SOCIAL BUSINESS ACADEMIA NETWORK

Presents

The 6th International Conference on

Healthcare, SDGs and Social Business

SOCIAL TECH SUMMIT 24
TOWARDS ZERO

THE 6TH INTERNATIONAL CONFERENCE ON
HEALTHCARE, SDGS AND SOCIAL BUSINESS

August 28-30, 2024
Hiroshima, Japan & Online

Transforming Healthcare:
Bridging Gaps, Empowering Communities

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SocialTech Summit 2024

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August 28-30, 2024
Hiroshima University, Hiroshima, Japan & Online

Conference Tracks

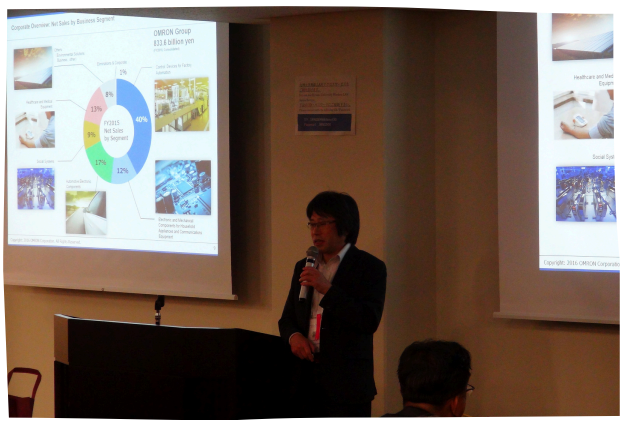
Topics of interest include but are not limited to:

Digital Health Platforms and Infrastructure:

- Cloud Computing in Healthcare
- Big Data Analytics for Health
- Interoperability and Standards
- Cybersecurity in Digital Health

Artificial Intelligence in Healthcare:

- Machine Learning for Disease Diagnosis
- Natural Language Processing in Healthcare
- Robotics and Automation in Medicine
- AI for Personalized Medicine

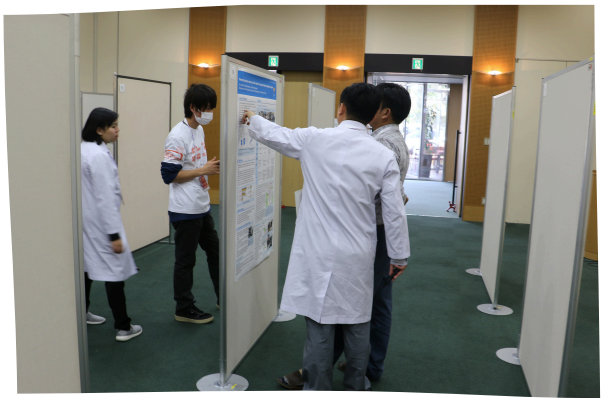


Wearable Technologies and Sensors:

- Remote Patient Monitoring
- Smart Wearable in Healthcare
- IoT Application in Health
- Sensor Technologies for Healthcare

Telemedicine and Virtual Healthcare:

- Telehealth Services and Solutions
- Virtual Reality in Medical Training
- Telemedicine Ethics and Regulations
- Remote Consultation and Diagnosis



Health Informatics and Data Management:

- Electronic Health Records (EHR)
- Data Privacy and Ethics
- Health Information Exchange
- Data-driven Decision Making in Healthcare

Sustainable Approach for Healthcare Service Delivery:

- SDG Progress and Challenges in Healthcare
- Social Business and Digital Health Entrepreneurship
- Healthcare Workforce Resilience
- Public Health, Policy, & Community Engagement

Oral Health:

- Oral Epidemiology
- Oral Health Promotion and Education
- Geriatric Dentistry
- Tele-dentistry and Dental Data Management

Overview	The 6th SocialTech Summit and International Conference on Healthcare, SDGs, and Social Business is an upcoming event that aims to bring together experts, scholars, practitioners, and policymakers from various fields to discuss the latest advancements, challenges, and opportunities in social technology, healthcare, sustainable development goals (SDGs), and social business. The conference will provide a platform for sharing innovative ideas, best practices, and research findings related to these domains, with the ultimate goal of promoting social impact and positive change. Through keynote speeches, panel discussions, workshops, and networking opportunities, attendees will gain insights into the latest trends, strategies, and technologies that can help address the most pressing social and environmental issues of our time.
Date	August 28-30 (Wednesday, Thursday, Friday)
Time & Venue	8:30 to 18:30 JST Hiroshima University, Medical Campus (Koujin Kaikan, 1-2-3 Kasumi, Minami Ward, Hiroshima, 734-8551, Japan)
Types of Participants	Academicians, Researchers, Healthcare Professionals, Dental Professionals, Digital Health Entrepreneurs and Executives, Healthcare Policy Makers, Healthcare Activists, Social Entrepreneurs, Social Development Activists, Students, Youth Leaders, etc.
Sessions	This summit features a diverse range of sessions focused on innovative approaches to healthcare, sustainable development, and the intersection of technology with social entrepreneurship. The sessions include opening remarks, expert panel discussions, paper and poster presentations, and thematic sessions exploring topics such as sustainable healthcare delivery, the impact of HealthTech on real lives, digital healthcare transformation, and the future of smart dentistry initiatives. Participants will also have opportunities to engage in hospital visits and network with peers, while the final day includes a plenary session, awards ceremony, and closing remarks. The conference integrates both in-person and online formats, allowing for a broad exchange of ideas and experiences among global experts, researchers, and practitioners.

Preface

It is my great pleasure to welcome you all to the proceedings of our conference on Disruptive Healthcare Technology to Achieve Sustainable Development Goal 3. As the chair of this conference, I would like to express my sincere gratitude to the organizers, participants, speakers, sponsors, committee members, and student volunteers both from Hiroshima and Kyushu University who have contributed to the success of this event.

Over the past few days, we have had the opportunity to exchange ideas, share our research findings, and learn from one another about the latest innovations and breakthroughs in healthcare technology. We have explored how disruptive technologies can help us address the challenges facing healthcare systems worldwide and how we can leverage these technologies to achieve SDG #3 - good health and well-being for all.

We have observed a steady but significant growth through this 5th event and gradually the number of participants is increasing. So, we are expecting a greater audience in our future events. We believe we will have your continuous support in our future events to contribute to the areas of Healthcare, SDGs, and Social Business.

This conference proceedings contain the papers and posters presented at the conference. There were 43 submissions in total. On average, papers submitted for oral presentations were carefully reviewed by more than three reviewers. The committee decided to accept 19 papers for oral presentations and 22 for poster presentations.

I would like to thank the program committee members and the reviewers for carefully reviewing the papers and selecting the best papers and posters. Congratulations to all the three best paper and best poster winners. I hope everyone can exchange information, ideas, knowledge, and expertise during the conference. We hope to see you again next year.

Dr. Ashir Ahmed
General Chair

August 28, 2024
Fukuoka, Japan

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Dr. Mayumi Kako	Graduate School of Biomedical and Health Sciences, Hiroshima University, Japan

List of Presentations

1 Accepted for Paper Presentation

2 Accepted for Poster Presentation

Accepted Paper Presentations

An Effective Machine Learning Framework for Sleep Disorders Detection

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***Abstract*—Insomnia and Sleep Apnea are popular sleep disorders. Sleep disorder detection is an important step, especially in the earliest diagnosis of mental disease analysis. Moreover, sleep disorders affect body health such as blood pressure and stroke. Traditional detection methods are expensive and time-consuming due to devices required to read signals and experts for understanding and analyzing these signals. Therefore, different automatic systems based on machine learning algorithms have been developed to detect sleep disorders based on pre-assembled data from different clinics. In this paper, a sleep disorders detection model is proposed using a Random Forest Classifier. The detection accuracy of the Random Forest Algorithm is 89.33%. Moreover, different algorithms were trained and tested on our collected dataset to measure the performance of the selected algorithm. The result showed that the Random Forest Algorithm is better than the other algorithms.**

***Index Terms*—Insomnia, Machine Learning, Random Forest**

I. Introduction

Sleep is a basic requirement for both physical and mental health [1]. While sleeping, our bodies support healthy brain efficiency and maintain the necessary physical health [2]. Furthermore, sleeping is important for body growth as well as development, particularly in children and teenagers. Sleeping has a significant impact on how we think, work, learn, react, and a lot of other facets of our daily lives. It also has an impact on our bodies' circulation, the immune system, and respiratory systems [3].On the other hand, sleep deprivation (sleep disorder) causes a variety of issues and challenges in daily life [4]. Sleep disorders, for example, increase the levels of hormones that control hunger, increase the consumption of sweet, salty, and fatty foods, decrease physical activity levels, and increase the risk of overweight and obesity, stroke, and heart disease [5]. It may also result in anxiety, tiredness, and functional deficiencies [6] [7]. Furthermore, sleep apnea is caused by a sleep disorder. According to recent census data, more than 140 million people (70 million men, fifty million women, and twenty million children) snore, primarily due to sleep apnea. Around 936 million adults worldwide suffer from mild to serious sleep apnea [8]. Furthermore, as reported by several global research studies, approximately 10%, if not up to 30%, of the world's population suffers from a sleep disorder, with the percentage reaching 60% in some countries. Finally, sleep disorders are a worldwide epidemic that threatens the standard of life and health of approximately 45% of the world's population.

Extensive research on this condition has been conducted utilizing machine learning techniques. An approach is described in this study for developing an efficient Machine learning model for sleep disorders detection. Afterward, a number of models are created, set up, and evaluated using the standardized data set. The effectiveness of xgboost, random forest and other effective classifiers were assessed for this task. According to the results of the trials, the random forest classifier performs better than the individual ones in terms of AUC, precision, recall and accuracy.

II. Literature Review

Methods and tools for detecting and predicting numerous diseases that significantly impact human health have garnered considerable interest from the research community. Here, we'll discuss the recent research that has used machine learning to the problem of detecting sleep disorders.

Prono et al. [8] conducted a comprehensive investigation to examine the correlation between vitamin D and sleep issues in children and adolescents with sleep disorders, including insomnia, obstructive sleep apnea (OSA), restless leg syndrome (RLS), and other sleep disorders. The study consolidated data on the function and mechanism of action of vitamin D.

Al Khaldy et al. [9] conducted a systematic investigation and meta-analysis to identify the fundamental factors that contribute to sleep and anxiety issues during the lockdown period of the COVID-19 pandemic. Furthermore, the study sought to predict possible associations and factors related to stress and challenges caused by the COVID-19 pandemic. It also examined the different symptoms and complaints related to sleep patterns that individuals encountered. The outcomes were analysed using the Pittsburgh Sleep Quality Index (PSQI), machine learning algorithms, and the general assessment of anxiety disorders. The study examined a substantial correlation between symptoms such as disrupted sleep, anxiety, depressive symptoms, and insomnia, in addition to the lockdown measures implemented during the COVID-19 pandemic.

Anbarasi et al. [10] proposed a cross-validated model for classifying sleep quality based on the act graph's goal. When the final classification model was evaluated using two machine learning techniques, support vector machines (SVM) and K-nearest neighbours (KNN), it demonstrated acceptable performance metrics and accuracy. The findings of this study can be used to treat sleep disorders, develop and build new methods to assess and monitor the quality of one's sleep, and improve existing technological devices and sensors.

Crivello et al. [11] suggested a general-purpose sleep monitoring system that can be used to monitor bed exits, assess the risk of developing pressure ulcers, and track the impact of medications on sleep disorders. Researchers also compared several supervised learning algorithms to determine which was best suited for this situation. The experimental results from comparing the chosen supervised algorithms revealed that they can correctly infer sleep duration, sleep postures, and routines using a completely unobtrusive method.

