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Developing a Neurocare Framework for Migraine Management

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ABSTRACT
Migraine, a neurological disorder impacting over one billion people worldwide, leads to debilitating headaches and diminished quality of life. Existing mobile applications and machine learning (ML) models offer some support for migraine management but often lack comprehensive care, real-time insights, and essential assessment tools like the MIDAS questionnaire. Current solutions are also limited in tracking triggers and capturing complete patient histories, highlighting the need for a more holistic approach. This review evaluates 20 migraine-focused applications(14 mobile and 6 web-based) and 13 ML/deep learning (DL) studies, identifying key limitations and paving the way for improved solutions. In response, NeuroCare, a prototype app, provides validated MIDAS assessments, personalized tracking for symptoms and triggers, detailed migraine logs, and electronic health record (EHR) displays for healthcare providers. This study demonstrates NeuroCare's potential as a comprehensive tool with future AI/ML integrations, benefiting both patients and clinicians in effectively managing migraines.

Keywords: Migraine management, Migraine Disability Assessment (MIDAS), AI/ML, EHR, healthcare

INTRODUCTION

Migraine is a complex neurological disorder marked by repeated, intense headaches often accompanied by symptoms like nausea, vomiting, and sensitivity to both light and sound. These headaches generally affect one side of the head and, if not managed, may persist from four to 72 hours [1], greatly diminishing an individual's quality of life. Globally, migraines impact over one billion individuals [2], affecting roughly 1 in 7 people, with a higher prevalence among women compared to men [3].

The World Health Organization (WHO) identifies migraine as one of the top 20 causes of disability, attributing considerable economic strain to healthcare expenses and lost productivity. While the precise origins of migraines remain uncertain, they are believed to result from a combination of genetic and environmental influences. Common treatment approaches often include lifestyle adjustments, medications, and, when necessary, preventive therapies aimed at reducing the frequency and severity of migraine episodes.

Numerous mobile applications, as well as machine learning (ML) and deep learning (DL) models, have been developed to assist with migraine management and prediction. Despite this progress, a comprehensive evaluation of these systems is essential to understand their functions, limitations, and areas needing improvement. This review paper analyzes 20 existing applications—14 mobile and 6 web-based—currently available for managing migraines, alongside an examination of 13 research studies focused on predictive ML/DL models. By reviewing these sources, we compare key features and limitations, providing valuable insights into the strengths and areas for enhancement in current tools.In this context, NeuroCare, a free app available on Google Play Store [4], serves as a prototype to address gaps in migraine management tools. It includes the validated Migraine Disability Assessment (MIDAS) [5] for assessing migraine impact, a personal diary for tracking triggers, migraine logs to document episodes, and an FAQ section for common concerns. These features offer a holistic, user-friendly approach to help individuals manage migraines effectively.

The research paper begins by addressing the importance of effective migraine management and the challenges faced by individuals in dealing with their condition. It introduces NeuroCare, a mobile application designed to enhance migraine tracking and management, featuring tools like the Migraine Disability Assessment (MIDAS) questionnaire, a personalised diary for monitoring triggers and habits, and a migraine log for documenting episode details. Following the introduction, the paper provides a detailed comparison of various migraine care apps, highlighting their features, advantages, and limitations. This section includes a table summarising key functionalities of different apps, such as tracking, symptom monitoring, and user engagement, giving readers a comprehensive overview of the available tools in the market. The paper also explores the use of machine learning techniques for migraine classification and prediction, evaluating research papers on the performance measures, preprocessing methods, and algorithms employed. In the Results and Discussion section, the paper contrasts NeuroCare with existing migraine apps, showcasing its strengths in personalised tracking, MIDAS integration, and ease of use. Visuals of the app's interface, including its home page, migraine log, and notifications, illustrate how the app supports users in managing their migraines. Finally, the paper concludes by suggesting future enhancements, such as the integration of AI and machine learning for better prediction and management, and emphasises NeuroCare's potential as a clinical tool. It ends with a list of references for further research on migraine management technologies.

LITERATURE REVIEW

The following table 1.1 provides a detailed comparison of currently available mobile and web-based applications designed for migraine management. This analysis identifies each app's target users, reach (in terms of downloads or user traffic), salient features, advantages and limitations, offering insights into what these platforms achieve and where they fall short. By examining aspects such as tracking capabilities, personalization options, and ease of use, it aims to highlight gaps in existing migraine apps and establish a foundation for NeuroCare's unique contributions. The findings will clarify the motivations behind developing NeuroCare as a comprehensive and user-friendly alternative, ultimately tailored to address common user needs more effectively.

Name	Target Users	Reach*	Salient Features	Advantages	Limitations
Migraine Buddy (Mobile - Android + iOS)	3+	3.5M+	• Tracks symptoms, duration, pain intensity. • Exportable reports. • Weather analysis, cycle tracking in premium. • Detailed insights on pain and triggers. • Developed with neurologists.	• Recommended by top neurologists. • Tracks symptoms and triggers. • Generates Migraine Impact Reports. • Syncs with weather data. • Positive reviews, educational tools.	• Best for frequent sufferers. • Not ideal for infrequent migraines. • Premium features require subscription.
Headache Log (Mobile - Android)	All ages	100K+	• Tracks headache severity, location, and duration. • Allows custom entries for pain types, triggers, and meds. • Offers stats, calendar, and graph views. • Option to export data as a spreadsheet or backup.	• Fast, simple headache tracking. • Highly customizable for symptoms, triggers, and medications. • Provides graphs and calendar views to spot patterns.	• No direct report printing for doctors. • Not available for Apple devices. • Data stored locally, not backed up to cloud.
UCLA Mindful (Mobile - Android + iOS)	3+	100K+	• Basic meditations for beginners in 15 languages. • Wellness meditations for managing health conditions. • Informative videos on mindfulness and meditation techniques. • Weekly recordings from live meditations. • Timer feature for independent meditation sessions.	• Provides mindfulness meditation practices anytime, anywhere. • Offers a variety of guided meditations in multiple languages. • Completely free to use, promoting accessibility.	• Meditations are for educational purposes, not clinical treatments. • May lack personalized features found in other meditation apps.

