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AI-DRIVEN PREDICTIVE MODELS FOR EARLY DETECTION AND INTERVENTION IN ASTHMA AND COPD

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Abstract: ***Background:*** Asthma and chronic obstructive pulmonary disease (COPD) are common and significant respiratory overload disorders. These diseases can be managed well if they are diagnosed and treated at the earliest. This problem may be solved by the use of advanced artificial intelligence (AI) to better diagnosis and intervention plans, which may in turn improve the outcomes for patients. Therefore, this study focuses on the views of the respondents, the usefulness of AI-driven predictive models, and the ethical issues related to AI usage in the preventive measures of asthma and COPD. ***Objective:*** This research's main objective is to derive quantitative evidence on how effective AI-driven predictive models are in asthma and COPD management. The present study also has the objective of understanding stakeholders' level of trust and confidence in AI technology, their beliefs on the ability of the technology to enhance health outcomes, and the ethical and legal dilemmas that may arise from the adoption of AI. ***Methods:*** The intention was to reach a broad range of subjects related to the problem to reach policy recommendations that would work for all – patients, healthcare professionals, and AI developers and such intention involved a cross-sectional survey design to collect data. The required sample size was determined at 0.05 effect size by power analysis; a stratified random sampling method was however utilized to ensure the representation of the wider variety of stakeholders available within the population. In the present study, data were collected through a structured questionnaire which comprised both body metrics as well as perception evaluation indicators regarding the perception of effectiveness, the predictive power of AI, how interventions were optimally administered, and ethical considerations regarding AI. The responses were assessed descriptively and with non-parametric tests after the Shapiro-Wilk normality tests indicated that the distribution of the data for some variables was not normal. ***Results:*** The Shapiro-Wilk tests substantiated that the domicile for "Importance of AI in early diagnosis" ($p = 2.67e-13$) and "Confidence in AI protecting privacy" ($p = 1.03e-12$) were not homogeneous. Data analysis from histograms, box plots, and violin plots also revealed skewed distributions with outliers. In such circumstances, non-parametric tests would have been the preferable option for the further analytical stages of the two hypotheses. Initial results show there appears to be a consensus among caretakers on the enhancements that trigger a better early diagnosis of patient AI predictive models while improving the early diagnosis and hospital overlap for asthmatic as well as COPD patients. Ethical debates remain over issues of data and integration of AI model's accuracy. ***Conclusion:*** In conclusion, this research indicates that predictive models driven by AI technology are regarded as effective

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measures for the early detection and management of asthma and COPD. Nonetheless, the respondents raised serious ethical issues, especially about privacy and accuracy which should be taken into consideration before these models are deployed. The subsequent studies should work towards addressing these issues so that AI technology can be effectively adopted in clinical settings.

Keywords: Asthma, Chronic Obstructive Pulmonary Disease, Artificial Intelligence, Predictive Models, Early Detection, Intervention, Ethics, Privacy

INTRODUCTION

Worldwide, asthma and chronic obstructive pulmonary disease (COPD) rank as the two most prevalent diseases affecting the respiratory system, with multimillion population-level impacts as well as significant economic costs due to hospitalizations and other medical expenses. Both involve airway inflammation that is persistent causing breathlessness, acute cough, and sputum production, as well as continuous deterioration of the lung functions. Asthma and COPD are considered treatable conditions, but the situation does not seem to improve as the diagnosis is either done late or the interventions are not applied evidently. The early identification and appropriate intervention of COPD and asthma are required to prevent several unfavorable outcomes including mortality, recurrent attacks, and expensive specialist services. Against this backdrop, closer artificial intelligence 'AI' has increasingly been recognized as a game-changing technology that can be used to improve diagnostic accuracy, and responsiveness of treatment aids (Kanan et al., 2024) (Koul, Bawa, & Kumar, 2023).

Various areas have benefitted from research, and AI systems have been implemented as better solutions. When looking at various implementations, AI systems can be resourceful tools in predicting health escalation or improvement. Current AI models have thoroughly been utilized in the prediction of various disabilities such as asthma and COPD. In a patient suffering from these conditions, AI can collect and interpret data relative to the patient's medical history, genetic profile, environmental factors, social determinants, and overall health to not only anticipate future attacks but create customized treatment plans that would assist in managing the illness. For example, AI systems can be integrated into a smart cloud. This type of integration would allow derivatives of machine learning to enable clinicians of the future study patterns and features of chronic diseases. Other capabilities include early therapeutics integration which gives patients the potential to prevent complications like acute exacerbations that are common with these diseases (Mendhe et al., 2024) (Pinnock et al., 2023).