Satapathy et al. [12] proposed an effective method for identifying various phases of sleep using a sleep standard known as AASM and a single channel of electroencephalogram (EEG) data. The primary contributions of this work were the employing of statistical features to analyze sleep characteristics, as well as the 3 distinct feature combinations used to categorize the two-state sleep phases. Patients with sleep disorders and healthy control subjects took part in three separate trials with three different sets of characteristics. As a result, many machine learning classifiers were created to categorize the different stages of sleep. In recent years, research into developing a sleep disorders detection system has taken various shapes. The accuracy, recall, and precision of these systems are insufficient for flawless detection.

III. Proposed Methodology

In "Fig. 1", our proposed model for sleep disorders detection is illustrated.We collect data from Kaggle [13]. Utilizing the Python programming language and library with the Anaconda data science platform to implement our proposed model. Data visualization explains the insights of the data and decides whether the dataset is balanced or imbalanced. Then the dataset is checked for null values. Then, this preprocessed dataset is stored for further tasks. Extra trees Classifier is used to find important features.80% data is used for training and 20% is used for testing. After splitting the dataset, several traditional machine learning algorithms such as Random Forest [13], XGBoost [14], Decision Tree etc. are used as classification algorithms to check their classification performance. Among all these algorithms, Random Forest shows better performance.

A. Dataset Description

our study was based on a Kaggle dataset,We concentrated on participants who were different age. Participants totaled 373, and dataset contains 12 features. But 1 feature that is 'Gender' not used because it is unselected by feature selection technique.We selected best 10 features that are impactful for our model.Age, Occupation, Sleep duration, Quality of Sleep, Physical activity level, Stress level, BMI category, Blood pressure, Heart rate, and Daily steps[11,12,15] are used as input for ML models and the target class—is Sleep Disorder.The description of features is given below:

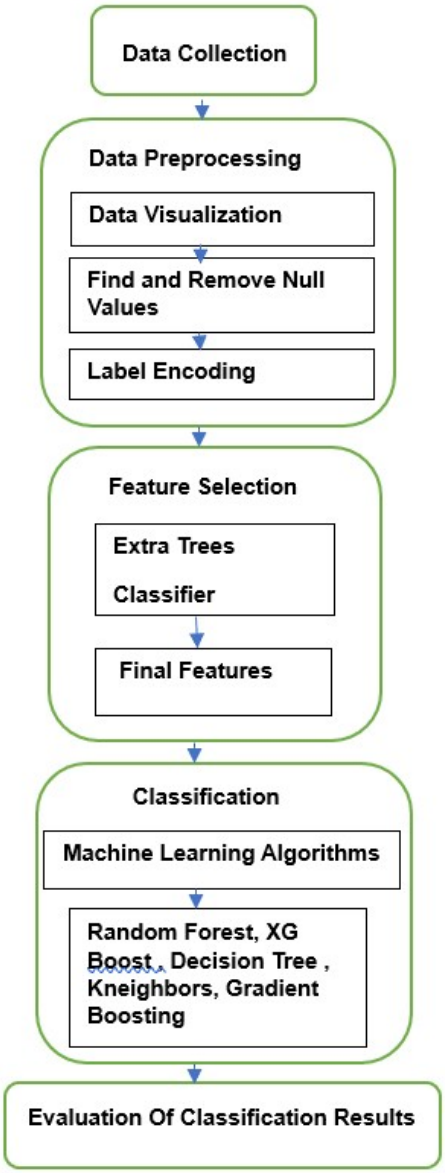

Fig. 1. Framework of the proposed method

- **Age:** The age of the person in years.
- **Occupation:** The occupation or profession of the person.
- **Sleep Duration (hours):**The number of hours the person sleeps per day.
- **Quality of Sleep(scale: 1-10):**A subjective rating of the quality of sleep, ranging from 1 to 10.
- **Physical Activity Level(minutes/day):** The number of minutes the person engages in physical activity daily.
- **Stress Level (scale: 1-10):**A subjective rating of the

stress level experienced by the person, ranging from 1 to 10.

- **BMI Category:**The BMI category of the person (e.g., Underweight, Normal, Overweight).
- **Blood Pressure (systolic/diastolic):** The blood pressure measurement of the person, indicated as systolic pressure over diastolic pressure.
- **Heart Rate (bpm):**The resting heart rate of the person in beats per minute.
- **Daily Steps:**The number of steps the person takes per day.
- **Sleep Disorder:**The presence or absence of a sleep disorder in the person (None, Insomnia, Sleep Apnea).

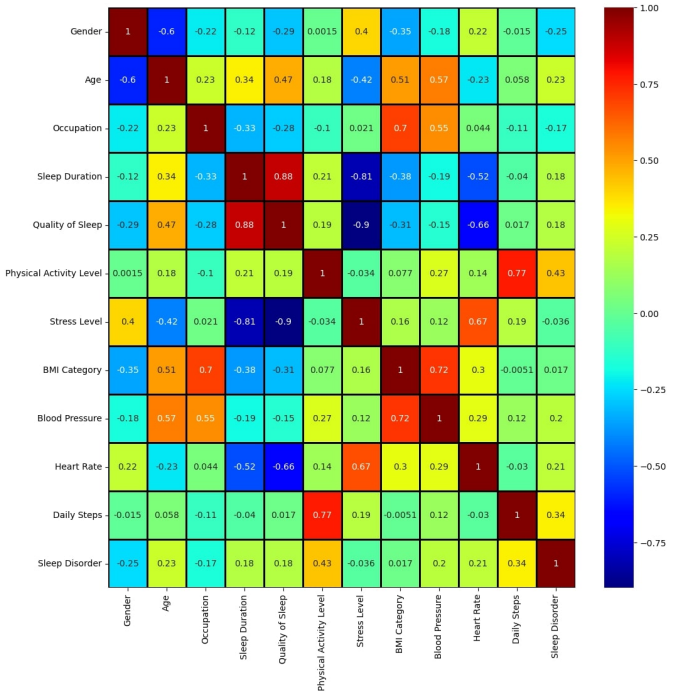

Fig. 2. Heatmap of features

B. Data Preprocessing

Because of missing values or noisy data, the raw data quality may be lower, which could have an impact on the quality of the final prediction. Preprocessing, which includes feature selection, data discretization, and duplicate value reduction, is necessary to prepare data for mining and analysis. After examining the data insights, we clean up the dataset by removing any null values and applying label encoding.

C. Evaluation Metrics

Several performance indicators are logged during the consideration and evaluation of the ML models. The most frequently utilized in the pertinent literature are taken into consideration in the current study. The proportion of people who experienced a sleep disorder and had been correctly identified as positive, relative to all positive participants, is known as recall. The precise number of sleep order persons who genuinely fall into this category is shown. The predictive performance of a model is summed up by the F1-score, which is the harmonic mean of the precision and recall. Here, TP

$$\textbf{Recall=TP/(TP+FN), Precision=TP/(TP+FP)}$$

$$\textbf{F1-score= 2(Precision· Recall) / (Precision +Recall)}$$

$$\textbf{Accuracy=(TN+TP)/(TN+TP+FN+FP)}$$

stands for true positive, TN for true negative, FP for false positive, and FN for false negative.Area under curve (AUC) is a valuable measure whose values fall between 0 and 1. The closer the value is to one.

IV. Result Analysis

The novelty of this work is that it delivers greater precision, recall, and accuracy than any existing model. In "Fig. 3", the performance of our proposed model in different classifiers regards to accuracy, recall, precision are shown.

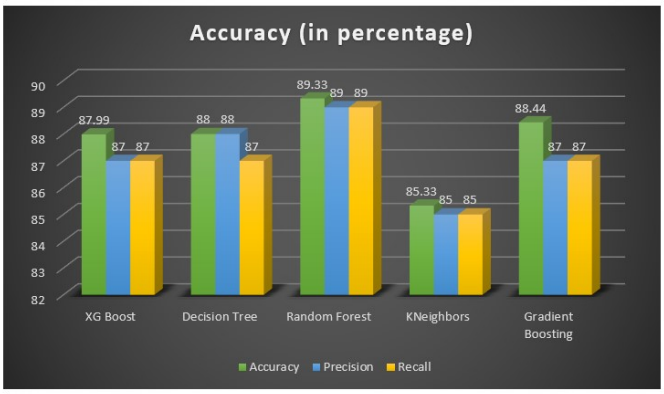

Fig. 3. Performance of our proposed model in different classifiers.

We see that random forest's accuracy,recall,precision higher than other classifiers. A method for summarizing a classification algorithm's performance is the confusion matrix. We can acquire a better understanding of the categorization model's successes and failures by calculating a confusion matrix.In "Fig. 4", Confusion matrix of random forest classifier is shown.As usual, the diagonal elements represent the accurately predicted samples. From a total of 75 samples, 67 are properly predicted. Therefore, the overall accuracy is 89.33%.

The accuracy of predictions made by a classification algorithm is evaluated using a classification report. how many of the forecasts came true and how many didn't.Classification report of random forest is shown in "Fig. 5".We see that True Positive Rate or Recall is 89% and precision is also 89%.

Receiver Operator Characteristic (ROC) curve is a way to measure performance. It is a probability curve that shows the relationship between the TPR and the FPR at different threshold values. In "Fig. 6", ROC curve for random forest classifier is shown and we see that it's AUC score is 0.9.

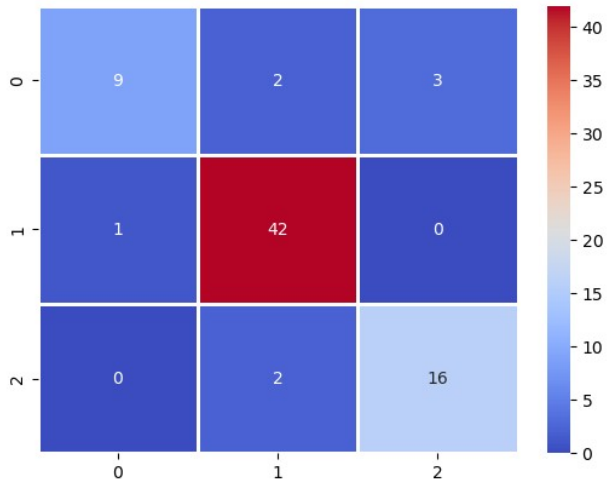

Fig. 4. Confusion Matrix of random forest classifier

	precision	recall	f1-score	support
None	0.90	0.64	0.75	14
Sleep Apnea	0.91	0.98	0.94	43
Insomnia	0.84	0.89	0.86	18
accuracy			0.89	75
macro avg	0.89	0.84	0.85	75
weighted avg	0.89	0.89	0.89	75

accuracy: 89.33

Fig. 5. Classification report of random forest classifier.

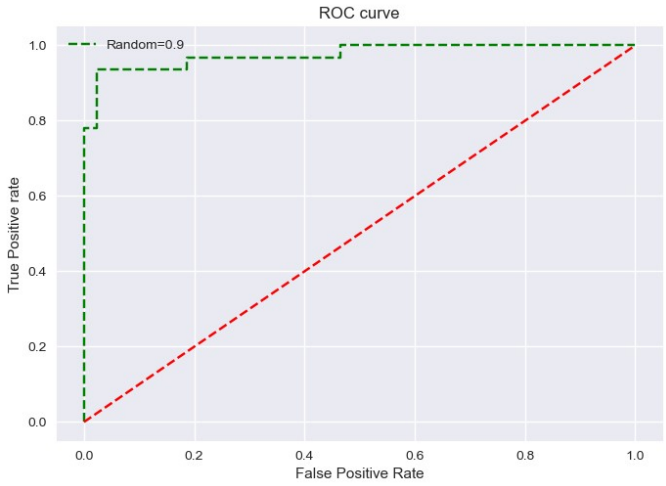

Fig. 6. ROC curve for random forest classifier

V. DISCUSSION

Random forest employs ensemble learning, which combines multiple classifiers to solve complex problems. It decreases dataset overfitting and boosts precision [14].Extreme gradient boosting (XGBoost) is a boosting technique based on the ensemble approach. XGBoost is owned by the Distributed Machine Learning Community (DMLC), and it performs so well because [15] it examines every data value in the dataset. It provides various intuitive features, such as parallelisation, distributed computing, cache optimisation, and more. For this reasons, We apply the Random Forest, XGBoost and Gradient Boosting Algorithm to ensure a quick execution time, robustness against overfitting, and accurate prediction. The performance of our proposed model in different classifiers is shown in "Table I" regards to accuracy, recall, precision. When compared to other classifiers, Random forest clearly produces the finest outcomes. From "Table II", in terms of accuracy, recall, and precision, we can see that the performance of our suggested model outperforms all existing models.Limitation: The dataset we utilized only has 12 features, and there are 373 total instances, which is one of our work's limitation. We have to apply proposed model to a large dataset which contains more features for further analysis.