*No.of downloads/User Traffic

Name	Target Users	Reach	Salient Features	Advantages	Limitations
Health Log (Mobile - Android)	All ages	50K+	• Logs detailed health events and tracks trends. • Provides statistics to identify patterns. • Customizable time formats and event types. • Export data to spreadsheets for reports or backups.	• Flexible logging for various health events (headaches, cramps). • Tracks severity, pain type, location, triggers, medications, and relief. • Data visualization with calendar and graph views.	• Free version includes ads; some features require an upgrade. • Local data storage, but upgrade allows cloud backups and syncing via Dropbox.
Bezzy Migraine (Mobile - Android + iOS)	Teens	10K+	• Live discussions on various topics. • Daily matching with other users. • User-friendly interface for easy navigation.	• Community connection for support. • Live chats and forums for advice. • Extensive health library on migraine management.	• No symptom tracking or health history analysis. • Primarily focuses on education and community.
Migraine Relief Hypnosis (Mobile - Android)	All ages	10K+	• Peaceful background music and nature sounds. • Hypnotic Booster with binaural beats for optimal brainwave frequency. • Separate volume controls for voice, background, and hypnotic booster. • Option to disable the "Awaken at End" feature for sleep. • Sessions can be repeated or looped during sleep.	• Daily 30-minute guided hypnosis sessions for migraine pain relief. • Effective within 1–3 weeks of regular use. • Soothing voice of a certified hypnotherapist enhances relaxation.	• Available only on Android devices. • Results may vary; not a substitute for medical treatment.

Name	Target Users	Reach	Salient Features	Advantages	Limitations
HeadApp (Mobile - Android + iOS)	3+	100K+	• Guided input, no personal info • Tracks pain, triggers, symptoms, and meds • Provides stats, graphs, and reports • Logs sleep data automatically • Highlights headaches on a calendar • Assists with record filling • Works offline	• Simplifies headache tracking • Covers multiple headache-related factors • Facilitates discussions with healthcare providers • Allows logging anytime, anywhere • Does not require personal data	• Cannot replace professional treatment • Accuracy relies on user consistency • Lacks advanced forecasting capabilities • Data may be misunderstood without guidance • Requires active participation to be effective
Nerivio App (Mobile - Android + iOS)	3+	10K+	• Operates Nerivio neuromodulation device. • Tracks preventive treatments and symptoms. • Provides diary and analytics for migraine tracking. • Can be used without the device as a tracker.	• Controls FDA-approved Nerivio device. • Tracks migraine symptoms in a diary. • Shares data with healthcare providers.	• Requires a prescription for the device. • Only for ages 12+. • HealthKit access may be needed for sleep data.
MigraineManager (Mobile - Android + iOS)	All ages	5K+	• Personal headache tracking assistant • User-friendly diary for logging headaches and side effects • Provides personalized summaries to understand headaches • Offers medication reminders and tips for headache management • Pro version includes an interactive web dashboard for consultations • Visualizes treatment efficacy with neurologists	• Free for patients • Developed with input from neurologists and sufferers • Improves patient-provider communication • Ensures data security with encryption • Enhances headache management and understanding	• Pro features require payment • Does not replace traditional medical care • Data is informative, not professional advice • Relies on user input for effectiveness • May not fully address chronic conditions

*No.of downloads/User Traffic

Name	Target Users	Reach	Salient Features	Advantages	Limitations
Migraine Trainer (Mobile - Android + iOS)	13+	100+	• Tracks attack time, pain location, sleep, and exercise. • Headache log shareable with healthcare providers. • Developed by NINDS.	• Designed specifically for teens. • Helps discover migraine triggers. • Free to use.	• Limited to teens 13+. • Focused on basic tracking features.
Juva for Migraine (Mobile - iOS)	12+	NA	• Includes breathing exercises and muscle relaxation. • Audio and visual games to calm the nervous system. • Uses phone camera to monitor vitals. • Step-by-step biofeedback coaching. • Free one-year trial during testing.	• Doctor-developed biofeedback sessions. • Reduces migraine frequency and severity. • Monitors vital signs like heartbeat and breathing. • Provides feedback after each session.	• Requires 20 minutes per session, 5 times a week. • Only available for iPhone 8 and up. • Still in testing, limited availability.
Migraine Insight: Tracker (Mobile - iOS)	12+	NA	• Full-featured journal for easy tracking. • Automated tracking for weather, workouts, steps, and sleep. • Customizable tracking options based on user preference. • Clear records for healthcare team and medication decisions. • Integrates with HealthKit for seamless data syncing.	• Helps identify real migraine triggers. • Chronic migraine pain level tracking mode. • Integrates data from other apps (sleep, weather, workouts).	• Primarily focuses on tracking; lacks symptom analysis tools. • Requires user input for detailed tracking.