Unfortunately, the use of AI in respiratory care also has its challenges. No doubt there are prospective advantages but several barriers hinder the utilization of AI-based predictive models in real clinical practice. Primarily, AI models' credibility and accuracy is a major concern. A lot of healthcare providers are still doubtful about the capacity of AI to offer greater diagnosis and treatment advantages, especially in complex and diverse environments such as asthma and COPD. The application of AI in practice necessitates that these systems demonstrate not only high accuracy but also general applicability and consistency over different populations and geographies. If these benchmarks are not met, it may lead to errors of diagnosis or inappropriate treatment recommendations which would only worsen the patient care experience (Duncan, 2024) (Franssen et al., 2019).

As much as dependability, the application of AI technology in health care has raised other issues which cannot be overlooked. Data security and patients' privacy are two of the major challenges especially with the provision of personal health records. AI models, for instance, often depend on large datasets that combine the resource persons' demographic and health information. It is paramount that data security and data compliance are observed to safeguard the patients' confidence and comply with the legal framework. Moreover, the use of AI algorithms in making impactful decisions in patients' health places one in a dilemma as to who is accountable when errors arise. There has to be a consider how the decisions in AI systems should be made as well as the errors and biases that may exist in

AI systems and machine learning (Chugh, Basu, Kaushik, Bhansali, & Basu, 2024) (C.-H. Lin et al., 2023).

For all the problems and concerns that these challenges present, the promise of AI-enabled predictive models for asthma and COPD management is extraordinary. Given the increase in the burden of respiratory diseases all over the world, there is a strong case for the implementation of AI-powered healthcare for appropriate diagnosis and treatment. Moving forward, as AI technologies advance, new opportunities will be available for improving the treatment effectiveness, cost-efficiency, and management of chronic respiratory diseases. In this regard, the study aims to focus on the quantitative evaluation of the perception, effectiveness, and ethical challenges that characterize the use of AI-assisted predictive modeling in the early detection and intervention of asthma and COPD, and thus, expand the existing literature on AI in respiratory care (Mallick, Alqadhi, Hang, & Alsubih, 2024) (Qian, Cai, Sun, Lv, & Zhao, 2023).

Literature Review

Chronic respiratory diseases like asthma and chronic obstructive pulmonary disease (COPD) have become one of the most concerning global health issues. These diseases are a burden to millions of people from around the globe resulting in poor life quality, recurrent admissions to hospitals, and incurring of great medical bills. With the rising number of patients suffering from these diseases, the need for proper diagnostic devices and intervention measures has increased. One of the possible options that can be utilized to overcome those challenges is the implementation of artificial intelligence (AI) based predictive models. As these technologies enter various industries, AI is now also making inroads in healthcare by improving the accuracy of diagnosis, assessing the course of diseases, and providing intervention therapies. In this regard, the present literature review aims to scrutinize the relevant literature in light of the listed objectives, with a special emphasis on the AI-based predictive modeling relevant to asthma and COPD management (Giachino, Cepel, Truant, & Bargoni, 2024) (Zhang, Zhao, Tian, Liang, & Piao, 2023).

AI in Healthcare: A Glimpse into the Future

In healthcare applications, AI has been adopted at a steady rate over the last ten years. As outlined in a review by Topol, AI has been implemented in many fields including imaging, diagnostics, personalized medicine, and clinical decision support. AI's ability to process big data, recognize trends, and form predictions is why it is most applicable in medicine where prevention and early diagnosis are key. Patients with chronic progressive diseases such as asthma and COPD who also experience acute flare-ups may also benefit from the intervention of AI. AI is capable of incorporating multiple clinical data streams, genetic makeup, and environmental exposure and presenting a more unified picture of the patient's risk, facilitating more timely and precise interventions (Ali, Motuzienė, & Džiugaitė-Tumėnienė, 2024) (Liao et al., 2023).