TABLE I
PROPOSED MODEL PERFORMANCE IN DIFFERENT CLASSIFIERS FOR CLASSIFICATION

Classifiers	Accuracy	Recall	Precision
XG Boost	87.99	87	87
Decision Tree	88	88	87
Random forest	89.33	89	89
Kneighbors	85.33	85	85
Gradient Boosting	88.44	87	87

TABLE II
COMPARISON OF DIFFERENT SLEEP DISORDERS DETECTION APPROACHES BASED ON PERFORMANCE

Approaches	Accuracy	Recall	Precision
Liang. et al.[16]	83.6	84	83
Roebuck.et al.[17]	82.9	83	82
Zhu et al.[18]	87.5	87	87
Hsu. et al.[19]	87.2	87	87
Our proposed approach	89.33	89	89

VI. CONCLUSION

Sleep disorders are a complex and pervasive health challenge that goes beyond simply disrupting sleep patterns. Sleep disorders are multifaceted in nature, with physiological and environmental factors all contributing to their prevalence and impact on people's overall well-being. The healthcare providers, medical specialists, and decision-makers can now take advantage of the existing models to find the most pertinent aspects for the occurrence of sleep disorders and can evaluate the corresponding probability or risk. In this regard, machine learning can help with the early diagnosis of sleep disorder

and lessen its severe aftereffects. This study examines the efficacy of multiple ML algorithms to determine the most reliable algorithm for sleep disorders detection based on a number of variables that capture the profiles of the participants.The models' interpretation and the classifiers' classification performance are mainly supported by the performance assessment of the classifiers applying AUC, precision and recall, F1-score, and accuracy. Additionally, they demonstrate the models' reliability and prognostication power for the sleep disorder class. Random forest classifier performs better than the previous approaches, with a 90% AUC, 89% F1-score, 89% precision, 89% recall, 89.33%accuracy. Consequently, our proposed framework is an efficient strategy for identifying people who are at a high risk of having a sleep order in the long run. The future plan of this study is to use deep learning techniques to improve the ML framework. Especially we will use Artificial Neural Network in our model.ANN may learn from data and adjust internal parameters to improve performance.

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Effect of Age and Body Size on Ovarian Development and Fecundity of *Culex quinquefasciatus* Say (Diptera: Culicidae)

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***Abstract*— *Culex quinquefasciatus* is a significant vector of bancroftian filariasis and an expected vector of *Dirofilaria immitis*, a few arboviruses like West Nile infection (WNV), and Break Valley fever infection. For the effective control of these diseases through genetic control, a better understanding of *Cx. quinquefasciatus* reproductive biology is crucial. In this study, we observed how age and body size effect the ovarian development and fecundity of *Cx. quinquefasciatus*. The present study was conducted under laboratory conditions at Insect Rearing and Experimental Station at JU during February-December 2023. The laboratory-reared female mosquitoes of desired age (1, 3, 5, and 10 days old) and body size (small, medium, and large) were chilled to death, then dissected and measured the reproductive organs (ovaries, spermathecae, and the bursa) under a stereoscopic microscope. Mean ovary lengths of 1, 3, 5, and 10-days-old females were 0.759±0.005, 0.933±0.039, 1.056±0.003, and 1.123±0.023mm respectively. In a similar vein, the mean ovary lengths of mosquitoes with small, medium, and large body sizes were 0.92±0.07, 0.98±0.08, and 1.01±0.08 mm. The result shows that the age and body size is significantly correlated with the length of the ovary ($p<0.05$ for both factors). After 10 days of eclosion when blood fed, the ovary began to grow quickly and each ovariole grew into a fully formed egg that was ready to lay in approximately 72 hours. These findings provide insightful knowledge for optimizing genetic control methods by understanding mosquito ovary development based on age and size. Further research using cutting-edge technologies is required to elucidate the impact of sperm transfer on ovary development.**

***Index Terms*— *Culex quinquefasciatus*, Age, Body size, Ovarian development, Ovary length**

I. Introduction

Culex quinquefasciatus (Diptera: Culicidae) is a significant vector of bancroftian filariasis and an expected vector of *Dirofilaria immitis*. These types of mosquitos are likewise a possible vector of arboviruses like West Nile infection (WNV) and Break Valley fever infection [1]. According to current estimates, about 120 million people worldwide are infected with lymphatic filariae, especially those that cause bancroftian filariasis [2].

In many areas, mosquito control is getting better, but there are several impediments, such as the rise in pesticide resistance and the dearth of safe, affordable alternatives to pesticides. The need to extend the use of highly effective vector control compounds is necessitated by the rise in insecticide resistance [3]. Traditional vector control strategies include reducing larval breeding grounds [4] and use of insecticides; But these methods don't always work to lower the burden of disease [5].

As there is presently no approved vaccine or antiviral medication available, thus vector control is the sole method of preventing these diseases [6]. Genetic control strategies to target disease vectors have received considerable attention over recent years [7]. Therefore, a detailed understanding of mosquito mating biology is necessary to ascertain the minimum requirements that genetically modified mosquitoes must meet in order to succeed as well as the key performance indicators [8]. The relationships between fecundity, age factors, and body size are less well understood. Numerous studies have looked at mosquito reproduction decreases after an age, and a number of these have described similar decreases in different mosquito strains [9].

In order to support genetically controlled vector control programs, we sought to ascertain the fecundity and gradual ovary development in relation to age and body size. This work improves our understanding of the complex reproductive biology of mosquitoes and refines estimations of reproductive capacity for genetic control efforts. It also highlights the possible influence of age and body size on *Culex quinquefasciatus* ovary length. Genetic control over *Culex quinquefasciatus* egg-laying ability may be achieved if ovarian development can be stopped at a specific age or size. Further research using cutting-edge technologies is required to elucidate the impact of different insecticides and sperm transfer on ovary development for laboratory reared and wild mosquitoes.

II. Materials and Methods

A. Mosquito Collection and Rearing

Larvae of wild *Culex quinquefasciatus* were collected from Savar, Dhaka-1342, Bangladesh by using a hand-held dipper and kept in a plastic jar. Then collected larvae were brought to the Insect Rearing and Environmental Station (IRES),

Jahangirnagar University and reared in a tray containing clean water (as culture medium) at 28 ± 2°C and 80 ± 5 % (RH) relative humidity and a photoperiod of 12:12 (L:D). When the larvae began to pupate, the pupae were transferred into a mosquito-rearing case (30 × 30 × 30 cm) in which the maximum adults emerge from the pupal case the following day. The adult mosquitoes were fed with 10% (Dextrose (D+)-Glucose) solution every day and after 10 days of eclosion the mosquitoes were fed with blood.

B. Dissection of Reproductive Organ of Different Age and Body Sizes

The adult mosquitoes of different age and body size were isolated, collected, and brought into the entomology laboratory and knocked down by putting them in the refrigerator for 15 minutes. Female reproductive organs (ovaries, Spermathecae and the bursa) were dissected after 3, 5 and 10 days eclosion of small, medium and large size. For the approximate body sizes wing lengths were measured. For staining, one drop of eosin was added on the sample for 30 seconds and washed with saline water.

C. Microscopic Analysis

Stained organs were placed carefully in a drop of saline water on a microscale slide (1 mm). Organs on the slide were then examined using a light microscope. Ovary lengths were measured by means of the scale attached to the slide. After measuring the ovary length, the ovarioles were freed carefully by slitting the ovarian sheath with fine pins (0.3 mm). Under a cover slip, the ovarioles were examined without compression. Dissected spermathecae and bursa on the microscopic slide was pressed slightly to tear the spermathecae and analyzed the presence of sperm. After 10 days of eclosion the mosquitoes were fed blood. The ovaries were then dissected and analyzed after being fed blood for 24, 48, and 72 hours.

D. Data Analysis

Raw data was recorded in a notebook and then entered and calculated all data in Microsoft Excel 2016. The ovary lengths, mean, standard error, and significant correlation were calculated by the same software. The effect of age and body size on ovary length was also analyzed by using a line graph in Microsoft Excel 2016.

III. Results

The present study was carried out to investigate the effect of age and body size on ovary development. It shows a gradual increase of ovary size in relation to age or body size. Data were taken after 1, 3, 5 and 10 days after eclosion and the mosquitos were measured as small, medium, and large size.

A. Effect of Age and Body Size on Ovary Length

The ovary length of large female mosquito was significantly greater than the smaller one of different ages and detected a significant effect of female ages (Fig 1). The average ovary length of small 1-day-old females was 0.75 ± 0.03 mm, medium 0.76 ± 0.02 mm, and large 0.77 ± 0.02 mm; of small 3-days-old 0.86 ± 0.03 mm, medium 0.95 ± 0.02 mm, and large 0.99 ± 0.01mm; of small 5-days-old 1.01 ± 0.06 mm, medium 1.06 ± 0.07mm, and large 1.10 ± 0.06mm; of small 10-days-old 1.08 ± 0.07 mm, medium 1.14 ± 0.03mm; and large 1.15 ± 0.03mm (Fig 1).

B. Sperm and Spermathecae Analysis

Dissected spermathecae shows numerous sperm stored in since the female has already been copulated. Presence of sperms in the spermathecae indicates that the insemination status is positive (Plate 1).

C. Ovary Development After Blood Fed

The ovary began to grow quickly after 10 days of eclosion when blood fed. Each ovariole grew into a fully formed egg that was ready to lay in approximately 72 hours (Plate 2).

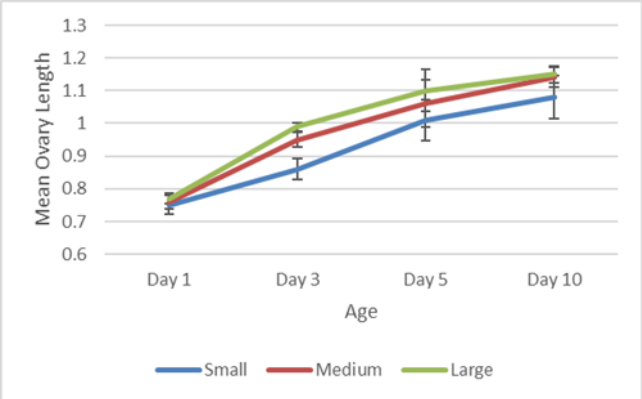

Fig. 1. Mean Ovary Length of Female *Culex quinquefasciatus* of Different Age (1, 3, 5, and 10 Days Old) and Body Size (Small, Medium, and Large)

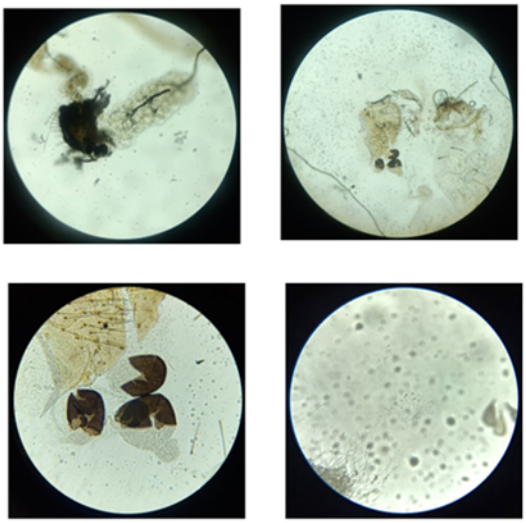

Plate 1. Sperm and Spermathecae Analysis Under Microscope

Plate 2. Overy Development After 24, 48, and 72 Hours of Blood Fed

IV. Discussions

Our study indicates that age and body size effect the ovary length of *Culex quinquefasciatus*. The mosquitoes of larger body size have relatively larger ovaries than the medium and smaller one. The size of uninfected female *Cx. quinquefasciatus* mosquitoes and their ability to produce eggs were found to be significantly correlated in a recent study [10]. Afterwords the blood feeding of *Cx. Quinquefasciatus*, microscopic analysis shows the ovaries rapid development and matured just after 72 hours. Among the factors influencing female fecundity, age and body size was the factor that shows the greatest effect as our result. Ponlawat and Harrington's study also shows the possible impact of age and body size on the mating capacity of *Aedes aegypti* [11]. Based on our laboratory result, large 10-days-old females shows larger ovary. A similar study shows a positive correlation between fecundity and body size up to 13 days old [12].