Name	Target Users	Reach	Salient Features	Advantages	Limitations
Manage My Pain (Mobile - Android + iOS + Web)	3+	100K+	• Tracks treatments, symptoms, and emotional events.Provides a diary feature.Some doctors can access data in real time.Free version available for trial.	• Tracks migraine and other chronic pain.Offers insights with stats, charts, and calendar.Generates 30-day pain reports for doctors.	• Not migraine-specific.Extra cost for detailed reports.Tracks general chronic pain, not just migraine.
N1-Headache (Mobile - Android + iOS)	All ages	10K+	• Tracks migraine triggers, severity, and treatments.Creates personalized "trigger map."Dark mode interface.Available in German.	• Identifies personal migraine risk factors.Provides daily diary and data visualization.Connects patients with clinicians.	• Available only for Apple devices.Premium version lacks clear value.Requires regular tracking for trigger map.
Migraine Diary - American Migraine Foundation (Web)	All ages	229.2K	• Educational resources on migraines • Guides for communicating with healthcare providers • Access to advocacy and fundraising network	• Customizable headache and migraine diary for tracking symptoms, triggers, and medications • Doctor-verified information to aid in understanding and treatment decisions • Part of a nonprofit, offering educational resources, advocacy, and community support	• No dedicated mobile app, web-based only • Primarily focused on education, not community features

*No.of downloads/User Traffic

Name	Target Users	Reach	Salient Features	Advantages	Limitations
Headache Tracker by Migraine.com (Web)	NA	1.3k	• Daily tracking of headache frequency, severity, symptoms, and triggers • Access to articles, expert advice, and personal stories • Community forums for support and shared experiences	• Intuitive tool for logging headache patterns and triggers • Accessible on multiple devices for convenient updates • Integrated with Migraine.com for articles, expert advice, and community forums	• May feel cluttered with community discussions and ads, distracting from tracking • Limited customization for personalizing headache logs or tracking additional health metrics
MyMigraineTeam (Web)	NA	774	• Integrates symptom tracking with a social platform where users can interact, share stories, and offer support. • Provides resources on managing migraines, including tips and articles on lifestyle changes and treatments. • Customizable headache logs to track frequency, duration, and intensity alongside personalized medication and treatment plans.	• Combines migraine tracking with a social support network, allowing users to connect with others who experience similar symptoms. • User-friendly mobile app that supports tracking of symptoms, triggers, and treatments on-the-go. • Provides a space for users to share experiences, advice, and coping strategies, enhancing emotional support.	• Some users may find the focus on community interaction less appealing if they are primarily interested in symptom tracking. • Frequent notifications and prompts to engage with the community might be overwhelming for some users.

Name	Target Users	Reach	Salient Features	Advantages	Limitations
The Daily Headache Diary (Web)	NA	NA	• Diary Format: Tracks headache frequency and intensity visually. • Exportable Records: Printable headache logs for healthcare providers. • Medication Tracking: Logs medication use and effectiveness.	• Streamlined Interface: Focused on daily headache logging, without extra features. • Visual Summaries: Clear views of headache patterns over time for easy review. • Printable Reports: Allows users to share detailed logs with doctors for better medical discussions.	• Web-Based: Limited on-the-go tracking compared to mobile apps. • Fewer Resources: Offers less educational content and community features than other platforms.
CareTuner (formerly 'Ctrl M Health') (Web)	NA	NA	• Integrated Health Tools: Offers meditation, nutrition guides, and exercise for holistic migraine care. • Tracking and Analytics: Logs headache episodes and gives insights based on habits and environment. • Educational Resources: Provides expert articles and videos on migraine management and balanced living.	• Personalized Health Management: Tailored tools for tracking diet, sleep, and exercise. • Expert-Backed Resources: Guidance from neurology and pain management specialists. • Educational Content: Videos, articles, and tips on triggers, pain relief, and lifestyle improvements.	• Subscription-Based: Full feature access requires a subscription, which may limit free resource access. • Limited Customization: Personalization is available but may be less comprehensive than dedicated migraine apps.

*No.of downloads/User Traffic

Table 1.1 : Detailed comparison of existing migraine applications

The tables 2.1 and 2.2 given below present a comparative review of various research papers focusing on ML and DL models for migraine prediction. Each model's methodologies, accuracy, and limitations are analysed to gauge the current state of predictive technology for migraines. This review provides crucial insights into how NeuroCare could leverage advanced AI/ML techniques in future iterations to enhance migraine forecasting. By understanding these models' strengths and weaknesses, the study identifies promising approaches and sets the groundwork for integrating robust, data-driven prediction features within NeuroCare in future work.

