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# A REVIEW ON AI SOUND RECOGNITION ON ASTHMA MEDICATION ADHERENCE:EVALUATION WITH RDA BENCHMARK SUITE

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**Abstract:** This project explores the application of artificial intelligence(AI) for recognizing sounds indicative of asthma medication adherence. Utilizing the RDA Benchmark suite, we evaluates the performance of our AI sound recognition system. By detecting relevant sounds like inhaler usage or coughing, the system aim to monitor and assess patient adherence to asthma medication regimens. Robust evaluation against established benchmark enables validation of the systems accuracy and the effectiveness. Such technology holds promise for enhancing healthcare outcomes by providing real-time monitoring and support for asthma patients in managing their condition. Our results show that AI can accurately detect these medication sounds. This suggests that AI could be helpful in making sure people with asthma take their medication as prescribed. This could be a big step in managing asthma and improving people's health.

## I. INTRODUCTION

Asthma is a chronic disease characterized by airway inflammation and symptoms such as wheezing, coughing, and chest tightness. It affects approximately 334 million people worldwide and is prevalent in all age groups, races, and ethnicities. The prevalence of asthma varies among different countries and ethnic groups, with higher rates in developed countries and certain populations. Accurate diagnosis of asthma can be challenging, as there is no universally accepted definition or single test for diagnosis. The prevalence of asthma is increasing globally, with an anticipated 100 million new cases in the next decade .Mortality from asthma is low compared to other chronic diseases, but it still accounts for 250,000 potentially preventable deaths annually. Asthma leads to frequent acute healthcare resource utilization, with millions of emergency room visits each year. The economic costs of asthma care are significant, with asthma being one of the main contributors to increased healthcare expenditures. Elderly patients with asthma experience substantial morbidity and have a higher risk of hospitalization and longer hospital stays. More population-based studies are needed to better understand the prevalence and impact of asthma in the elderly population globally[1]..Furthermore, it is crucial to acknowledge the role of genetics in asthma mortality, as certain genetic variations can increase susceptibility to severe asthma attacks and higher mortality rates. Understanding these genetic factors can help identify individuals at greater risk and implement targeted interventions to prevent asthma-related deaths. Additionally, the influence of socioeconomic status on asthma mortality cannot be understated. Individuals from lower socioeconomic backgrounds often encounter barriers to healthcare access, including asthma management and treatment, leading to delayed or inadequate care and ultimately higher mortality rates. Addressing these socioeconomic disparities through policies that ensure equal access to healthcare and resources is essential in reducing asthma-related deaths. Moreover, the presence of comorbidities such as obesity and cardiovascular disease can exacerbate asthma symptoms and elevate the risk of mortality. Managing these comorbid conditions alongside asthma treatment is crucial in preventing unnecessary deaths. Integrated care models that address both asthma and comorbidities can enhance outcomes and decrease mortality rates. Lastly, the impact of climate change on asthma mortality should not be underestimated. Rising temperatures, increased air pollution, and changes in pollen seasons can all contribute to worsening asthma symptoms and increased mortality rates. Implementing sustainable practices and policies to mitigate the effects of climate change can help alleviate the burden of asthma-related deaths[2].