V. Conclusion

For the better control of the diseases associated with *Culex quinquefasciatus*, we have worked to define the development of ovaries in relation to age and body size in this study. These findings provide insightful knowledge for optimizing genetic control methods by understanding mosquito ovary development based on age and size. To support genetically controlled vector control programs, we find out the optimal age and body size for female reproductive success. Further research using cutting-edge technologies is required to elucidate the impact of sperm transfer on ovary development.

Acknowledgment

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Assessment of Medical Transcriptions in Low-Resource Language for the Underserved Population

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***Abstract*—Speech-based Information Extraction in the medical domain for text-illiterate people is difficult as the use of Automatic Speech Recognition (ASR) tools for Low-Resource Languages (LRLs) lacks linguistic resources, affecting its efficiency. The performance of an ASR system is calculated using a standardized system called the Word Error Rate (WER). The evaluation system requires a reference text to assess the quality of transcription in the hypothesis text. The reference text refers to the manually scripted Ground Truth Text (GTT). In the context of a doctor-patient conversation, the process is impromptu and unscripted. This research proposes the use of the Large Language Model (LLM) to generate a hypothetical GTT and compare it to the conventionally scripted GTT to estimate its efficiency. The best achieved WER from the LLM generated GTT for doctor-patient conversations in Bangla was 0.0645 (6.45%) and the average WER was 0.1712 (17.12%). Observations were made along with the goal of reducing overall cognitive load in scripting GTT without compromising efficiency and provide speech-based healthcare service to disadvantaged LRL users.**

***Index Terms*—Medical Transcript, Automatic Speech Recognition, Word Error Rate, Ground Truth Text, Large Language Model**

I. Introduction

The current scenario of speech recognition technology for low-resource languages is not very application friendly. Given from the name, this lack of linguistic resources has resulted in a drawback when it comes to development of effective ASR tools [1]. LRLs exhibit dialect variation and intricate phonetic complexities combined with scarcity of digitized linguistic resources. The shortcomings include lack of extensive annotated speech dataset and reference text for transcription quality assessment. It becomes more problematic when the technology is aimed to be used for a specific domain, such as health data retrieval from a doctor-patient conversation, the performance of ASR systems deteriorates drastically [2]. Proposing speech-based health information retrieval for people with no knowledge in any High Resource Language (HRL) and also lacking in reading and writing skills in their own LRL introduces signficant adversity [3].

Linguistic resources are determined from the ASR system performance. The accuracy of the transcription determines the efficiency of the involved ASR tools. One of the commonly used standardized metric for evaluation is the Word Error Rate (WER). The fundamental requirement of this metric is transcribed hypothesis text and its ground truth text for referencing [4]. However, a doctor-patient interaction is a self-guided impromptu process that usually does not have a script. In such situations, the assessment of any ASR tool in transcribing such an occurrence would require manual scripting of the conversation in high precision. The lack of such resources results in the hindrance of performance evaluation of linguistic tools and observe the scopes of improvement.

Looking at the recent advancements of Generative Artificial Intelligence (GenAI), LLMs have quite a significant tool in the aspect of understanding and generating human language. Being trained on vast datasets in different languages and topics of interest, the prompt-based interface of LLMs have been in use for multifarious works. These tools have clearing United States Medical Licensing Examination, giving light to the prospect of being suitable as an assistive component in clinical education and healthcare information accumulation [5]. In the context of language-based operations in the medical domain, LLMs' capability of quick assimilation, paraphrasing information and structured representation of information while keeping it contextually unchanged has been of great use in medically relevant queries and interactions [6]. The language diversity in the LLMs broadens its application for LRLs as well. This, in turn, also brews the prospect of using LLMs in generating reference data for evaluation of transcription quality of transcribed doctor-patient conversations using an LRL.

This research aims to explore the scope of generating hypothetical GTT from the transcribed output using an LLM from speech data of doctor-patient conversation in the Bangla language, which is an LRL. Using ChatGPT, the chatbot interface of GPT-4o, a generalized prompt is used for multiple instances of doctor-patient conversation recorded from a health check-up camp. The performance of the LRL generated hypothetical GTT is compared with the conventional GTT scripted by from human understanding for the same instances. The goal is to assess the efficiency of GenAI in replicating the process of scripting GTT and reduce the cognition load of doing it manually for large amount of data. Fig. 1 determines the flow of operations in the experiment.

The following parts of the article are organized as follows. Section II talks about the research endeavors and findings done aiming for similar goal. Section III consists of an elaborate

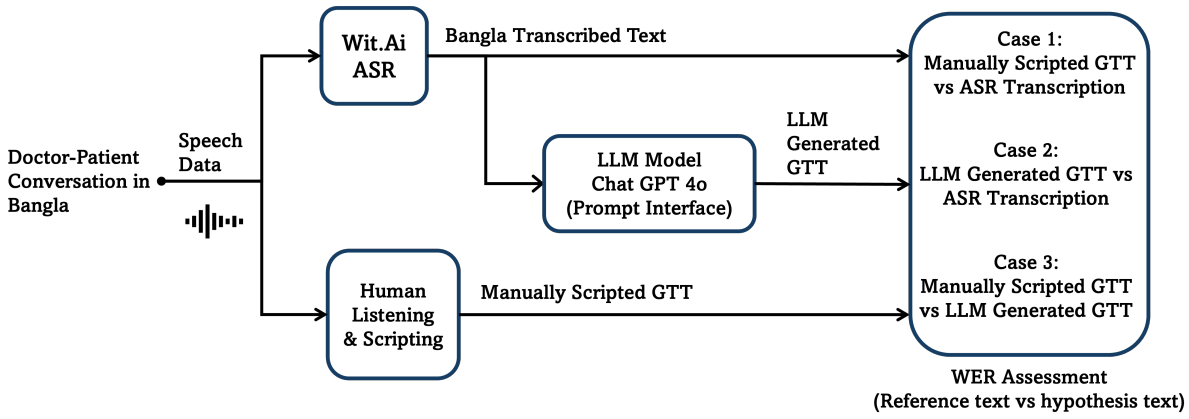

Fig. 1. Flow Diagram of converting speech data to text using ASR tools and manual transcription, generating LLM generated hypothetical GTT using ASR output

discussion of the experimental process and its key components, mainly the evaluation metric, the speech dataset and LLM models along with the introduction of the case-studies. Based on the case studies, the results and observations that emerged are presented in Section V. Additionally, the future scope of this conceptual approach is discussed with expected outcomes and possibilities.

II. Related Research

Measurement of WER without gold standard GTT has been attempted using multifarious methodologies over the years. Huang et al. relied on using confidence classifiers for ASR decoding following 2 separate approaches to ASR confidence measurement. It resulted in a 38.6% relative reduction in the aspect of the correct-reject rate [7]. For imbalanced datasets, the use of a Stacked Auto-Encoder in fine-tuning the Neural Network classifier to detect ASR errors showed better results than its contemporary attempts [8]. The process of detecting deletions and adapting the deletion-informed confidence approach by Seigel and Woodland using the Conditional Random Field (CRF) model and the best achieved relative improvement was 21.4% [9]. The use of a bidirectional recurrent neural network performed significantly better than CRF in ASR error detection, with a classification accuracy of 94.87 for deletion error detection [10]. Most of the studies focused on Machine Translation assessment rather than transcription. For LRLs the amount of research done drastically reduces. Ali and Renals introduced the idea of estimating WER or e-WER for 24 Arabic broadcast programs. The achieved estimated WER was 25.3% with the actual value being 28.5% [11]. Tam et al. attempted to use a recurrent neural network to capture long-distance word context and a complementary ASR system to detect the error of the primary ASR for languages English and Iraqi Arabic [12]. The use of LLMs in the process of text generation in Bangla for medical context is relatively unexplored domain. However, use of LLM for medically relevant scenarios and also in different aspects of the Bangla language has decent amount of existing research. Faria et al. conducted a comprehensive study on all the existing transformer models based on their inference for Bangla language [13]. However, inconsistency in selection of evaluation metric in research relevant to Bangla language makes it difficult for ASR assessment. [14] LLM efficiency has gained significant traction in the case of medical science and clinical knowledge, focusing on its capability of information accumulation and organization [6] [15]. GPT-4o displayed promising potential in multiple perspectives for the field of surgical oncology [16].

III. Experimental Environment

This section explains the fundamentals of the evaluation metric WER, the experiment approach of generating the hypothetical GTT, a brief explanation of the speech data in use and the LLM model used.

A. Word Error Rate

WER is a widely preferred evaluation metric when it comes to the evaluation of transcription accuracy of ASR systems. The measurement is done based on the difference between a sequence of words produced by the ASR tool and the reference or ground truth sequence of words. It is a ratio of total number of errors against the total number of words in the reference text. The errors are categorized in 3 types, that is substitutions, insertions, and deletions. Substitutions (S): It is the number of words that are replace by incorrect words in the ASR output. Insertions (I): This indicates the number of extra words added in the ASR output Deletion (D): It represents the words that are missing in the ASR output but is there in the reference text. Equation 1 shows the percentage representation of WER. Lower percentage indicates less error and better quality of transcription.

$$\text{WER } (\%) = \left(\frac{S + D + I}{N}\right) \times 100 \tag{1}$$

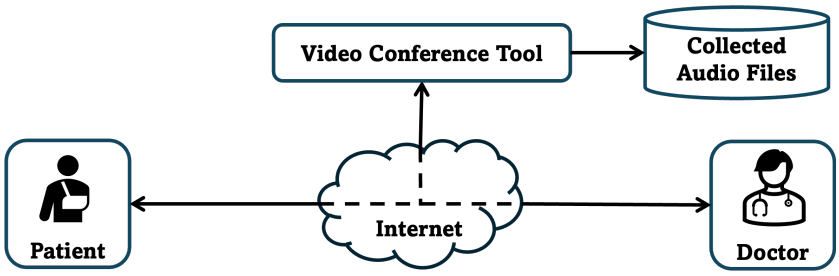

Fig. 2. Audio data collection system from doctor-patient conversation. Online consultation using video conference tool from where audio data is collected

B. Experimental Setup

The experimental setup consists of the ASR tool Wit.Ai from Meta, an environment set up in Google Collaboratory, and the chatbot interface of GPT-4o as access to LLM. The prompt was designed based on the requirements and characteristics of a conventional GTT, minimizing the effect of hallucination of GenAI. In this context, hallucination refers to the parts of the generated text that are out-of-context, created beyond the constraints of the given prompt, and the addition of irrelevant information in total [17]. Fig. 1 depicts the transcription and GTT generation process along with the WER assessment. There are mention of 3 test cases to build the argument.

- **Case 1** is the WER assessment of **Manually Scripted GTT** against the **ASR transcription**
- **Case 2** looks at the evaluation of WER for **LLM-generated GTT** versus the **ASR transcription**
- **Case 3** compares the **Manually Scripted GTT** against the **LLM-generated GTT** using WER

In every case, the prior is the reference text while the latter is the hypothesis text.