Table 2.1: Overview of research papers and the datasets used, Preprocessing techniques used and Methodologies/Algorithms employed

Name	**Datasets used**	**Preprocessing techniques used**	**Methodologies/Algorithms**
Automatic migraine classification using artificial neural	400 medical records of patients with migraine pathologies (Hospital Materno Infantil de Soledad, Colombia, 2013)	• Data Cleaning: Noise elimination, error detection, data translation • Feature Selection: Reduced from 23 to 18 variables using recursive elimination	• Artificial Neural Network (MLP, backpropagation) • Logistic Regression, SVM, Nearest Neighbour, CART

networks (2024)[26]			
Classification of Migraine Disease using Supervised Machine Learning (2023)[27]	Dataset from Kaggle, 400 patients with migraine-related conditions (Hospital Materno Infantil de Soledad, Colombia, 2013)	• Data Cleaning: Handling missing values, removing noise, correcting inconsistencies • Attribute Selection: Focus on 16 attributes (e.g., headache duration, frequency, intensity) • Data Transformation: Formatting data for algorithms	• Naive Bayes: Simple, efficient, good for small datasets • SMO (SVM): Optimizes decision boundaries for classification • Multinomial Logistic Regression: For multi-class problems • J48 (Decision Tree): Builds decision trees, handles missing values • Random Forest: Combines decision trees for improved accuracy
Developing Gradient Boosting Machine Learning Model For Predicting Headaches Among Adult Headache Patients (2023)[28]	Three-month headache diary dataset from 23 adult patients (phase 2 of CDST study by Yeshiva University); collected via Status/Post Apple device app.	• Missing Data: Removed rows with over nine consecutive missing responses; applied multivariate imputation for others. • Correlation Analysis: Calculated Pearson coefficients; no features removed for high correlation. • Data Imbalance: Noted headache presence imbalance; chose not to balance data to avoid bias. • Feature Selection: Removed features relevant only to headaches; merged responses across times; finalized 45 features.	• Gradient Boosting Classifier: Used for predicting headaches within 24 hours. • Grid Search: Optimized hyperparameters for maximum F1 score. • 5-Fold Cross-Validation: Evaluated model generalizability and overfitting.
Forecasting migraine with machine learning based on mobile phone diary and wearable data (2023)[29]	Data collected from a prospective study at St. Olavs University Hospital, Norway, including headache diary entries and biofeedback data via the Cerebri app and wearable sensors.	• Feature Engineering: Calculated maximum/minimum heart rate, temperature, and SEMG voltage, along with mean values. • Data Cleaning: Removed samples with missing diary entries following a biofeedback session. • Data Scaling: Scaled data by mean subtraction and standard deviation division.	• Logistic Regression: Predicts binary outcomes from independent variables. • Support Vector Machines: Classifies and analyzes data. • Random Forest Classifiers: Combines multiple decision trees for classification/regression. • Gradient Boosting Machines: Creates predictions using weak models, typically decision trees. • Adaptive Boosting: Enhances performance of other learning algorithms. • Extreme Gradient Boosting: Decision-tree-based ensemble algorithm. • Hyperparameter Optimization: Used a three-fold cross-validation

			Bayesian search strategy with 50 iterations.
Machine learning approach for Migraine Aura Complexity Score prediction based on magnetic resonance imaging data (2022)[30]	MRI data from 40 migraine with aura (MwA) patients; 340 features and average Migraine Aura Complexity Score (MACS) from 6+ attacks.	• Freesurfer Analysis: Automatic cortical reconstruction from MRI. • Cortical Parcellation: Desikan-Killiany Atlas used. • Feature Selection: • a)Correlation-based: Selected significant features ($p < 0.05/0.01$); removed redundant features ($r \geq 0.85$). • b)Wrapper Method: Best-first search with 5-fold cross-validation for optimal features. • Data Normalisation: Normalised data before SVM and RBF applications.	• SVM for Regression (SVR): Linear kernel; minimized output deviations. • Linear Regression (LR): Used M5 model tree; iteratively removed features. • Radial Basis Function (RBF) Network: Activation functions via k-means clustering; trained with BFGS updates.
Machine learning approach to predict medication overuse in migraine patients (2022)[31]	Dataset of 777 consecutive migraine patients from the IRCCS San Raffaele Pisana, Rome, Italy, collected since January 2008.	• Missing Value Imputation: Predictive Value Imputation (PVI) replaced missing values with attribute averages from the training set. • Group Clustering: Features grouped by clinical significance (demographics, migraine features, treatments, comorbidities, biochemical variables, lifestyle, and DBH polymorphism).	• RO-MO System: Custom decision support system using: a)SVM: Baseline model. b)Random Optimization (RO): Optimises feature group weights for improved predictions. c)Multiple Kernel Learning (MKL): Combines SVM and RO.
Migraine classifcation by machine learning with functional near-infrared spectroscop y during the mental arithmetic task (2022)[32]	fNIRS data from 34 subjects: 13 healthy controls (HC), 9 chronic migraine (CM), and 12 medication-overuse headache (MOH).	• Signal Filtering: Low-pass Filter: 4th-order Butterworth (0.1 Hz) removed systemic noise. Band-pass Filter: 0.01 Hz to 0.3 Hz filtered PFC hemodynamic response to task stimuli. • Signal Segmentation: Divided into rest, task, and recovery stages. • Feature Extraction: 144 features focused on changes in HbO, HHb, HbT, and COE, including: a)Stage Mean Difference: Average hemoglobin difference across stages. b)Transition Slope: Slope during the first 8 seconds after stage change.	• LDA: Assumes Gaussian distribution and equal covariance; suitable for multiple classes and small datasets. • QDA: Allows unequal covariance; performed better than LDA in this study.