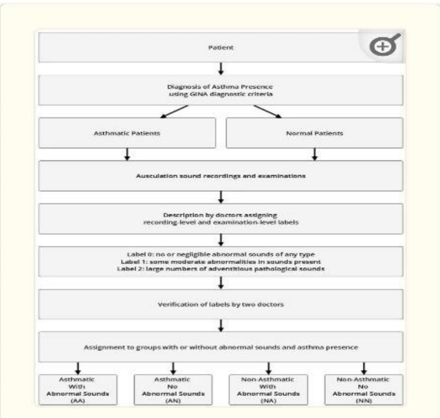
## II.DISCUSSION

The global burden of asthma in adults based on the World Health Survey (WHS) conducted by the World Health Organization. The study aimed to estimate the prevalence of asthma worldwide using different definitions, including doctor-diagnosed asthma, clinical/treated asthma, and wheezing symptoms. The global prevalence rates for these categories were 4.3%, 4.5%, and 8.6%, respectively, with significant variations among the 70 countries surveyed. Australia reported the highest rates for all three categories. It highlights the high prevalence of smoking among individuals with clinical asthma and the challenges posed by asthma as a major public health concern globally. Asthma is identified as a significant cause of disability, healthcare resource utilization, and reduced quality of life, particularly among children and young adults. The study emphasizes the need for strategies to address this common disease, given its substantial impact on healthcare costs and productivity loss. The GINA report provided global estimates of asthma burden, projecting an increase in the number of asthma cases worldwide. The WHS survey, conducted from 2002 to 2003, aimed to provide standardized data for estimating the health status of populations across different countries, allowing for comparisons and policy development. The study utilized three definitions of asthma to estimate its burden: doctor-diagnosed asthma, clinical asthma, and wheezing symptoms. These definitions aimed to capture individuals with active asthma based on diagnosis, treatment, and respiratory symptoms. The prevalence rates varied significantly across countries, with Australia, Sweden, the UK, the Netherlands, and Brazil reporting the highest rates of clinical asthma. The study underscores the importance of addressing smoking as a major barrier to combating the global burden of asthma and highlights the impact of asthma on both resource-rich and resource-poor nations, posing challenges to development efforts[3] The study examined the relationship between asthma and COVID-19 severity. Asthma was not found to be a risk factor for severe COVID-19 disease. Allergic asthma was associated with a lower risk of hospitalization compared to non-allergic asthma. Lower eosinophil levels were linked to a more severe COVID-19 disease trajectory. Recovery from COVID-19 symptoms was similar among asthmatics and non-asthmatics, with over 50% reporting ongoing lower respiratory symptoms three months post-infection. The study provides valuable insights into the impact of asthma on COVID-19 outcomes[4]. By the incidence of asthma in men and women from birth to 44 years old across 16 countries. It found that girls had a lower risk of developing asthma in childhood, but the risk became equal around puberty and higher in women after puberty. This pattern was consistent across all countries studied. Factors like airway caliber and smoking influenced asthma risk in women, with smaller airway caliber playing a significant role. Hormonal factors and lung growth rate were also suggested as potential explanations for the sex differences in asthma incidence. Epidemiological data on asthma prevalence and morbidity showed a sex difference that varied with age, with women older than 20 having higher rates of asthma. The study aimed to assess the influence of smoking and airway caliber on asthma incidence through a case-control study using data from the European Community Respiratory Health Survey. The study design involved a two-stage process, including a screening questionnaire and a structured interview, lung function tests, and airway challenge tests. The analysis of lifetime asthma incidence was based on reported age of first asthma attack, smoking habits, and lung function measurements. The study adjusted for recall bias and cohort effects to provide accurate estimates of age-specific asthma incidence in men and women[5]. Depression and anxiety often occur together in patients with asthma, and they can greatly affect the overall well-being of these individuals. The study discovered that patients with uncontrolled asthma had higher levels of depression and anxiety, resulting in a lower quality of life compared to those with controlled asthma. The study's findings emphasize the significance of addressing mental health concerns in asthma patients to enhance their quality of life. Healthcare providers should be mindful of the potential impact of depression and anxiety on asthma management and strive to provide comprehensive care that caters to both physical and mental health needs. Additionally, the study identified various factors that predict a lower quality of life in asthma patients, such as being female, smoking, the severity of asthma, and the presence of anxiety and depression. By recognizing these risk factors, healthcare providers can better customize their treatment plans to meet the specific requirements of each patient. In conclusion, this study highlights the importance of taking a holistic approach to asthma management that considers the mental health of patients. By addressing both physical and mental health issues, healthcare providers can contribute to improving the overall quality of life for individuals living with asthma[6] The guidelines for diagnosing, monitoring, and managing asthma in adults, young people, and children. It emphasizes the importance of accurate diagnosis, asthma control, and reducing the risk of asthma attacks. The guidelines do not cover severe asthma or acute asthma attacks. Recommendations include involving patients in decision-making, taking a structured clinical history, conducting objective tests for acute symptoms, and monitoring airway inflammation and hyperreactivity. Specific recommendations are provided for diagnosing asthma in young children, children aged 5 to 16, and adults aged 17 and over. Diagnostic hubs and various objective tests such as FeNO, spirometry, bronchodilator reversibility, and peak flow variability are discussed in detail to aid in the diagnosis of