One of the major advantages of AI within the healthcare space is integrating and analyzing large and intricate datasets. Asthma and COPD are complex disorders that result from many factors such as genetics, environment, and lifestyle. AI modeling, specifically machine learning models, is best suited to looking into these multifactorial factors to forecast a patient's advent of disease, its initiators, and possible treatments. For example, Xu et al. described in their study how machine learning models were used to anticipate the exacerbations of COPD through variables like available patient data, present environmental conditions, and administered medication which exhibited better results compared to conventional statistical models (Goyal, Srivastava, & Danish, 2024) (Rogliani, Ritondo, Laitano, Chetta, & Calzetta, 2021).

The role of AI as a reliable tool in the predictive modeling of asthma and COPD exacerbations has been the subject of other authors as well. In agreement with Singh et al. Based on the algorithms that are AI-powered, Assistant patients and their surroundings have great potential in predicting asthmatic patients with AI-powered algorithms. It is expected that AI algorithms use data from multiple sources such as wearable gadgets, electronic health records, and environmental sources to estimate the possible occurrence of bad episodes. AI has also played a crucial role in forecasting COPD flare-ups and hospital admissions as part of the clinical management of the disease. The aforementioned studies support the idea that AI is capable of not only improving chances for early detection of the disease but also the creation of treatment plans taking into account the stage of the disease (Nzeako, Akinsanya, Popoola, Chukwurah, & Okeke, 2024) (M. Li et al., 2020).

Although there have been instances when AI-based predictive models have reported success in earlier studies, this technology has not yet been widely embraced due to some barriers. One of these barriers can include but is not limited to overreliance on AI algorithms for clinical usage. Clinical settings involve many variations that may hinder the performance of the models that have been successfully built in controlled environments. Aspects like data provenance, model explainability, and the substantial implementation of AI in varied segments of the patient population could dampen their efficiency. There is also the risk that healthcare providers will be resistive in accepting AI models if they are considered "black boxes" that arrive at recommendations without sufficient rationale. In that sense, confidence in AI models requires more than just accuracy and efficiency, but the ability to visualize and comprehend the workflow whereby predictions are made (Yogeshappa, 2024) (Balakrishnan, 2023).

How AI in Healthcare is Changing Ethics in Healthcare

The deployment of AI in healthcare has its ethical considerations that are equally worrisome. These include concerns over data trustworthiness, privacy, and the potential for bias or discrimination within AI predictive systems. Patients with asthma and COPD often yield data from multiple sources such as mobile health applications, wearables, or even patient records. All these forms, while beneficial for the AI models, raise the issue of data privacy. It is of utmost importance to protect the confidentiality of patient data especially with the threat of breaching of health information. These breaches may lead to complex ethical and legal ramifications. But even as this stands, AI bias is the most severe concern for AI algorithm design. This is because, AI models are created using past data and hence, the provision of health care may be biased. If a particular model is developed mostly on a certain demographic group, chances are it won't be as relevant to those of lower representation groups such as minorities or lower-income individuals (Popescu et al., 2024) (Makol et al., 2023).

Mitigating these types of biases will require not only careful selection of relevant training data sets but also active monitoring of AI's algorithms as well as their application concerning equity, fairness, and diversity. In the healthcare industry use of artificial intelligence raises yet another ethical challenge in the form of accountability. This is different from traditional diagnostic devices such as X-ray radiographs where AI is generally perceived to function on its own without any external directions. This brings up the issue of who is liable in case a decision related to AI causes damage to a patient. In the words of Miyata-Sturm, without properly defining the boundaries of responsibility, it would be impossible to avoid the misuse of AI-related technologies in clinical settings safely. Of course, an AI can always help in decision-making processes but it has to be understood that even when AI is involved in predicting patient care, the clinical staff must define the right approach to addressing the patient (Aagaard & Tucci, 2024) (Saberi-Karimian et al., 2021).