		c)Transition Slope Difference: Slope differences between stages. d)Normalisation: Features normalised between 0 and 1 for comparison. e)Stage Standard Deviation: Dispersion of fNIRS signal within each stage. f)Stage Skewness: Asymmetry of signal distribution. g)Stage Kurtosis: Tail length of signal distribution indicating outliers.	
Migraine headache (MH) classifcation using machine learning methods with data augmentation (2020)[33]	Patient records from Hospital Materno Infantil de Soledad; initial 400 records, augmented to 1447, focusing on migraine-related diseases.	● Noise Removal: Irregular patterns, typos, blanks, and incomplete/inconsistent data were removed. ● Data Augmentation: SMOTE used to balance class distribution by adding synthetic minority class examples.	● SVM ● KNN ● Decision Tree (DST) ● Random Forest (RF) ● Deep Neural Network (DNN) with: - Input Layer - Two Hidden Layers - Classification Layer
Migraine Prediction Using Deep Learning Model (2020)[34]	Migraine database from Kaggle, including 24 features for predicting migraine types.	● Data Loading: Dataset with 400 training examples and 24 features was loaded. ● EDA: Patterns in intensity, frequency, type, and severity of migraines were visually analysed using graphs. ● Sampling: Lossless sampling based on dataset columns and rows. ● Data Splicing: Split into independent (X) and dependent (Y) variables.	● Deep Neural Network (DNN): - Model with multiple hidden layers for predicting migraine types and severity. ● Architecture: - Input Layer: Receives migraine features. - Hidden Layers: Processes features using activation functions like ReLU and SoftMax. - Classification Layer: Outputs predicted migraine type and severity. ● Training Method: - Stochastic Gradient Descent (SGD) for iterative parameter updates.
Multimodal MRI-based classifcation of migraine: using deep learning convolutional neural network (2018)[35]	Resting-state functional magnetic resonance imaging (rs-fMRI) data from 64 participants, divided into three groups: - 21 patients with migraine without aura (MWoA) - 15 patients with migraine with aura (MWA) - 28 healthy controls (HC) - Demographic and	● Discarding Initial Volumes: First 10 volumes removed for signal stability. ● Slice-Timing Correction: Corrects slice acquisition timing differences. ● Realignment: Motion correction by aligning images to the first volume. ● Spatial Normalization: Normalized to MNI template. ● Band-Pass Filtering: Filtered (0.01–0.08 Hz) to reduce noise. ● Functional Measures Extracted:	● Convolutional Neural Networks (CNNs): Two models used: - AlexNet-Based CNN: Three convolutional layers, two pooling layers, and two fully connected layers. - Inception Module-Based CNN: Incorporates Inception module for increased depth and efficiency.

	clinical characteristics are summarized in Table 1, with no significant differences in age or gender.	• ALFF: Reflects intensity of spontaneous neuronal activity. • ReHo: Measures local brain activity synchronisation. • RFCS: Assesses global brain activity synchronization.	
MyGraine: Predicting Migraines Through Various Machine Learning Models Utilizing User-Inputted Data (2018)[36]	The study used the "Analysis of Trigger Factors in Episodic Migraineurs Using a Smartphone Headache Diary Applications" dataset, published on February 22, 2016. It contains 4,580 entries of migraine and non-migraine days, with binary features for triggers like stress, sleep, exercise, fatigue, drinking, overeating, caffeine, smoking, and travel (1 for "yes" and 0 for "no").	• Handling Missing Data: Null entries replaced with 0s, indicating "no" response. • Feature Removal: Irrelevant features (e.g., "number," "patient," "ID") removed.	• Logistic Regression: Used for classifying migraine occurrence based on predictors. • Random Forest: A regression-based algorithm using multiple decision trees to improve accuracy and reduce overfitting. • SMOTE: A data augmentation technique for addressing class imbalance by generating synthetic "migraine" instances.
Robust and Accurate Modeling Approaches for Migraine Per-Patient Prediction from Ambulatory Data (2015)[37]	Data collected from a wireless body sensor network (WBSN) worn by migraine patients. Included four hemodynamic variables: - Heart rate (HR) - Electrodermal activity (EDA) - Skin temperature (TEMP) - Peripheral capillary oxygen saturation (SpO2) Subjective pain levels reported by two patients during migraine attacks.	• Synchronization: Data from sensors synchronized to a 1-minute interval using a FIR filter decimator. • Data Recovery: GPML recovered missing data, achieving fits of 73.4% to 93.2%. • Symptomatic Curve Modeling: Pain levels modeled with semi-Gaussian curves based on key timestamps.	• N4SID Algorithm: Used in MATLAB for modeling and predicting migraine attacks, with a linear decider for event detection.

Automatic detection of migraine disease from EEG signals using bidirectional long-short term memory deep learning model[38]	EEG data (512 Hz, 128 channels) 21 controls (19–54 yrs, 12F/9M) 18 migraine patients (19–54 yrs, 13F/5M) Resting state Open source	• Feature selection: Exp 1 used 14 channels, Exp 2 used 128 channels • Feature extraction: Welch method for power density (1-49 Hz) • Holdout method: 70% training, 30% testing	• Random Forest • Linear Discriminant Analysis (LDA) • Support Vector Machine (SVM) • Bidirectional Long Short-Term Memory (BiLSTM)

Table 2.2: Overview of research papers, their performance measures and limitations