asthma. Referral to specialists is recommended in certain cases for further assessment[7].By discussing the risk factors of asthma as a chronic respiratory disorder with a complex genetic background and strong environmental influences. It highlights the increasing prevalence of asthma, especially in children, and the burden it poses on society in terms of morbidity and healthcare costs. It emphasizes the importance of gene-environment interactions in the development of asthma, with environmental risk factors such as exposure to air pollution, tobacco smoke, and occupational hazards playing a significant role. It also mentions the impact of atopy, stress, and obesity on asthma risk in genetically susceptible individuals. Further the immune system component of asthma, the connection between asthma and atopy, and the role of dysregulated immunity in asthma development. It also touches upon the genetic underpinning of asthma and the complexity of the disease. Additionally, the text delves into specific environmental risk factors like tobacco smoke, pollution, and obesity, and their associations with asthma development and exacerbation. It also highlights the importance of recognizing occupational asthma as a potential risk factor for asthmatic patients[8]. System used for classifying asthma using an artificial neural network. The system was trained using 1800 medical reports and tested using 1250 reports from physicians at Sarajevo hospital. Out of the 728 diagnosed asthmatics, 97.11% were correctly classified, and the healthy subjects were classified with an accuracy of 98.85%. The system uses spirometry and Impulse Oscillometry System (IOS) test results as inputs to the neural network, providing both static and dynamic assessment of the patient's respiratory system. Sensitivity and specificity were also assessed, with values of 97.11% and 98.85% respectively[9]. The lack of predictive evidence in public health policies for developing preventive guidelines for allergic diseases due to limitations in real-time big data and model predictability. It highlights the potential of IoT and machine learning techniques in collecting and analyzing real-time data for more accurate predictions of allergic disease risks. The pilot study focused on using a deep learning algorithm to predict asthma risk based on PEFR data of pediatric asthma patients and indoor PM10 and PM2.5 concentrations. The study classified PEFR results into three categories and trained a Long Short-Term Memory (LSTM) model to predict asthma risk categories better than multinomial logistic regression by considering cumulative effects of PM concentrations over time. The study suggests that with further modifications and a larger sample size, this approach could significantly impact data-driven medical decision-making[10]. Many asthmatic patients struggle with adhering to their medication regimes. Monitoring patients' adherence to their asthma medication is important. Detecting inhalations from recordings of inhaler use can provide evidence of patients' adherence. Manually listening to recordings of inhaler use is time-consuming and tedious. An algorithm was developed to automatically detect and demarcate inhalations from acoustic signals. The algorithm was tested on a dataset of 255 recordings of inhaler use in real-world environments. The dataset was obtained from 12 asthma outpatients over a three-month period. The algorithm achieved a sensitivity of 95%, specificity of 94%, and an accuracy of 89% in detecting inhalations compared to manual detection[11]. One of the type of asthma is Bronchial asthma it is a chronic inflammatory disease of the airways that affects 5% to 10% of people of all ages. It is diagnosed based on clinical history, physical examination, and pulmonary function tests. The goal of treatment is to effectively control symptoms, and long-term treatment with inhaled corticosteroids is the mainstay of therapy. Bronchodilators are used for rapid relief of acute attacks. Recurrent episodes of shortness of breath, cough, wheezing, and chest tightness are common symptoms of asthma. Allergies are a major risk factor for asthma, but non-allergic asthma can also occur. Acute exacerbations of asthma can be life-threatening, and mortality rates vary between countries. Objective measurements such as spirometry and peak expiratory flow can help assess airway obstruction and monitor asthma control. Diagnostic criteria for asthma include demonstrating airway obstruction and improvement with bronchodilator use, exercise-induced asthma, improvement with high-dose inhaled corticosteroids, and bronchial hyperreactivity[12] . Asthma affects a large number of people worldwide, with over 300 million individuals being affected by the condition. Home monitoring of lung function is recommended for both physicians and asthma patients to effectively manage the disease. The development of accurate and efficient asthma monitoring devices that are easy for patients to use is crucial. Classic spirometry is currently the best method for capturing a comprehensive view of airflow obstruction and lung function, but these machines are bulky and require supervision. Portable peak flow meters are available but are inconvenient to use. There are currently no portable and affordable exhaled breath biomarker devices on the market that can measure multiple chemical biomarkers simultaneously. A user-friendly, accurate, and portable external mobile device accessory has been created to collect spirometry, peak expiratory flow, exhaled nitric oxide, carbon monoxide, and oxygen concentration information from patients. A software application has also been developed to record and store the gathered test information, as well as email the results to a physician. Telemetric capabilities enable physicians to track asthma symptoms and lung function over time, allowing for quicker adjustments to a patient's medication regimen[13]. Lung sounds can provide valuable information about the pathology of the lungs. The combination of advanced digital signal processing methods and