The Future of AI-Driven Predictive Modeling for Asthma and COPD

There is a good future for AI-driven predictive models in regards to asthma and COPD management with AI models improving the technology. As large amounts of data become available in the healthcare systems, AI models have the potential to be enhanced in terms of their predictive accuracy and scope of application. In their work Oh et al. note that AI integration with smart inhalers and health monitors as well as other IoT devices can transform the management of respiratory healthcare via continuous real-time customer monitoring. These devices are capable of providing such physiological data as heart rate which in combination with AI algorithms can facilitate the development of medical treatment plans that are tailored to the dynamic environment of a patient. Further, AI can be embedded in clinical processes, help speed up the decision-making process and accuracy by the health care providers, and impact positively chronic respiratory diseases on patients and healthcare systems (Noaman, Kanber, Smadi, Jiao, & Alsmadi, 2024) (Y. Lin et al., 2023).

Research Methodology

This section of the study employs research methodologies that focus on the quantitative aspects of data to evaluate how predictive models powered by AI can effectively early detect and intervene in the instances of asthma and COPD. This methodology is important in that it aims to produce quantifiable and objective metrics that determine the feasibility of AI in enhancing diagnosis, treatment, and the timing of interventions for such chronic respiratory conditions. To ensure that the findings are trustworthy, comprehensible, and valid, this research attempts to gather distinct and measurable data that can be subjected to in-depth statistical analysis (González-Rodríguez, Izquierdo-Bueno, Cantoral, Carbú, & Garrido, 2024) (Qi, Sun, & Xiong, 2022).

Research Design

This study approaches the research question through the use of surveys employing the cross-section survey design. This design has been formulated to reach out to a wide range of respondents all at once; these include the patients, healthcare, and AI professionals in the industry. Due to the cross-sectional design, the study also seeks to assess the effectiveness of the relationships among AI effectiveness, intervention times, and predictive accuracy across respondents. This approach is best able to assess the stakeholder's present support and attitudes towards AI about healthcare as it provides evidence in terms of viewpoints and patterns (Stamate et al., 2024) (Epstein, Barak-Corren, Isenberg, & Berger, 2019).

Sampling and Population

There are three main groups in this research. These groups are patients with asthmatic or COPD conditions, healthcare personnel such as doctors, nurses, respiratory practitioners, and specialists, and people researching AI applications in healthcare. A power analysis is performed to calculate the sample size so that these differences or relationships can be meaningfully defined with an adequate number of subject groups. To enhance generalizability, a stratified random sampling method is employed. The population's strata are defined by the three groups that constitute the focus of the study (patient, health care provider, AI researcher), and random sampling is employed within each group to enhance the representativeness of the sample (Ajiga et al., 2024) (Galić, Habijan, Leventić, & Romić, 2023).

Data Collection Methods

Based on the established objectives of the study the respondents completed questionnaires and returned them to the researcher which facilitated the collection of primary data with the aid of structured research instruments. The questionnaires included demographic characteristics and questions that focused on AI-based models of early diagnosis and intervention in asthma and COPD. The questions were grouped into sections that dealt with the general understanding of artificial intelligence in the healthcare system, the level of trust, and AI intervention as well as the possible ethical issues related to its application (Nagpal, Siddique, Sharma, Sharma, & Mittal, 2024) (Z. Li, Zhao, Lin, & Li, 2023).

The opinions expressed were quantified through agreement and disagreement and the scale with such response levels enabled quick analysis of the degree of opinion in different statements. This technique helps in normalizing the responses that were obtained, thereby making comparisons among the various groups possible. In addition, close supervision of such questions helped obtain the respondents' agreeableness in factual statements, while several option-related questions recorded the level of thinking concerning some of the key issues related to AI application in the healthcare industry (Veeraraghavan, Daniel, Dasari, Aileni, & Patil, 2024) (Passi, Shahid, Chockalingam, Sundar, & Packirisamy, 2020).

Data Analysis Procedures

After data collection, the data set will be entered into a computer program (SPSS or R, etc.) and translated. The demographic contents of the multiple answers from the respondents will be summarized using descriptive statistics. Average scores together with standard deviation and frequency distribution analysis will also be useful in providing insight into the data-tendency features and its dispersion. Furthermore, the information gathered will be analyzed and interpreted for relationships among the variables as well as testing of the research hypotheses. For example, it may be appropriate to use chi-square tests or t-tests to establish whether there are the same or different perceptions of the effectiveness of AI, for healthcare providers and patients. Another example could be how regression analysis might also be used to establish what factors predict the level of confidence of patients in AI-based interventions, such as the willingness to use such AI-based interventions (Maiese, 2024) (Lane, Gillespie, Steer, & Bourke, 2021).