Name	**Performance Measures**	**Limitations**
Automatic migraine classification using artificial neural networks (2024)	• Accuracy: 97.5% (MLP, 10 neurons) • Precision: 98% (MLP, 20 neurons, 18-variable dataset)	• Limited dataset size • Overfitting issues with complex models • Single hospital data • Subjective symptom data • No external validation
Classification of Migraine Disease using Supervised Machine Learning (2023)	• Naive Bayes outperformed others(94.2%); Random Forest had higher ROC Area but lower accuracy	• Limited dataset size (400 instances) • Class imbalance issues, especially with "Sporadic Hemiplegic Migraine" (14 instances) • Generalizability limited to single hospital data in Colombia
Developing Gradient Boosting Machine Learning Model For Predicting Headaches Among Adult Headache Patients (2023)	• Confusion Matrix: Sensitivity = 0.72, specificity = 0.99. • Classification Report: Precision = 0.90, Recall = 0.72, F1 Score = 0.80, Accuracy = 0.96. • ROC Curve and AUC: AUC = 0.94, indicating strong performance. • Feature Importance: Most influential feature was "no premonitory symptoms," followed by fatigue, stiff neck, dizziness, and medication use.	• Directionality: Only magnitude of feature influence provided; suggests using SHAP for directionality. • Generalizability: Small sample size (23 patients) and limited demographic details. • Recall Bias: Self-reported data may introduce recall bias, especially in older participants.

Forecasting migraine with machine learning based on mobile phone diary and wearable data (2023)	• Random forest classifier is best model with cross-validated AUC of 0.68 and out-of-sample AUC of 0.62.	• Small Sample Size: 17 participants and 295 data points limit performance. • Generalized Model: Risks losing individual patterns. • Headache Type Distinction: Lack of differentiation affects accuracy. • Limited Features: Need for additional predictors. • Low Confidence: Calibration plot showed low prediction confidence. • Convenience Sampling: May not reflect the general migraine population. • Gender Bias: Only one male participant limits generalizability. • Unvalidated Diary: App-based diary lacks formal validation. • Unsupervised Collection: Increases risk of inaccuracies. • Short Duration: Data collected for one month, below recommended guidelines.
Machine learning approach for Migraine Aura Complexity Score prediction based on magnetic resonance imaging data (2022)	• Best Model: SVM with wrapper selection, R^2 score = 0.89; effective in predicting average MACS scores.	• Small Sample Size: Only 40 MwA patients, limiting generalizability • Single Data Modality: Used structural MRI only; adding functional MRI could provide more insights • Future Investigation: Further study needed on headache symptoms, MACS, and cortical features
Machine learning approach to predict medication overuse in migraine patients (2022)	• RO-MO models outperformed SVM; combined model AUC = 0.83, accuracy = 0.87, indicating effective personalized risk assessment for medication overuse.	• Small Sample Size: 162 patients with medication overuse, limiting generalizability • Homogeneous Population: Sample from a specialized center may lack diversity • Future Validation: Multicenter studies needed to confirm applicability
Migraine classifcation by machine learning with functional near-infrared spectroscopy during the mental arithmetic task (2022)	• Good performance distinguishing HC from migraine, with best model achieving 73.9% training, 63.6% testing, and 60.9% validation accuracy • Stepwise classification reached over 90% accuracy for HC and migraine, and over 85% for CM and MOH, showing fNIRS and machine learning's potential in migraine diagnosis	• Limited Research: Few studies on NIRS for MOH or CM, complicating result verification. • Age Differences: MOH subjects were about ten years older than CM subjects, potentially influencing results. • Small Sample Size: Need for a larger sample for improved reliability and generalizability.
Migraine headache (MH) classifcation using machine learning methods with data augmentation (2020)	• Data augmentation notably enhanced model performance, DNN achieved 99.66% accuracy post-augmentation.	• Limited Dataset: Few large publicly available datasets; plans for a larger dataset • Generalizability: Data from a single hospital in Colombia limits broader applicability • Transformer-Based Algorithms: Future work could explore BERT for improved performance

Migraine Prediction Using Deep Learning Model (2020)	• Achieved high accuracy of 0.9 after 100 epochs. DNN model is effective for predicting migraine type and severity, showcasing potential in medical diagnosis through machine learning.	• Limited Dataset: Small size (400 examples), needs expansion • Data Source: Single source (Kaggle), needs diversity • Feature Specificity: 24 features, more needed • Lack of Comparison: Only DNN model, more algorithms needed • Generalizability: Findings need external validation
Multimodal MRI-based classifcation of migraine: using deep learning convolutional neural network (2020)	• RFCS feature was best for distinguishing groups; Inception module-based CNN consistently outperformed AlexNet-based CNN.	• Small Dataset Size: Limited to 5760 images; larger datasets needed for generalizability. • Lack of Region Specificity: No focus on specific brain regions for feature extraction; future research could explore this. • Transparency of Deep Learning Models: Need for increased transparency in models for trust and clinical applicability.
MyGraine: Predicting Migraines Through Various Machine Learning Models Utilizing User-Inputted Data (2018)	• Logistic regression achieved 97% accuracy with SMOTE; random forest achieved 89.66%. • Random forest identified the number of triggers and helping factors as the most important features.	• Dataset Size: Limited size for specific trigger combinations. • Generalizability: Findings require confirmation with larger, diverse datasets. • Website Limitations: Current website relies solely on user-inputted data without real-time biometrics.
Robust and Accurate Modeling Approaches for Migraine Per-Patient Prediction from Ambulatory Data (2015)	• Prediction Horizon: Targeted 30 minutes before pain onset, validated across 1 to 100 minutes. • Robustness: Evaluated against sensor failures using $SDMS^2$ for model selection. • Evaluation Metrics: TPR, PPV, and F-score showed N4SID models predict attacks with an average horizon of 47 minutes.	• Small Sample Size: Only two patients, limiting analysis • Generalizability: Needs validation in larger, diverse groups; models are patient-specific • Limited Features: Only four hemodynamic variables; more factors could improve predictions • Subjectivity: Self-reported pain adds subjectivity • Computational Complexity: N4SID model demands significant resources
Automatic detection of migraine disease from EEG signals using bidirectional long-short term memory deep learning model	• BiLSTM model with Welch features: 95.99% accuracy, 96% sensitivity, 95% specificity • Precision: 96%, F1-score: 96%, MCC: 0.91 • Effective in learning long-term EEG patterns • Potential for early migraine detection and diagnosis support • Promising use of deep learning for migraine diagnosis with EEG	• Machine learning may struggle with excessive data • Study used resting state EEG only; future research could include EEG during migraine attacks ○