machine learning frameworks has the potential to diagnose the status of the lungs using lung sound signals. This focuses on classifying normal, asthma, and COPD subjects based on their posterior lung sound signals, which has not been explored before. Asthma and COPD have similar manifestations, making it challenging to classify these diseases in a single platform. The researchers collected lung sound signals from 60 subjects, including 20 normal, 20 asthma, and 20 COPD patients, using a novel 4-channel data acquisition system. They proposed a feature extraction scheme to extract features from the sub-bands of the power spectral density (PSD) and used an artificial neural network (ANN) classifier for the 3-class classification. The feature extraction focuses on changes in the posterior lung sound signals, independent of the presence of wheeze or any other marker. The proposed multichannel-based multiclass classification system achieves reasonable classification accuracy, surpassing both theoretical and empirical chance levels when all four channels' information is utilized together[14]. The guidelines for managing severe asthma do not focus on measuring airway inflammation to determine treatment or monitor treatment response. Inflammation is a key aspect of asthma and impacts symptoms, physiology, and airway structure. Various strategies, including proteomics, transcriptomics, and metabolomics, can assess inflammation. Simple cellular responses in sputum can also indicate inflammation levels. Bronchitis can be eosinophilic, neutrophilic, mixed-granulocytic, or paucigranulocytic. Eosinophilic bronchitis is typically driven by Type 2 processes, with a sputum eosinophilia over 3% indicating a response to corticosteroids or therapies targeting T2 cytokines. Neutrophilic bronchitis is non-T2-driven and may respond to antibiotics or therapies targeting neutrophil recruitment pathways. Paucigranulocytic disease may not require anti-inflammatory treatment, with symptoms potentially benefiting from smooth muscle or mast-cell directed therapies. This review summarizes omics-based signatures and cellular endotyping in severe asthma, highlighting the segmentation of asthma therapeutics based on endotype[15]. The performance of support vector machine (SVM) classification in detecting asthma attacks in a wireless remote monitoring scenario. It highlights that the mobility of the user and Doppler effects significantly influence the performance of the SVM classification algorithm in detecting asthma attacks. The study finds that SVM classifiers outperform other methods, such as the hidden Markov model (HMM) based classifier, especially when considering wireless channel impairments. It emphasizes the importance of wireless transmission in remote monitoring systems for asthmatic patients. Cough signals and other vital signs are collected by sensors and transmitted wirelessly to a hospital PC for analysis. A classification algorithm is then applied to determine the patient's condition, enabling prompt medical intervention to prevent severe attacks. The study also addresses the impact of wireless channel impairments on the classification accuracy of medical signals. Channel impairments like amplitude variations, time dispersion, and Doppler effects can degrade the receiver's ability to accurately recover the transmitted signal. Medical signals are particularly sensitive to these impairments due to their low bandwidths. Therefore, understanding the relationship between classification accuracy and channel parameters is crucial to identify the channel conditions that may affect the diagnosability of body signs[16]. Ultrasound imaging is a popular choice in bio-medical diagnosis due to its advantages such as no radiation, deep penetration, and real-time imaging capabilities. The paper introduces an ultrasound-based system for monitoring the respiratory status of asthma patients by tracking diaphragm movement. The system uses the Chan-Vese algorithm to segment the diaphragm area accurately and extracts a 1D breathing waveform by calculating mutual information between consecutive ultrasound frames. It identifies four types of respiratory signals - normal breath, fast breath, apnoea, and cough - which are linked to symptoms of asthma attacks and serve as templates for early detection. The proposed system was tested using a public dataset from the "Ultrasound image gallery" and a dataset collected with the "Interson Seemore" probe. Results indicate that the Chan-Vese segmentation method outperforms other algorithms like adaptive thresholding, EM/MPM, and Fuzzy C Means (FCM). Mutual information is found to be a reliable method for extracting accurate respiratory signals and providing clear information about the phase of the respiratory cycle from 2D images[17]. A flexible acoustic sensor designed to detect wheezing by being attached to the human chest. It utilizes a parallel-plate capacitive structure with air as the dielectric material, where pressure waves from wheezing cause vibrations in the diaphragm, altering the output capacitance. The sensor resonates in the 100-1000 Hz frequency range, eliminating the need for signal amplifiers and acting as a low-pass filter to reduce background noise effects. This design minimizes power consumption and space usage due to its analog interface. The sensor is constructed from low-cost materials like aluminum foil, reducing manufacturing complexity and cost. A robust wheezing detection algorithm is employed to differentiate wheezing sounds from other chest noises, with the sensor connecting to smartphones via Bluetooth for signal processing and integration into IoT-based medical systems. The sensor undergoes various tests to assess its performance under harsh conditions like bending, cyclic pressure, heat, and sweat exposure[18]. A novel machine learning framework called BOMLA (Bayesian Optimisation-based Machine Learning framework for Asthma) detector for early detection of asthma. The BOMLA detector utilizes ten classifiers, including state-of-the-art classifiers like Support