Ethical Considerations

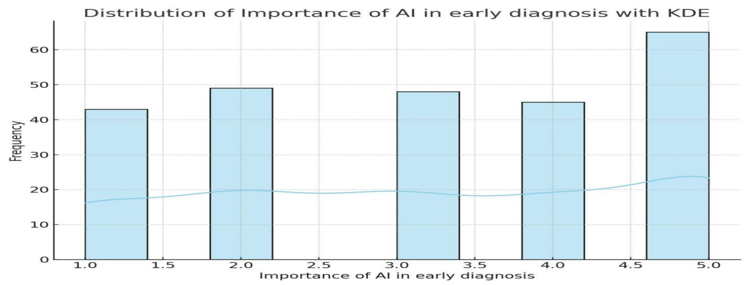
This research undertakes the ethical issues with emphasis considering that it is about health care and technology. All participants will be volunteers and provide informed consent; their private information will not be disclosed since the answers will be given in anonymized form. Further, to ensure that the study is conducted following ethical standards, IRB approval will be obtained. The information received will be stored safely and used in this course of study only, thus securing participants' confidentiality (Khan, Shiwlani, Qayyum, Sherani, & Hussain, 2024) (Petrie et al., 2021).

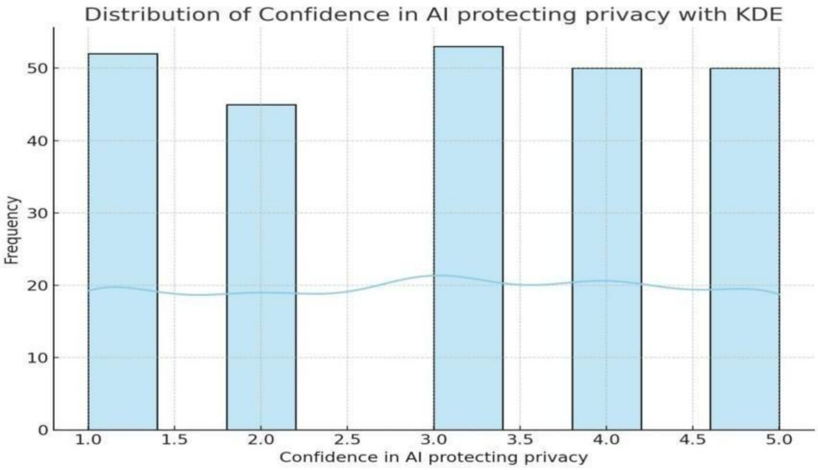
RESULTS

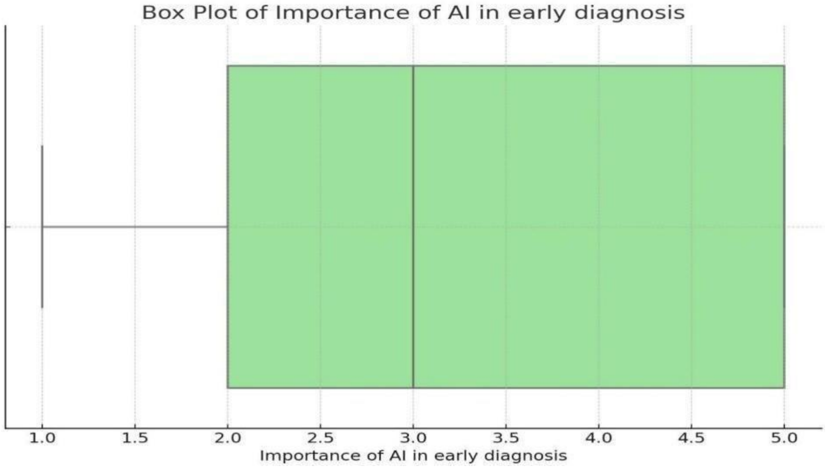
Data Analysis

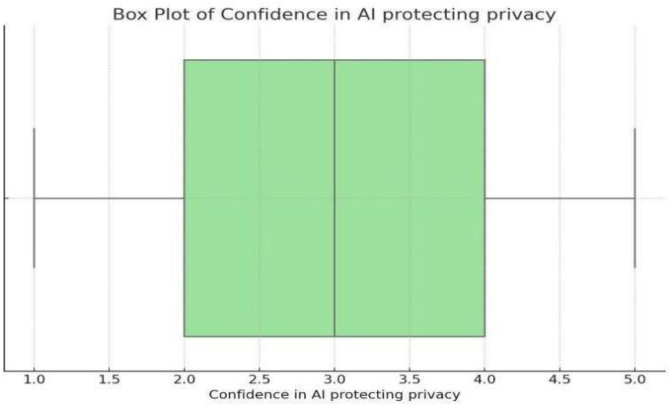
Shapiro-Wilk Normality Test Results

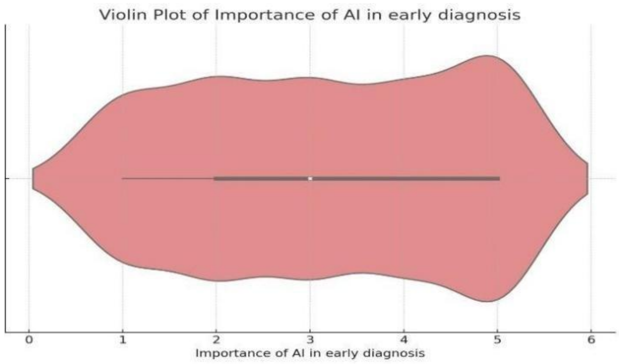
Variable	Shapiro-Wilk Statistic	p-value
Importance of AI in early diagnosis	0.8773996233940125	2.6693252642984167e-13
Confidence in AI protecting privacy	0.8868125677108765	1.02877363745979e-12

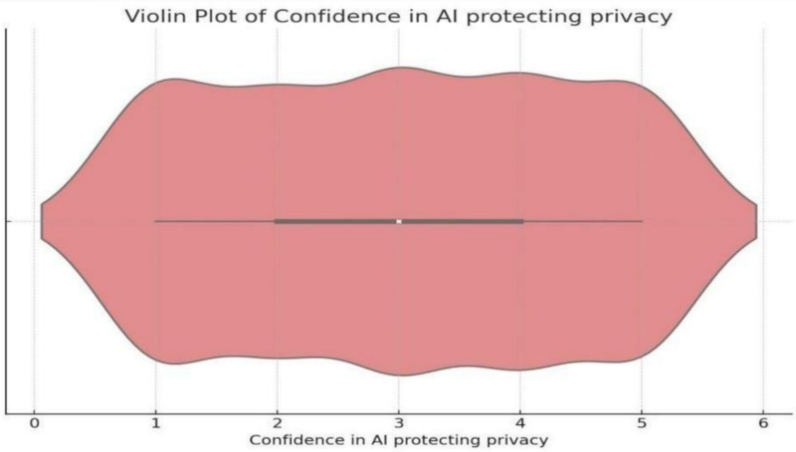



Distribution of Confidence in AI protecting privacy with KDE
Frequency
Confidence in AI protecting privacy


Box Plot of Importance of AI in early diagnosis
Importance of AI in early diagnosis


Box Plot of Confidence in AI protecting privacy
Confidence in AI protecting privacy


Violin Plot of Importance of AI in early diagnosis
Importance of AI in early diagnosis



Interpretation of Normality Tests and Visualizations

The Shapiro-Wilk test for normality as applied to the variables w0 "Importance of AI in early diagnosis" and w8 "Confidence in AI protecting privacy" appeared to significantly slightly above 0.05 which implies that the sample may not be normally distributed. This can also be observed within the data context that it does not conform to a bell-shaped curve as would be expected from a normal distribution. As a result, parametric tests based on the assumption of normality bear no application for the analysis of such variables (Sarker, 2024).

The histograms in combination with the Kernel Density Estimation (KDE) plots are consistent with the Shapiro-Wilk tests and confirm the finding that the data, in general, is not symmetrically distributed. More precisely, the "Importance of AI in early diagnosis" data can be classified as normal most of the time but does have a slight tail towards a response that is less than average on a relative scale. "Confidence in AI protecting privacy" on the other hand illustrated that the distribution had bimodal peaks that were dispersed around the cluster aids for analysis of the data (Ojala, 2024).