Table 2.2: Overview of research papers, their performance measures and limitations

Implementation

NeuroCare is a mobile application developed to provide a holistic approach to migraine management through features that cater to tracking, assessment, and self-management. At its core, the app includes a Migraine Disability Assessment (MIDAS) questionnaire to help users evaluate the impact of their migraines, along with a personalized diary for logging potential triggers and tracking daily habits. Users can document migraine episodes in detail through a migraine log, recording duration, intensity, and associated symptoms to build a comprehensive history. Additionally, a frequently asked questions (FAQ) section addresses common user concerns, offering guidance and support. Together, these modules position NeuroCare as an effective, user-friendly tool to support individuals in understanding and managing their migraines more effectively.

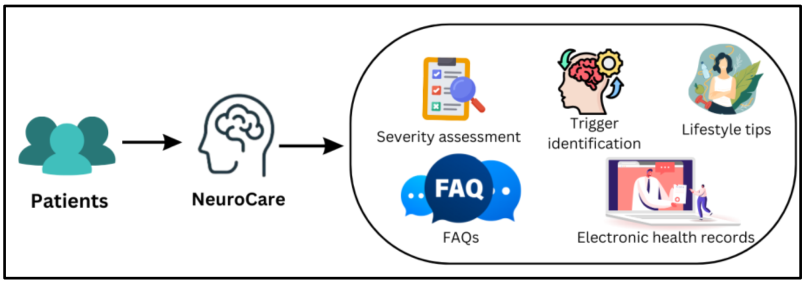

Fig. 1: Block diagram of the system

The diagram illustrates the NeuroCare mobile app, designed to help patients manage their health and improve communication with healthcare providers. Patients can assess their condition, identify triggers, and access lifestyle tips, with the data securely stored in electronic health records (EHR). Providers can then use this information to make informed decisions. The app fosters proactive healthcare management, improved communication, and better health outcomes, likely including a FAQ section for common questions. Overall, it promotes a patient-centered approach to healthcare.

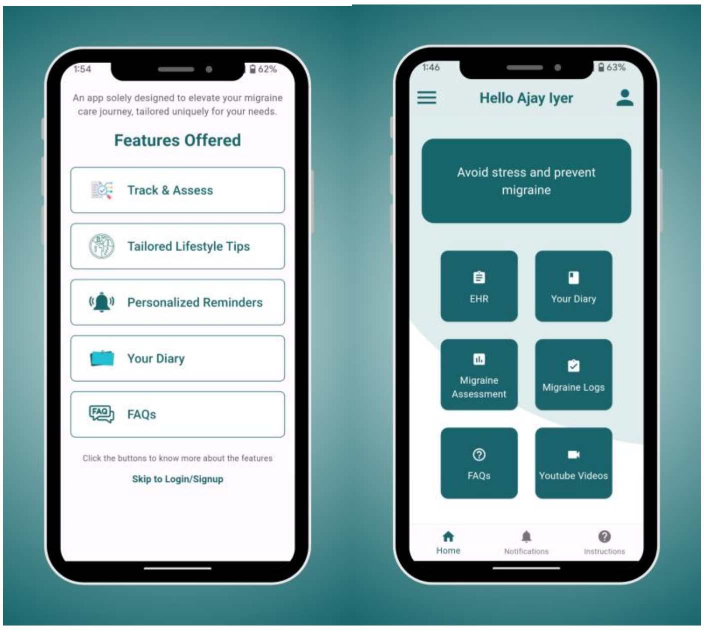

Fig. 2: Features page & Home Page

The Home Page provides a quick view of recent activity, health tips, and easy logging access, while the Features Page highlights key tools like migraine tracking, lifestyle recommendations, and personalized insights—helping users take control of their health and make informed decisions.