Prompt:

- Take the ASR transcribed text as input
- Not make any contextual changes to the original text
- Avoid summarizing the context or any sentence
- Correct probable spelling mistakes and word misinterpretation
- Do not translate any English words
- Keep the number of words unchanged
- Ensure it remains a coherent doctor-patient interaction

Fig. 3. Considerations of manually scripting an audio file was imitated using these instructions as a prompt for the LLM

C. LLM Model

ChatGPT-4o with GPT-4 Turbo in its backend is currently one of the smartest and fastest-performing LLM-based chatbots. It is a relatively faster version of GPT-4 [18]. With a reduction in the number of tokens per instance in different languages, it supports contextual understanding and paraphrasing in LRLs like the Bangla Language. A common prompt, shown in Fig. 3 was used for all the instances with the following instructions.

D. ASR System

Wit.Ai is one of the few ASR tools that support the LRL Bangla. Based on some experimental observations it performs better than its peers when it comes to medically relevant conversations in Bangla. Meta has this tool as open source and is available as a GitHub repository to be used as an Application Programming Interface (API). The API was accessed using Google Collaboratory.

E. Speech Dataset

The speech data is collected following the process in Fig. 2 from 20 doctor-patient interactions from a health check-up initiative using the Portable Health Clinic (PHC) system [19] at a school in Dhaka, Bangladesh. All the conversation was conducted in the native Bangla language with a few uses of medically relevant terms in English. The consultation process was done online using the Zoom web meeting with access to both audio and video interaction. Each interaction contained formal greetings, prior health check-up data analysis, asking and reporting health complaints (if any), diagnosis, and prescription. The conversations ranged from 44 seconds to 7 minutes and 30 seconds. The doctor attended the consultation using a personal smartphone and a setup was made for the patients on the school premises. The audio from the doctor's end was quite clear and understandable but the patient audio had noise interference from the surroundings.

IV. Result and Discussion

The average, highest and lowest achieved WER from the 3 case studies for different combinations of reference and hypothesis text has been presented in Table I. Comparison of Case 1 and Case 2 portrays the performance evaluation of an LLM in generating GTT and it's efficiency against the conventional method. The Average WER for the LLM generated GTT is 17.12% which is 0.79% lesser than of the manually scripted GTT. In case of highest and lowest achieved WER, case 2 displayed better performance with WER scores of 31.9% and 6.45%, respectively. Fig. 4 demonstrates the WER variation for all the cases. Though differing in value, the variation pattern is quite similar for case 1 and case 2. There is inconsistency in the values of WER when observed from the perspective of instance-to-instance comparison. Case 3 depicts the WER measurement of the LLM-generated GTT against the human scripted GTT. This is intended to show the deviation of

Fig. 4. WER Variation for Case 1, Case 2 and Case 3 based on the voice data instances; Comparison of Case 1 and Case 2

TABLE I
AVERAGE, HIGHEST AND LOWEST ACHIEVED WER FOR THE 3 CASE SCENARIOS

Cases	Reference Text	Hypothesis Text	Average WER	Highest WER	Lowest WER
Case 1	Manually Scripted GTT	ASR transcribed Text	17.91%	41.81%	8.4%
Case 2	LLM Generated GTT	ASR transcribed Text	**17.12%**	**31.9%**	**6.45%**
Case 3	Manually Scripted GTT	LLM Generated GTT	21.57%	46.33%	8.64%

the hypothetical GTT in comparison to the conventional GTT. The average measurement of deviation using WER is 21.57% with a high of 46.33% and a low of 8.64%.

V. Observation and Future Prospect

Analyzing the resultant WER values from the three different case studies led to several observations regarding the performance of LLM in GTT generation. These observations highlighted influencing factors and drawbacks, as well as potential areas for further optimization. Additionally, necessary initiatives for our intended application in medical conversations using the low-resource language Bangla were identified.

A. LLM in GTT Generation

GPT-4 Turbo generated hypothetical GTT displayed an improvement in the value of WER. The consistency in the constraints provided in the prompt resulted in the consistency of variation in WER value with the conventional approach. Observing Equation 1, instructions to avoid summarizing and keeping the number of words unchanged resulted in mitigation of all deletions and insertions, so the resultant WER is the ratio of substitutions against total number of words in the reference text. To ensure proper substitution of the misinterpreted words and spelling mistakes, the contextual format of a doctor-patient conversation according to the LLM's understanding. There were some English words in the ASR transcribed text, mostly being medically relevant terms. Not translating those also had an effect on the overall WER.

B. Other affecting factors and drawbacks

The effect of the audio quality of the doctor patient conversation was a significant affecting factor in this assessment scenario. In the online consultation process, the doctor had a loud and clear audio source, while the patient end had high amount of surrounding noise. This resulted in the transcription of the doctor's audio more in comparison to the patient's audio in times of overlapping. The complexity of the conversation also resulted in higher WER in some of the instances. Furthermore, the involvement of video in the interaction affected the

process. So of the yes/no questions asked by the doctor was recorded but there was no verbal answer. Patient nodded in reply resulting in the information not getting recorded in the audio of the interaction. In case of using the ASR transcription for GTT generation, information that is not transcribed due to ASR tool capacity or sound distortion is likely to be missing from the hypothetical GTT as well. This creates a shortcoming on the efficiency of carrying the complete information in comparison to the conventionally scripted GTT.

C. Potential Future Prospect in Healthcare Services

The initial endeavors of exploring the usability of LLMs as a GTT generation tool for transcriptions of doctor-patient interaction in Bangla has numerous prospects of improvement. Looking at the fact that medical interactions are not scripted or guided in any manner, so for large datasets of conversation data in Bangla, the measurement of efficiency of the ASR tool using WER would be practically hectic. Manual scripting is time consuming and the resultant cognition load also has an effect on the quality of the script. This initiative can prove useful for such situations. Furthermore, the currently used prompt has scope of improvement using advanced prompt engineering. There has been promising outcomes reported in use of GPT-4 Turbo in diagnosis of neuro-radiology cases [20]. The goal would be to imitate the process of manually scripting an audio file. Reducing the amount of relevant hallucination of the LLM along with creating a balance between relevance and constraints would result in better generation of hypothetical GTT.

In addition, people with LRL and the inability of reading and writing can conveniently have a conversation with the doctor in their local language and concurrently have health information extracted from the interaction. EHR system data collection becomes easier for the underserved community.

VI. Conclusion

This research explores the potential of using GenAI and its capabilities in preserving linguistic semantics to generate hypothetical GTT for evaluating the transcription quality of ASR systems. The study utilizes Wit.Ai as the ASR tool for transcribing doctor-patient conversations in Bangla and replicates the process of manually generating audio scripts. Initial observations indicate that the WER of the GTT generated by the LLM performed better. However, various influencing factors and drawbacks were noted, along with prospects for using this technology in extracting speech-based information from medically relevant interactions. The desired goal is to take digital healthcare services to the people who face the constraint of language literacy.

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Entrepreneurial Landscapes in Indonesian Digital Health: A Comprehensive Outlook

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***Abstract*—This study provides a comprehensive outlook on the entrepreneurial landscapes in the Indonesian digital health sector. It analyzes the current state of digital health services, identifies key challenges and opportunities, and evaluates the impact of government policies and initiatives on the growth and development of digital health entrepreneurship. The study highlights significant advancements driven by government initiatives, such as the establishment of the Digital Transformation Office (DTO) and collaborations with private entities. Despite these advancements, challenges such as the digital divide, technical issues, and cultural barriers persist, presenting both obstacles and opportunities for innovation. The study underscores the Indonesian government's commitment to digital health transformation, which, coupled with a favorable investment climate, positions the sector for substantial growth. The findings aim to provide valuable insights for stakeholders looking to enhance the sector's growth and effectiveness, ultimately improving healthcare accessibility and quality in Indonesia.**

***Index Terms*—digital health, entrepreneurship, Indonesia, health innovation, developing country**

I. Introduction

Digital health interventions have enormous potential as scalable tools to improve health and healthcare delivery by improving effectiveness, efficiency, accessibility, safety, and personalization [1]. Healthcare entrepreneurship using local human resources, digital health technology, proper training, and necessary funds can be a sustainable approach for affordable healthcare delivery in developing countries [2]. Digital health with comprehensive health data management can help reduce medical costs, decrease medical errors, and overall, increase access to healthcare within limited resources, contributing to the achievement of universal health coverage [3] [4].

Digital health entrepreneurship in Indonesia also promising. Indonesia, a vast archipelago with a population spread across 17,744 islands, has a health service system comprising primary and secondary care that serves about 272 million people. During the COVID-19 pandemic, these services faced numerous challenges, including disparities in access to health services and an imbalanced ratio of health facilities and workers to the population. To address these issues, leveraging digital information technology for COVID-19 testing, tracking, and treatment emerged as a viable solution [5] [6].

The Indonesian government is committed to promoting and endorsing the adoption of digital technology in public health. Digital transformation is a crucial initiative aimed at achieving a healthier Indonesia by leveraging data and technology. This commitment is evident in the government's collaboration with digital health companies amid the COVID-19 pandemic. In 2021, the Ministry of Health established the Digital Transformation Office (DTO) to enhance health services. The DTO aims to create electronic patient records (with consent), streamline health service applications, and bolster the health technology ecosystem through policy innovation [7] [8].

Continuous and comprehensive patient observation can assist health workers in evaluating treatments provided. Effective evaluation facilitates communication between health facilities, enabling efficient and timely referrals when needed. To ensure safe, high-quality, non-discriminatory, and effective telemedicine services between healthcare facilities, telemedicine services must meet requirements regarding human resources, infrastructure, equipment, and applications ("Regulation Of The Minister Of Health Of The Republic Of Indonesia Number 20 Of 2019 About Providing Telemedicine Services Between Health Service Facilities," 2019) [9] [10]. Currently, eleven telemedicine platforms are working with the Ministry of Health, including Halodoc, YesDok, Alodokter, Klik Doctor, SehatQ, Good Doctor, KlinikGo, Link Sehat, Milvik, Prosehat, and Getwell [11].

Digital health solutions have found a captive audience in Indonesia. The country's large, young, and technologically engaged population has already adopted technology to solve challenges in the transport, travel booking, and commerce sectors. As Indonesia's population grows and more people gain access to the internet and smartphones, the market for digital solutions will expand. Indonesia's domestic digital health ecosystem is uprising [12].

To provide a comprehensive outlook on the entrepreneurial landscapes in the Indonesian digital health sector, this study aims to analyze the current state of digital health services, identify key challenges and opportunities, and evaluate the impact of government policies and initiatives on the growth and development of digital health entrepreneurship in Indonesia. The research focuses on three primary questions:

(1) What is the current state of digital health services in Indonesia? (2) What challenges and opportunities do digital health entrepreneurs face in Indonesia? (3) What is the impact of government policies and initiatives on the digital health sector in Indonesia? Through this exploration, the study wants to contribute to digital health entrepreneurship in Indonesia and provide insights for stakeholders aiming to enhance the sector's growth and effectiveness.

II. Methodology

This research is conducted based on secondary literature to provide a comprehensive analysis of the entrepreneurial landscapes in the Indonesian digital health sector. The methodology involves the following steps:

Literature Review: A thorough review of existing literature was conducted, focusing on academic journals, industry reports, government publications, and relevant articles. Sources were selected based on their relevance to digital health, entrepreneurship, and the Indonesian context.

Data Collection: Secondary data was gathered from various credible sources, including government reports, publications from health organizations, and industry analyses. Specific documents such as "Regulation Of The Minister Of Health Of The Republic Of Indonesia Number 20 Of 2019 About Providing Telemedicine Services Between Health Service Facilities" and reports from the Digital Transformation Office (DTO) were reviewed to understand the regulatory and policy framework impacting digital health entrepreneurship in Indonesia.

To gather relevant literature, searches were conducted on top research search engines, including PubMed, Google Scholar, IEEE Xplore, ScienceDirect, and JSTOR. These platforms were chosen for their comprehensive databases and relevance to health and technology research.

Analysis: The collected data was analyzed to identify trends, challenges, and opportunities in the Indonesian digital health sector. The analysis focused on understanding the current state of digital health services, the impact of government policies, and the factors influencing the growth of digital health startups.