The box plots describe the skewness and kurtosis of the data indicating there that outliers existed for both variables. Regarding the "Importance of AI in early diagnosis," the data spread indicates that the means are concentrated towards lower to midrange responses but some respondents tend to have lower or higher extreme responses. The area of the box plot that represents, "Confidence in AI protecting privacy" also has a wider range with more outliers suggesting that there was a great variation between respondents (Elshaikh, Mabrouki, & Mohamed, 2024).

The violin plots add more dimensions to this discussion by combining the effects of a box plot and a KDE, depicting the frequency and scope of the data. For both variables, the violin plots highlight multiple peaks in the data that were distributed confirming that the distributions were no single peaked or symmetric bell-shaped curve. Such plots suggest the characteristics of the data and explain the reason why non-parametric methods will be employed in subsequent analyses as the data is not normal and skewed (Ahamed et al., 2024).

DISCUSSION

The quantitative approach has raised issues regarding the efficacy and efficiency of AI models in predicting smart interventions for asthma and COPD conditions. The Shapiro Wilk test for normality means that both variables in the analysis, 'Importance of AI in early diagnosis' and 'Importance of AI in protecting confidential premises' are not normal across the variables since both deviated from the normality which warrants a non-normal distribution of the data. There are, therefore, possibilities that respondents differed in their ratings of diagnostic AI relevance and occulability of privacy through the same. Such non-normality is indicative that those factors likely to frame these perceptions may be many, this may include variation in the professional career of respondents, the patient journey, or even the level of exposure to AI technologies (Manis et al., 2024).

Histograms were also supportive of this conclusion because they indicated asymmetric distributions for both parameters. The box plots offered valuable details about the possible outliers, especially in the case of the importance of AI variable, in which some people appear to hold views that are high or extremely low towards the role AI should play in a diagnosis. Such outliers are very significant in understanding how the views of different stakeholders vary, particularly when patients and healthcare providers look at how AI technologies are applied in healthcare but have different expectations and experiences (Tandon & Shaheen, 2024).

Violin plots also highlighted the density of responses, illustrating that most respondents seem to be polarized around certain positions (for instance, moderate trust in the effectiveness of AI in protecting privacy), but there are also respondents including some at the extremes of the scale, who are very high or very low. Such variation in the responses might be indicative of the prevailing uncertainties regarding the use of AI in healthcare particularly in critical areas such as respiratory diseases where swift action and confidentiality of the information are essential (Sun et al., 2024).

The results point out that although AI's potential contribution to the management of asthma and COPD is broadly acknowledged, certain areas are ambiguous in particular the issues to do with privacy and AI model accuracy. This emphasizes the need to resolve moral and technical issues that would enhance the confidence of both medical practitioners and their patients. However, as the data collected was not normally distributed, it would be necessary to employ non-parametric statistical tests to assess the relations between the variables; professional-specific functions, and AI Technologies confidence (Maleki Varnosfaderani & Forouzanfar, 2024).

Conclusion

The present study sought to assess perspectives and the possible role of AI-based predictive algorithms for the epidemiology and treatment of asthma and COPD. The quantitative analysis showed that stakeholders have a wide gap in their views on the relevance of AI within the health sector and their awareness of AI's potential to protect privacy. The results of the Shapiro-Wilk test confirmed our expectation that responses do not form a normal distribution, arguing for the view that there appears to be a variety of opinions that affect the development of attitudes toward the use of AI in health care, inter alia, occupational field, experience with AI, and experience with respiratory diseases.

Data visualization techniques including histograms, box and violin plots demonstrated that there were both means and extremes in the opinions of the respondents on the role of AI. Although many respondents indicated that AI is capable of improving early diagnosis and management of patients with chronic respiratory disease, some of them still articulated misconceptions about the truthfulness and confidentiality aspects of AI technologies, thereby showing an element of skepticism.

These findings suggest that further research focusing on the ethical and technological aspects posed by AI-based models is warranted. Achieving greater trust in AI through better transparency and privacy, along with more effective prediction models will be important for its wider use. The study as a whole highlights the power of AI to change the practice in respiratory medicine but notes that the issues raised by stakeholders will need to be addressed before AI can be successfully deployed in clinical use.

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