Vector Classifier (SVC), Random Forest (RF), Gradient Boosting Classifier (GBC), eXtreme Gradient Boosting (XGB), and Artificial Neural Network (ANN), as well as conventional classifiers like Linear Discriminant Analysis (LDA), Quadratic Discriminant Analysis (QLDA), Naive Bayes (NB), Decision Tree (DT), and K-Nearest Neighbor (KNN). The ADASYN algorithm is employed in the BOMLA detector to address the issues caused by imbalanced datasets. The highest accuracy and Matthews's correlation coefficient for an Asthma dataset are achieved using the BOMLA detector, with 94.35% and 88.97% respectively when SVC is adapted, and increased to 96.52% and 93.04% respectively when ensemble technique is adapted. A decision support system (DSS) is built as a potential application of the proposed system to visualize the probable outcome of the patient. The BOMLA detector is expected to help in the early diagnosis of asthma[19].

## III METHODOLOGY

The study aimed to assess the effectiveness of using artificial intelligence (AI) to analyze respiratory sounds in asthmatic patients. The researchers collected 1,043 auscultation examinations from 899 patients and categorized them based on the presence or absence of abnormal sounds and asthma. These examinations were used to train an AI algorithm, which was then tested on a separate set of 9,847 recordings. The AI algorithm was able to determine the intensity scores of various pathological breath phenomena, including wheezes, rhonchi, fine and coarse crackles, and their combinations. To evaluate its performance, the researchers used the Area Under ROC-Curve (AUC) to discriminate between different groups of examinations. The results showed that the AI algorithm had a high efficiency in distinguishing between asthma patients with normal and abnormal sounds. The Continuous Phenomena Index performed the best in separating




