control*, 79(April 2022). <https://doi.org/10.1016/j.bspc.2022.104233>
19. Sahu, P. K. (2023). Artificial intelligence system for verification of schizophrenia via theta-EEG rhythm. *Biomedical Signal Processing and Control*, 81(March), 23–25. <https://doi.org/10.1016/j.bspc.2022.104485>
20. Wang, D., Russel, W. A., Sun, Y., Belanger, K. D., & Ay, A. (2023). Machine learning and network analysis of the gut microbiome from patients with schizophrenia and non-psychiatric subject controls reveal behavioral risk factors and bacterial interactions. *Schizophrenia Research*, 251(January), 49–58. <https://doi.org/10.1016/j.schres.2022.12.015>
21. Zbello, B. T. (2020). Schizophrenia Disease Classification with Deep learning and Convolutional Neural Network Architectures using TensorFlow MASTER THESIS Title : Schizophrenia Disease Classification with Deep learning and Convolutional Neural Network Architectures using Tens (Number May).
22. De Filippis, R., Carbone, E. A., Gaetano, R., Bruni, A., Pugliese, V., Segura-Garcia, C., & De Fazio, P. (2019). Machine learning techniques in a structural and functional MRI diagnostic approach in schizophrenia: A systematic review. *Neuropsychiatric Disease and Treatment*, 15, 1605–1627. <https://doi.org/10.2147/NDT.S202418>
23. Fayaz, M., Qureshi, M. S., Kussainova, K., Burkanova, B., Aljarbouh, A., & Qureshi, M. B. (2021). An Improved Brain MRI Classification Methodology Based on Statistical Features and Machine Learning Algorithms. *Computational and Mathematical Methods in Medicine*, 2021. <https://doi.org/10.1155/2021/8608305>
24. Goel, S. (2025). Early Detection of Schizophrenia Using Machine Learning Algorithms: A Comprehensive Review. *Journal of Ecophysiology and Occupational Health*. <https://doi.org/10.18311/jeoh/2025/49515>
25. Göker, H. (2023). 1D-convolutional neural network approach and feature extraction methods for automatic detection of schizophrenia. *Signal, Image and Video Processing*, 17(5), 2627–2636. <https://doi.org/10.1007/s11760-022-02479-7>.