Synthesis: The findings from the literature review and data analysis were synthesized to provide insights into the dynamics of digital health entrepreneurship in Indonesia. This synthesis aimed to highlight key areas for improvement and potential strategies for stakeholders to enhance the sector's growth and effectiveness.

By relying on secondary literature from reputable sources, this research provides a well-rounded perspective on the Indonesian digital health landscape, drawing from a wide range of existing studies and reports to offer comprehensive insights and recommendations.

III. Key Findings

A. Public-Private Partnership (PPP)

Advances in information and communication technology (ICT) have significantly facilitated the development of electronic government (E-Government). Challenges such as human resources shortage, lack of funds, lengthy process, and other limited government capacity hinder the government development goals. Public-private partnerships (PPP) offer a solution to these problems, providing a means to overcome obstacles and achieve e-government objectives. Partnering with private health providers is particularly effective in addressing these limitations and promoting high-quality public health services. In Indonesia, the digital health sector has experienced significant advancements driven by government initiatives and collaborations with private entities. The Ministry of Health (MoH) has shown strong commitment to this sector by establishing the Digital Transformation Office (DTO) in 2021. The DTO's objectives include implementing electronic patient medical records, simplifying health service applications, and enhancing the health technology ecosystem through innovative public policies. During the COVID-19 pandemic, the government actively partnered with private digital health companies to expand available services, underscoring its dedication to the sector's growth [13] [14] [15].

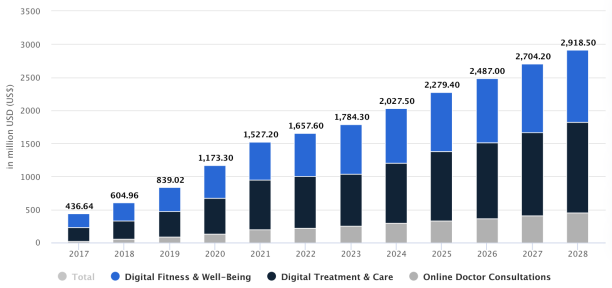

Fig. 1. Digital health market in Indonesia

B. Relevant Laws Governing Digital Health Operations in Indonesia

Indonesia has enacted specific regulations to guide the implementation and development of digital health systems. A key regulation is the decree from the Minister of Health, KEPUTUSAN MENTERI KESEHATAN REPUBLIK INDONESIA NOMOR HK.01.07/MENKES/1559/2022, which outlines the application of an electronic-based government system in health and strategies for digital health transformation. This regulation underscores the government's commitment to integrating digital technologies into healthcare delivery [16] [17] [18].

C. Digital Health Market in Indonesia and Significant Players

Figure 1 shows that the digital health market in Indonesia is projected to reach a revenue of USD 2,028.00 million in 2024. This forecast indicates an annual growth rate (CAGR 2024-2028) of 9.53%, resulting in a projected market volume of USD 2,919.00 million by 2028. The average revenue per user is expected to amount to USD 4.30. Indonesia's digital health market is experiencing rapid growth, driven by the increasing adoption of telemedicine and health monitoring apps [19].

Several entrepreneurial ventures have emerged as significant players in the Indonesian digital health landscape. According

to Tracxn, there are approximately 547 digital health startups in Indonesia. The table below shows the top ten I.

TABLE I
TOP 10 HEALTHTECH STARTUPS IN INDONESIA

Sl.	Name of Company	Established	Funding
1.	Halodoc	2016	$280M
2.	Alodokter	2014	$49.7M
3.	Riliv	2015	Not Mentioned
4.	Diri Care	2022	$4.3M
5.	Rey	2021	$4.2M
6.	Asa Rén	2020	$8.15M
7.	Prixa	2019	$4.5M
8.	PrimaKu	2017	Not Mentioned
9.	Diary Bunda	2020	Not Mentioned
10.	Klinik Pintar	2019	$9.1M

Notable among these are Halodoc, which serves 46.5% of users, and Alodokter, with 35.7% of users. Hospital and clinic telemedicine services are utilized by 41.8% of the population, while direct online consultations with doctors are used by 20.3% of respondents. KlikDokter is another prominent telemedicine service, used by 15.5% of respondents [20]. These platforms have significantly improved the accessibility and convenience of healthcare services in Indonesia.

D. Challenges Faced by Entrepreneurs in the Indonesian Digital Health Sector

Analyzing the digital health entrepreneurship landscape in Indonesia reveals several significant limitations. One of the primary challenges is the digital divide, which creates disparities in access to technology and digital literacy across different regions. This divide is particularly pronounced in rural and remote areas where internet connectivity is limited, and the population may lack the necessary skills to utilize digital health services effectively. Consequently, the potential reach and impact of digital health initiatives are constrained. Technical difficulties also pose a major barrier. Issues such as unreliable internet connectivity, inadequate infrastructure, and the high cost of technological investments hinder the seamless implementation and scalability of digital health solutions. These technical challenges require substantial funding and robust infrastructural support, which are often lacking in a developing country like Indonesia. Psychological and cultural barriers further complicate the adoption of digital health services. Resistance to change from both healthcare providers and patients can impede the integration of new technologies into traditional healthcare practices. Patients, especially the elderly and those from less technologically savvy backgrounds, may find it difficult to transition from conventional to digital health services. Additionally, cultural factors, such as a preference for face-to-face interactions and skepticism towards new technologies, can slow down the acceptance of digital health solutions [21] [22].

E. Prevailing Business Models Adopted by Digital Health Startups

Digital health startups in Indonesia have adopted various business models to cater to different healthcare needs. These include telemedicine platforms like Alodokter, health marketplaces such as Halodoc, health education platforms like KlikDokter, clinic and hospital management systems such as Konsula, and digital health insurance providers like Good Doctor. These models have enabled startups to provide comprehensive and accessible healthcare solutions [23].

F. Addressing Healthcare Access, Affordability, and Quality

Indonesian digital health startups are actively addressing issues of healthcare access, affordability, and quality through various initiatives. The Ministry of Health launched the SATUSEHAT platform as part of its 2024 Digital Health Transformation Strategy. This platform integrates various health applications and resources to improve data connectivity and analysis, enhancing the efficiency and effectiveness of healthcare delivery. Additionally, the Indonesian Digital Health Blueprint, developed in collaboration with the United Nations Development Programme (UNDP) and supported by the Government of Japan, focuses on building a comprehensive health technology architecture to expand inclusive healthcare coverage [24].

G. Innovative Technologies and Solutions in Development

Innovative technologies and solutions are at the forefront of Indonesia's digital health transformation. In 2022, the Ministry of Health signed an agreement with Google Cloud to enhance the digital transformation of healthcare. This collaboration focuses on improving data management, implementing artificial intelligence within health services, and developing tech-enabled health services, thereby advancing the overall quality and accessibility of healthcare in Indonesia [25].

1) Funding Sources and Investment Trends: The funding landscape for digital health startups in Indonesia spans various stages, from seed funding to initial public offerings (IPOs). The investment climate is favorable, driven by rapid growth in internet penetration and a young, tech-savvy demographic. Leading digital health platforms such as Alodokter, HaloDoc, KlikDokter, YesDok, KlinikGo, and Good Doctor have secured significant funding rounds. These investments are essential for scaling operations and enhancing service delivery, enabling these startups to expand their reach and improve the quality of healthcare services across the country.

Figure2 shows the recent trend that the health-tech sector in Indonesia experienced a substantial boost, with investments jumping from USD 8 million in the first half of 2022 to USD 51 million in the first half of 2023. This significant increase highlights the growing confidence and interest from investors in the digital health sector. The total year-to-date (YTD) investment in 2023 reached USD 151 million, driven in part by Halodoc's impressive Series D funding round, which alone secured USD 100 million. This influx of capital is pivotal for advancing digital health initiatives and expanding the sector's capabilities [26].

In the years 2022 and 2023, several sectors in Indonesia saw significant initial public offerings (IPOs), with healthcare being a notable performer. Ranking at number four among

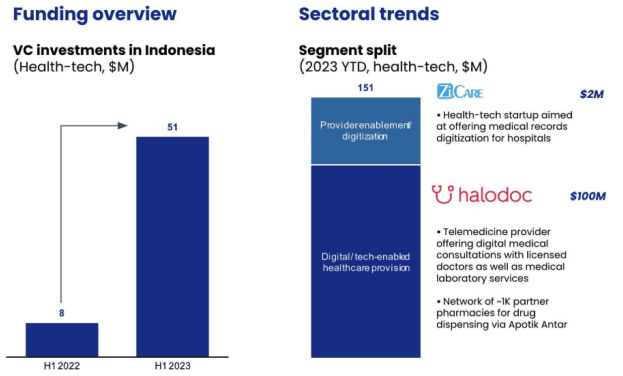

Fig. 2. Health-tech funding overview and sectoral trends

the top five IPO listings, the healthcare sector raised an impressive Rp828 billion. This substantial amount highlights the growing investor confidence and the sector's potential for further growth and development. The large capital influx from this IPO is expected to drive advancements in healthcare services and technology, further enhancing the quality and accessibility of healthcare in Indonesia [27].

A notable example of significant investment is HaloDoc, which raised USD 80 million in a Series C funding round led by Temasek, a global investment company headquartered in Singapore. This funding has been pivotal in expanding HaloDoc's telemedicine services and improving healthcare accessibility across Indonesia [28]. Similarly, Alodokter secured USD 33 million in a Series C round, which has enabled it to enhance its platform and services, reaching a broader audience [29].

These investments not only provide the necessary capital for expansion but also bring in expertise and global best practices, which are crucial for the sustainable growth of the digital health sector in Indonesia. The continuous inflow of funds and strategic partnerships highlights the promising future and significant potential for entrepreneurial growth in Indonesia's digital health industry.

H. Opportunities and Future Prospects for Entrepreneurial Growth

The future prospects for entrepreneurial growth in Indonesia's digital health sector are promising. The demographic bonus, which refers to the economic advantage arising from a decrease in the dependency ratio, and the high prevalence of non-communicable diseases due to unhealthy lifestyles, are likely to drive the demand for telehealth services. These factors create a conducive environment for digital health entrepreneurs to innovate and expand their offerings. Additionally, the increasing penetration of smartphones and internet access across the country further supports the growth potential in this sector.

Moreover, government initiatives aimed at promoting digital health and enhancing healthcare infrastructure play a significant role in fostering entrepreneurial growth. The establishment of the Digital Transformation Office (DTO) and collaborations with global tech companies are steps toward creating a supportive ecosystem for digital health innovations. These efforts are expected to reduce barriers to entry and provide the necessary resources for startups to thrive.

As healthcare needs evolve and technology advances, there are ample opportunities for entrepreneurs to develop innovative solutions that address gaps in healthcare delivery and accessibility. The favorable investment climate, coupled with strategic partnerships and robust policy support, positions Indonesia's digital health sector for substantial entrepreneurial growth in the coming years.

IV. Discussion

This study explores the entrepreneurial landscape of Indonesia's digital health sector, examining the current state of services, key challenges, opportunities, and the impact of government policies.

Current State: Indonesia's digital health sector has progressed, especially during the COVID-19 pandemic, which boosted the adoption of digital health technologies. The Ministry of Health's Digital Transformation Office (DTO), established in 2021, focuses on electronic patient records, health service applications, and enhancing the health tech ecosystem. Telemedicine platforms like Halodoc and Alodokter have improved healthcare access and convenience. The market is expected to grow, with revenues projected to reach USD 2,028 million in 2024 and a CAGR of 9.53% through 2028.

Challenges and Opportunities: Despite advancements, challenges persist, such as the digital divide, unreliable internet connectivity, and inadequate infrastructure, particularly in rural areas. Psychological and cultural resistance to new technologies also hinders adoption. However, opportunities arise from the increasing smartphone and internet penetration, a young, tech-savvy population, and the high prevalence of non-communicable diseases. Government initiatives like the SATUSEHAT platform and the Indonesian Digital Health Blueprint provide a supportive framework for innovation.