asthma patients with abnormal sounds from those with normal sounds. On the other hand, the All Phenomena Index showed the best performance in differentiating asthma patients without abnormal sounds from those with abnormal sounds. Based on these findings, the study concluded that the AI approach has significant potential in monitoring asthma symptoms at home. This technology could provide a convenient and accurate way for patients to track their respiratory health and detect any abnormalities. By analyzing respiratory sounds, the AI algorithm can help identify and monitor asthma symptoms, allowing for time intervention and management[20].

Fig 1 Process of assigning patients, examinations and recordings to groups based on presence of abnormal sounds and asthma diagnosis.

## IV COCLUSION

Asthma is a chronic respiratory disorder characterized by airway inflammation, hypersensitivity, and obstruction. It affects a significant portion of the population, with a higher prevalence among children. The pathophysiology involves various triggers, including allergens, emotional stress, and environmental factors. Treatment approaches aim to alleviate symptoms, reduce inflammation, and prevent exacerbations. While numerous medications and management strategies exist, understanding individual triggers and personalized treatment plans are crucial for effective asthma management. Continued research and education are essential to improve outcomes and reduce the burden of asthma on individuals and healthcare systems worldwide[21].

## V FUTURE SCOPE

In the realm of evaluating asthma medication adherence, the future holds tremendous promise for AI-driven sound recognition technologies, particularly when integrated with the robust RDA benchmark suite. Looking ahead, advancements in this field are poised to revolutionize how we monitor and support patients with asthma in adhering to their medication regimens. Firstly, the refinement of AI algorithms stands as a cornerstone for future progress. Researchers will delve deeper into optimizing algorithms, leveraging sophisticated models like convolutional neural networks (CNNs) and recurrent neural networks (RNNs) to enhance the accuracy and reliability of sound recognition. Through such advancements, the nuanced patterns and nuances associated with medication usage can be better captured and analyzed. Moreover, the integration of multi-modal data offers an exciting avenue for exploration. By combining audio analysis with data streams from wearable devices, smart inhalers, and environmental sensors, a more holistic understanding of patient adherence behaviors can be achieved. This comprehensive approach holds the potential to uncover correlations between medication usage patterns and external factors, facilitating personalized interventions tailored to individual needs. Real-time monitoring and intervention represent another frontier in this domain. Imagine wearable devices or smartphone applications equipped with AI-powered sound recognition capabilities, providing patients with timely feedback and reminders to adhere to their medication schedules. Such interventions hold the promise of mitigating the risk of asthma exacerbations and promoting better long-term health outcomes.

Furthermore, the pursuit of personalized adherence strategies will continue to drive innovation. By leveraging machine learning techniques to analyze patient-specific data, including demographics, medical history, and behavioral patterns, healthcare providers can tailor intervention strategies to resonate with each patient uniquely. This personalized approach fosters patient engagement and empowerment, key elements in fostering sustained adherence to asthma medication regimens. To realize these possibilities, rigorous validation studies and clinical integration efforts are imperative. Collaboration among researchers, healthcare providers, and technology developers will be essential in navigating regulatory frameworks, ensuring safety, and demonstrating the real-world effectiveness of AI-based solutions for medication adherence. In summary, the future scope for AI sound recognition in asthma medication adherence is characterized by ongoing innovation, interdisciplinary collaboration, and a steadfast commitment to improving patient outcomes. By harnessing the power of AI-driven technologies, we can usher in a new era of personalized, proactive care for individuals living with asthma, ultimately enhancing their quality of life and well-being.

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