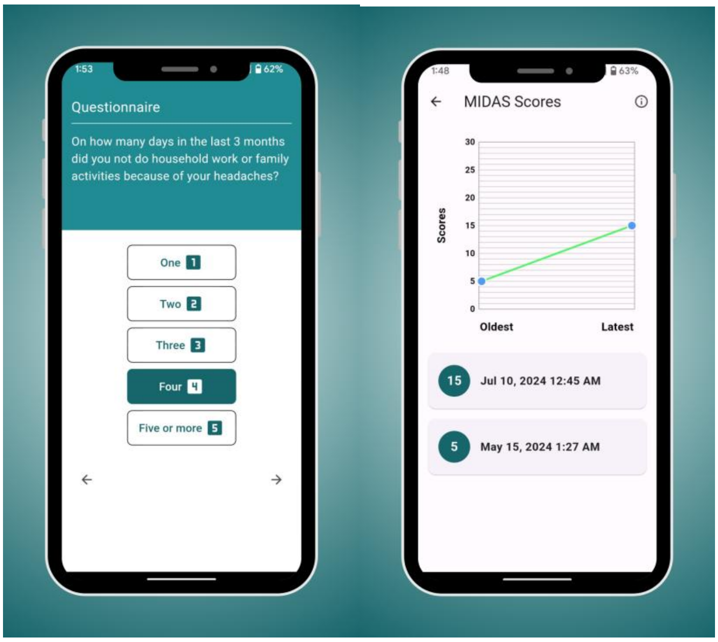

Fig 3: MIDAS test

The MIDAS Assessment in NeuroCare helps users measure the impact of migraines on their daily life by scoring the frequency and severity of episodes. Scores are presented on an easy-to-read graph, giving users a clear, visual overview of their migraine patterns over time and helping track progress in managing symptoms.

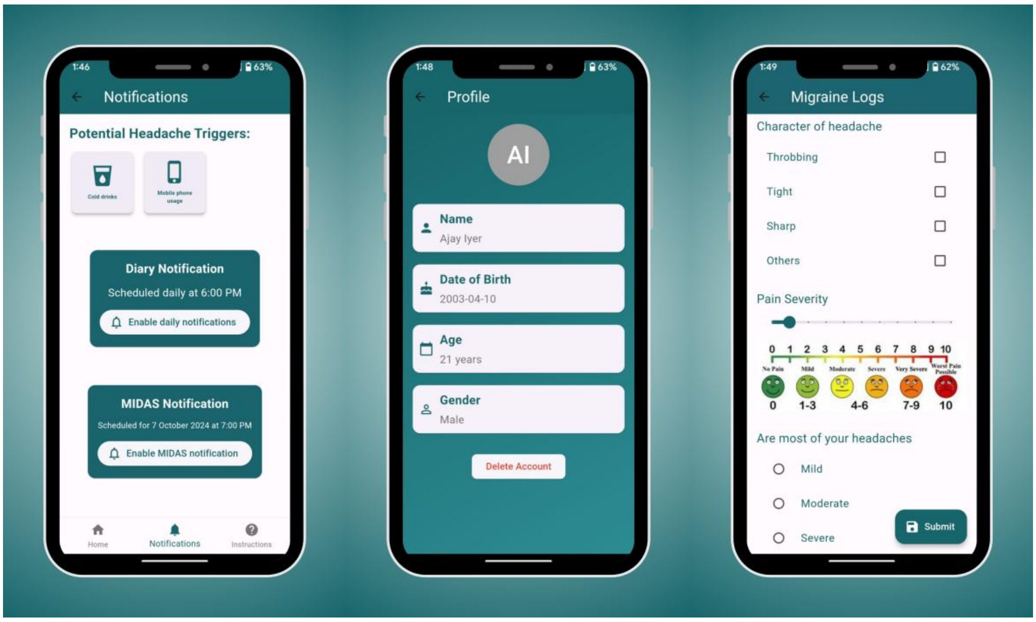

Fig. 4: Notifications page & Profile page **Fig. 5:** Migraine logs page

The Notifications Page in NeuroCare sends daily reminders for users to fill out their personal diary, prompts them to retake the MIDAS test every three months, and provides a list of potential migraine triggers. The Profile Page displays essential user details, including name, date of birth, age, and gender, allowing for a personalized app experience.

The Migraine Logs feature in NeuroCare allows users to document each migraine episode by answering a series of questions about symptoms, duration, triggers, and severity. This detailed log helps users track patterns and better understand factors influencing their migraines.

RESULTS AND DISCUSSION

After a thorough study of various existing mobile applications, along with their features, advantages, and limitations, we highlight the factors that distinguish NeuroCare from the prevalent options.

1. **In-Depth Tracking**: NeuroCare offers detailed tracking of migraine episodes, capturing duration, intensity, and symptoms to help users build a comprehensive migraine history for better self-management and clinical use.
2. **Validated MIDAS Assessment:** NeuroCare includes the MIDAS questionnaire, allowing users to gauge their migraine's impact on daily life, providing insights beyond typical headache tracking.
3. **Personalised Habit and Trigger Monitoring:** Unlike most apps, NeuroCare lets users log specific habits and triggers in a diary, helping identify patterns and enhancing preventive care.
4. **User-Focused Design:** NeuroCare's intuitive, user-friendly design supports broad accessibility, with free availability on the Google Play Store to reach a wider audience.
5. **Educational Support Resources:** NeuroCare includes an FAQ section for common migraine questions, giving users reliable information and a more supportive experience.
6. **Prototype for Clinical Application:** With its extensive features in assessment and tracking, NeuroCare is positioned as a potential clinical validation tool for individual management and research.

Conclusion and Future Work

This study compares existing migraine management apps and predictive models, evaluating features, user engagement, and areas for improvement. By analyzing 20 migraine apps and 13 research papers, it identifies key features for effective migraine tracking and assessment, while highlighting gaps in accessibility and predictive functions. NeuroCare emerges as a prototype integrating best practices, offering a personalized, evidence-based approach for migraine patients.

Looking ahead, NeuroCare aims to incorporate AI and ML for more accurate migraine predictions and pattern identification. Future updates will address current limitations, improve usability, and align with clinical needs, positioning NeuroCare as a valuable tool for both personal health management and broader healthcare applications.

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