Government Policies: Government policies and initiatives significantly shape the digital health landscape. The DTO and collaborations with global tech companies highlight the government's commitment to enhancing digital health infrastructure. These efforts aim to reduce barriers, provide resources, and create a conducive environment for startups. The government's proactive approach during the COVID-19 pandemic, including partnerships with private digital health companies, underscores its dedication to sector growth.

V. Conclusion

Indonesia's digital health sector is set for substantial growth, driven by supportive government policies, increasing digital adoption, and significant investment. While challenges like the digital divide, technical issues, and cultural barriers persist, they also present opportunities for innovation. The government's commitment to digital health transformation and a favorable investment climate support ongoing sector expansion. This study has limitations due to its reliance on secondary

data, which affects the depth of analysis and excludes primary data collection. Future research should incorporate primary data for a more comprehensive understanding. Additionally, the rapidly evolving nature of digital health technologies and policies requires continuous data monitoring to keep findings relevant.

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Evaluating Social and Financial Benefits of a Digital Health Management System for Developing Countries

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***Abstract*—This study evaluates the social and financial benefits of a digital health management system, specifically the Smart Health Gantt Chart (SHGC), in the context of developing countries. Focusing on Bangladesh, where there are significant issues related to necessary healthcare access and high out-of-pocket (OOP) health expenditures, this research explores how digital health technologies can address these challenges. The findings reveal that the SHGC system can help mitigate doctor shortages, enhance preventive care, and reduce OOP expenditures with a potential cost reduction of approximately 90.96%. This research provides valuable insights into the economic and social advantages of implementing a digital health management system and supports the broader adoption of digital health technologies to improve patient outcomes and financial well-being.**

***Index Terms*—Digital Health, Developing Country, Access to Healthcare, Cost-Benefit Analysis (CBA), Life-long Medical History Management, Electronic Health Records (EHR)**

I. Introduction

In 2021, about 4.5 billion people, more than half of the global population, were not fully covered by essential health services [1]. Low- and middle-income countries (LMICs) face the most challenges in terms of necessary healthcare access [2]. There are various reasons such as excessive costs, limited resources, shortage of human resources for health, inadequate infrastructure, lack of insurance, and insufficient preventive care, etc. One of the major issues is out-of-pocket health expenditure, which significantly affects access to healthcare. Around 800 million people allocate at least 10 percent of their household budgets to cover health expenses for themselves, a sick child, or another family member. For nearly 100 million individuals, these expenditures are substantial enough to plunge them into extreme poverty, forcing them to subsist on just $1.90 or less per day [3]. Globally, households face financial hardships due to out-of-pocket (OOP) health spending, with the most severe impact observed in low- and middle-income countries (LMICs) [4].

There are several ways to reduce healthcare costs and increase access to healthcare in developing countries. Healthcare entrepreneurship using local human resources, digital health technology, proper training, and necessary funds, and social business ideology can be a sustainable approach for affordable healthcare delivery in developing countries. Digital health technologies offer promising solutions to assist in increasing healthcare access while mitigating out-of-pocket (OOP) health expenditures [5], [6].

The objective of this study is to evaluate a digital health management system by considering the social and financial benefits towards increasing access to healthcare in developing countries.

The research questions addressed in this study are:

- What are the reasons behind inadequate healthcare access in developing countries?
- How can the proposed digital health system help increase access to healthcare?
- What are the social and financial benefits of the proposed digital health management system?

The study will focus on identifying the reasons behind insufficient healthcare access, the mechanisms through which digital health solutions can enhance accessibility, and the resulting social and financial benefits. Through this investigation, the study aims to contribute to the development of sustainable and effective healthcare strategies for developing countries.

II. Methods

To investigate the reasons behind inadequate healthcare access in developing countries, this study began with a review of secondary literature, focusing on Bangladesh as a representative case. This provided a foundational understanding of the contributing factors. The proposed digital health system was then introduced, highlighting its potential social benefits.

For the financial benefits, a cost-benefit analysis (CBA) was conducted from the patient's perspective. This involved a detailed analysis of cost items such as initial fees, subscription fees, time costs, and technology device costs. Assumptions included typical technology usage and internet access patterns.

The analysis involved identifying and documenting medical events within patients' ten-year histories and calculating associated costs, including direct medical expenses and indirect costs like time and lost productivity. Statistical methods were used to derive insights regarding the cost-benefit relationship of the proposed system.

All data collection and analysis were conducted with patient consent, and measures were implemented to safeguard sensitive information.

III. Reasons Behind Inadequate Healthcare Access

In developing countries, various factors contribute to inadequate healthcare access. Some key issues identified from the existing literature include:

A. Shortage of Medical Doctors

The shortage of healthcare professionals is a critical issue in many developing countries. This shortage leads to long waiting times, insufficient medical attention, medical errors, and overall reduced quality of care. For instance, Bangladesh has only 7 doctors per 10,000 patients as of 2021, whereas the WHO recommendation is 10 per 10,000 patients [7], [8]. The situation is even more concerning in rural areas, with only 1.1 doctors per 10,000 population, compared to 18.2 per 10,000 in urban areas [9].

B. Lack of Preventive Care

Bangladesh is experiencing a double burden of diseases, low service coverage, and a lack of preventive care [10]. Preventive healthcare services are often neglected due to insufficient resources and lack of awareness. This results in higher incidences of preventable diseases, which could be mitigated with proper preventive measures. The absence of routine check-ups, vaccinations, and early detection programs exacerbates health issues, leading to more severe health outcomes and higher treatment costs.

C. Excessive Healthcare Costs

High out-of-pocket healthcare expenses significantly impact households in developing countries. Out-of-pocket payments constitute the primary means of financing healthcare across much of Asia, where the proportion of OOP payments to total household healthcare expenditure ranges from 30 to 82% [11]. In Bangladesh, OOP health expenditures have surged multiple times over the past two decades, as depicted in Figure 1. The graph illustrates the trajectory of out-of-pocket health expenditure in Bangladesh from 2000 to 2020. During this period, expenditure has exhibited a consistent rise, starting from approximately 61.82% in 2000 to about 74% in 2020 [12]. This upward trend underscores an increasing burden on individuals to directly cover health-related expenses out of their own pockets over the years.

D. Lack of Digitization in Healthcare

The healthcare sector in many developing countries lacks digitization, which affects the efficiency and accessibility of healthcare services. According to survey in Bangaldesh on 104 physicians, only 4.81% use digital medical records [13]. Paper-based records, inadequate data management systems, and limited use of technology hinder the effective delivery of healthcare services. Digital health technologies have the potential to address these challenges by improving data management, reducing costs, and increasing accessibility.

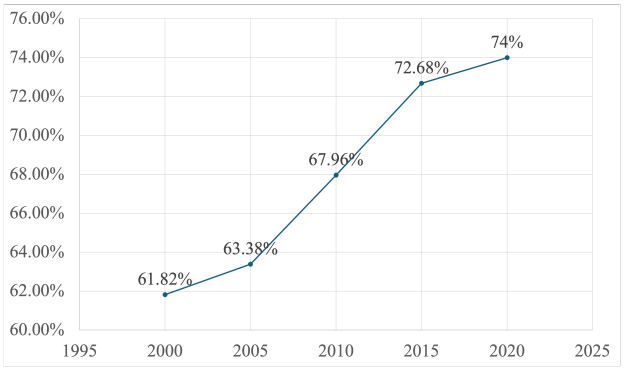

Fig. 1. Out-of-pocket health expenditure in Bangladesh from 2000 to 2020

E. Inadequate Infrastructure

Healthcare infrastructure in developing countries often falls short of meeting the population's needs. This includes a lack of medical facilities, poor transportation networks, and inadequate medical equipment. These deficiencies limit healthcare systems' ability to provide timely and effective care, particularly in rural and underserved areas. During the COVID-19 pandemic, the inadequacies of Bangladesh's healthcare infrastructure became evident. Three major issues were identified: (1) Poor governance and increased corruption, (2) Inadequate healthcare facilities, (3) Weak public health communication [14].

By addressing these multifaceted issues through targeted interventions and the implementation of digital health technologies, developing countries can improve healthcare accessibility and outcomes for their populations.

IV. Proposed Solution

This study introduces, the Smart Health Gantt Chart (SHGC), a digital health management system designed to collect, store, analyze, and visualize an individual's lifelong medical history. Both doctors and patients are the end users of this system. The SHGC system addresses healthcare accessibility issues in developing countries by granting patients full ownership of their data, which can be collected from various sources and integrated into a single platform for comprehensive management and visualization, as shown in Figure 2. An overview of the SHGC system is shown in Figure 3. The SHGC system enhances doctor productivity by providing quick access to a patient's complete medical history, facilitating efficient decision-making. Unlike current Electronic Health Records (EHR) and Electronic Medical Records (EMR), which are often fragmented and not easily shareable, the SHGC system integrates all health data—whether analog or digital—into a single, cloud-based chart. This allows for quick comprehension and easy sharing of patient information with any doctor globally, reducing medical costs, ensuring proper maintenance of health records, and decreasing medical errors [15].

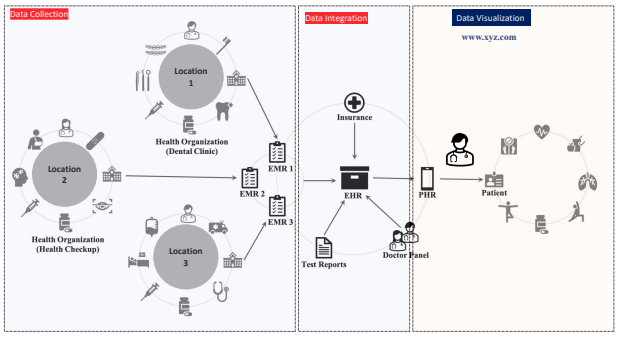

Fig. 2. System architecture of the Smart Health Gantt Chart System

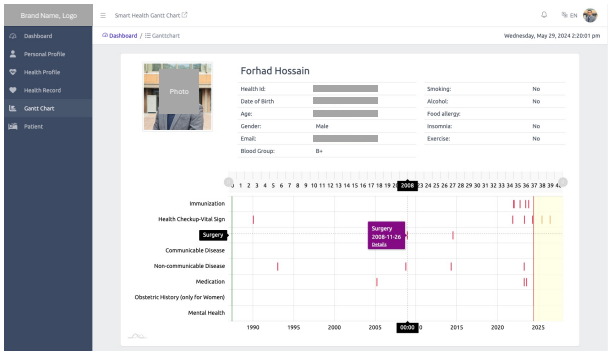

Fig. 3. Dashboard view of the Smart Health Gantt Chart System

The prototype of the system has been developed and tested with doctors and patients in Bangladesh. The system is now available online for limited use.

V. Evaluation of the System for Social and Financial Benefits

This section describes the evaluation of the SHGC system, focusing on its social and financial impacts. By examining the system's effectiveness in improving healthcare delivery and its potential to reduce medical costs, we aim to understand the broader benefits it offers. The evaluation includes an analysis of user feedback, cost savings, and overall improvements in healthcare quality. This comprehensive assessment will highlight how the SHGC system can contribute to both individual well-being and the healthcare system's efficiency, ultimately fostering better health outcomes and economic advantages.

A. Social Benefits of the Proposed System

To understand the limitations of past medical history taking and healthcare data management, we conducted a survey in Bangladesh with 104 physicians who have more than 2 years of experience and work in various healthcare organizations in both rural and urban areas. The survey found that 92.67% of the physicians face heavy workloads, with many working over 13 hours a day. Due to time constraints, 88.46% struggle with comprehensive medical histories, and only 4.81% use digital records due to inadequate tools. Additionally, 70% struggle with essential history-taking steps, and 81% find the lack of past medical history a significant obstacle. Statistical analysis shows that physicians' gender doesn't impact challenges ($p = 0.520$), but specialty area does, with certain disciplines facing fewer challenges (coef = -0.0406, $p = 0.006$). Work experience shows potential significance ($p = 0.076$), as does the number of patients per day ($p = 0.088$). Workload significantly increases challenges (coef = 0.6744, $p = 0.000$). Other factors like working hours, history-taking time per patient, and workplace efficiency are not significant. In summary, gender, work experience, and workplace support do not influence history-taking, while specialty and workload have the strongest influence.

The SHGC digital system offers many social benefits, particularly in addressing key issues related to inadequate healthcare access and healthcare data management as found in our survey. By leveraging advanced technology and centralized data management, the system aims to enhance healthcare delivery, improve patient outcomes, and promote health equity. Table I below outlines the key issues related to inadequate healthcare access in Bangladesh and illustrates how the SHGC digital system addresses these challenges to provide significant social benefits.

B. Financial Benefits of the Proposed System

This section presents a cost-benefit analysis of the Smart Health Gantt Chart (SHGC) system from the patient's perspective, detailing various cost items and potential benefits associated with using the SHGC platform for lifelong medical history management. The cost items include the initial fee, which is paid upon registration or setup of the SHGC system, and subscription or usage fees, which are recurring annual fees to maintain access to the system's services. Time costs account for the time patients spend managing their health events, calculated based on average wages. Training costs cover expenses related to training sessions and the time required for patients to learn how to use the SHGC system. Additionally, technology costs include the partial use of internet services and devices required for accessing the system. The benefits analyzed include redundant test avoidance, which results in cost savings from avoiding unnecessary medical tests. Hospitalization cost reduction and clinic visit reduction represent the savings from fewer hospitalizations and clinic visits facilitated by the SHGC system. Time savings are also considered, representing the reduced waiting times and quicker access to medical services provided by the system. Table II presents a detailed cost and benefit analysis based on a patient's 10-year medical history in Bangladesh, considering real-life health monitoring experiences, including two Shock Wave Lithotripsy (SWL) treatments and one Ureteroplasty surgery. This analysis highlights the significant financial benefits and cost savings that the SHGC system can provide to patients.

Each item lists its total cost over 10 years, adjusted for a 0.12% annual inflation rate, reflecting the average inflation rate in Bangladesh [16]. A sensitivity coefficient of 1.1 is applied to account for potential variations in cost estimates. Initial fees remain constant, while recurring costs like subscription

TABLE I
KEY ISSUES AND THE ROLE OF THE SHGC DIGITAL SYSTEM

Sl.	Key Issues Related to Inadequate Healthcare Access in Bangladesh	Role of the SHGC Digital System
1.	Shortage of Medical Doctors	Enables doctors to serve remotely, ensuring rural populations have access to quality healthcare. Saves doctors' time, allowing them to serve more patients. Enhances productivity by providing comprehensive patient history quickly, allowing efficient decision-making.
2.	Lack of Preventive Care	Collects, stores, and analyzes lifelong medical data, enabling future health risk prediction and promoting preventive measures.
3.	Excessive Healthcare Costs	Reduces costs by minimizing medical errors and avoiding unnecessary and repetitive tests through better data management and accessibility.
4.	Lack of Digitization in Healthcare	Centralizes all health data, both analog and digital, into a single, accessible digital platform. Patients manage their data independently and can share their healthcare information with any medical doctor, anywhere in the world, at any time.
5.	Inadequate Infrastructure	In remote areas, patients can access the system with the assistance of community healthcare workers.

TABLE II
COST-BENEFIT ANALYSIS OF THE SHGC SYSTEM COMPARED TO 10 YEARS OF MEDICAL HISTORY MANAGEMENT EXPERIENCE FOR A PATIENT

Costs (Patients' Perspective)	Yearly Cost in BDT										Total 10 Years	Sensitivity Coefficient (1.1)
	1	2	3	4	5	6	7	8	9	10		
Initial fee	1,000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,000.00	1,100.00
Subscription or Usage Fees	500.00	500.60	501.20	501.80	502.40	503.01	503.61	504.22	504.82	505.43	5,027.09	5,529.80
Time Costs (Yearly 15 health events, per health events 30 Minutes, 75 BDT per 30 minutes average wages, BDT. 75*15)	1,125.00	1,126.35	1,127.70	1,129.05	1,130.41	1,131.77	1,133.12	1,134.48	1,135.85	1,137.21	11,310.94	12,442.04
Training Costs (5 Hours, training, practice, trial, error fix etc.), BDT. 150*5	750.00	0.00	0.00	0.00	0.00	750.90	0.00	0.00	0.00	0.00	1,500.90	1,650.99
Technology Cost (Partially use of internet and device, 1:10 of total internet cost), BDT. 500/10	50.00	50.06	50.12	50.18	50.24	50.30	50.36	50.42	50.48	50.54	502.71	552.98
Total Cost											**19,341.64**	**21,275.80**
Benefits (Patients' Perspective)												
Redundant Test Avoidance (5 events * 2000)	10,000.00	10,012.00	10,024.01	10,036.04	10,048.09	10,060.14	10,072.22	10,084.30	10,096.40	10,108.52	100,541.73	110,595.90
Hospitalization Cost Reduction/Clinic Visit (Kidney stone surgery 1 time)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50,000.00	0.00	50,000.00	55,000.00
Time Savings (average waiting hours 2) per event, 15 health event, BDT. 150*30 hours	4,500.00	4,505.40	4,510.81	4,516.22	4,521.64	4,527.06	4,532.50	4,537.94	4,543.38	4,548.83	45,243.78	49,768.16
Total Benefits											**195,785.51**	**215,364.06**

fees, time costs, and technology costs increase slightly due to inflation. Training costs appear intermittently, reflecting specific events.

Significant cost savings are shown through redundant test avoidance and hospitalization cost reduction, adjusted for sensitivity. The sensitivity-adjusted totals provide a comprehensive view of the long-term costs and benefits, accounting for uncertainties. By applying a 10% increase to costs and benefits, the analysis evaluates the impact of variability in key parameters, aiding in risk assessment and decision-making.

The initial fee is a one-time expense of 1000 BDT in the first year. Training costs of 750 BDT are also a one-time expense, with potential additional costs if major technological changes occur. Subscription or usage fees start at 500 BDT in the first year, increasing to 505.43 BDT by the tenth year due to inflation. Time costs for attending health events start at 1125 BDT annually, reaching 1137.21 BDT by the tenth year. Technology costs start at 50 BDT in the first year, slightly increasing to 50.54 BDT by the tenth year.

The total cost over a decade is highest at 19,341.64 BDT. The cost-benefit analysis reveals significant potential for cost savings with SHGC. After sensitivity analysis, the total cost is 21,275.80 BDT, and the total benefit is 215,364.06 BDT. The cost reduction percentage can be calculated using the formula mentioned in equations (1) to (4).

$$\text{Cost Reduction Percentage} = \left(\frac{\text{Benefit} - \text{Total Cost}}{\text{Benefit}}\right) \times 100 \quad (1)$$

Substituting the given values into the formula, we get:

$$\text{Cost Reduction Percentage} = \left(\frac{215,364.06 - 21,275.80}{215,364.06}\right) \times 100 \quad (2)$$

$$\text{Cost Reduction Percentage} = \left(\frac{194,088.26}{215,364.06}\right) \times 100 \quad (3)$$

$$\text{Cost Reduction Percentage} \approx 90.96\% \quad (4)$$

This calculation indicates that the possible cost reduction is approximately 90.96%, demonstrating the substantial financial benefits of SHGC for patients.

VI. Discussion

The Smart Health Gantt Chart (SHGC) offers significant social and economic benefits by addressing doctor shortages, improving preventive care, reducing healthcare costs, and enhancing digitization. Economically, SHGC lowers out-of-pocket expenses by minimizing redundant tests and hospital visits. Accurate, accessible medical history prevents repeat tests, saving costs, while streamlined data management and timely health monitoring reduce hospitalization and clinic visits.

To address the research question (1): What are the reasons behind inadequate healthcare access in developing countries? The study identifies key factors such as the shortage of medical professionals, lack of preventive care, high healthcare costs, insufficient digitization, and inadequate infrastructure as major reasons for inadequate healthcare access in developing countries.

To address the research question (2) How can the proposed digital health system help increase access to healthcare? The SHGC system enhances healthcare access by allowing remote consultations, integrating comprehensive medical data for better preventive care, reducing redundant costs, and providing cloud-based solutions to overcome infrastructural deficiencies.

To address the research question (3) What are the social and financial benefits of the proposed digital health management system? The SHGC system offers significant social benefits by improving healthcare delivery, promoting health equity, and enhancing patient outcomes. Financially, it reduces overall healthcare costs by minimizing medical errors, avoiding redundant tests, and reducing hospitalization rates.

The limitations of this study include limited data adoption. We experimented with one patient's 10-year medical history and their experience with healthcare services to analyze cost benefits. Engaging more patients could provide more in-depth results. The SHGC fees used in this study are based on assumptions; in the future, real piloting by selling the services or conducting surveys to understand how much users are willing to pay may be necessary. To understand the social benefits, we conducted a survey with 104 physicians and 26 patients, but the sample group could be selected more scientifically to obtain more in-depth results. Future research can involve more in-depth analysis and include data from multiple patients over longer periods with specific cost and benefit amounts to understand the larger impact.

VII. Conclusion

This study highlights the potential of a digital health management system to achieve social and financial benefits, thereby increasing access to healthcare in developing countries. The social benefits indicate that this system can address key limitations in healthcare access, such as the shortage of doctors, lack of preventive care, high healthcare costs, and insufficient digitization. The financial benefits demonstrate how this system can significantly reduce healthcare costs for patients. The comprehensive cost-benefit analysis reveals that the implementation of SHGC can lead to a cost reduction of approximately 90.96%, demonstrating its effectiveness in reducing out-of-pocket healthcare expenditures. These findings underscore the importance of digital health technologies in enhancing healthcare accessibility, efficiency, and cost-effectiveness.

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Transforming School Health Services through Social Business: A Case Study in a Developing Country

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***Abstract*—This study investigates the implementation of a social business model for school-based healthcare programs in Bangladesh, focusing on feasibility, challenges, opportunities, and stakeholder perceptions. Through strategic partnerships, sustainable funding, and active engagement, the model effectively integrated comprehensive health services within schools. Challenges included logistical issues, technical difficulties, and stakeholder resistance, while opportunities highlighted improved student health outcomes, enhanced school reputation, and increased parent satisfaction. Among the stakeholders, 73.33% of students rated the health screening program as "Good", 50% of parents supported the inclusion of healthcare services in schools, and 40% of students were moderately interested in managing their lifelong medical history through a web-based application. These findings underscore the potential benefits and the importance of addressing challenges to enhance the effectiveness of school-based healthcare programs in developing countries.**

***Index Terms*—School Health, Preventive Healthcare, Developing Country, Portable Health Clinic, Uddog o Uddokta**

I. Introduction

In Bangladesh, annual school health checkups are often neglected despite funds allocated for other activities. Challenges include inadequate funding, infrastructure, and healthcare personnel. However, private and urban schools invest in various activities, and parents are willing to pay. Raising awareness about preventive healthcare could make annual checkups more feasible. There is a serious misconception that teenagers and young people do not need health monitoring, though they are at risk for various health issues. Adolescents and young people are indeed at risk for various health issues. The rising rate of overweight and obesity among youth is a growing concern, with the prevalence of overweight children and adolescents tripling since 1980, and the severity of obesity increasing over the past decade [1] [2]. Complications associated with youth overweight and obesity are well-documented, including metabolic health risks, chronic diseases, psychosocial problems, and an increased risk of cardiovascular diseases in adulthood [3] [4] [5]. Overweight and obese young people are at risk of developing health-compromising behaviors that may compound medical and social problems associated with excess weight [6]. In 2021, over 1.5 million adolescents and young adults aged 10–24 years died, averaging about 4,500 deaths per day. Mental health disorders often begin by age 14, yet most cases go undetected and untreated. Early substance use is linked to higher risks of dependence and other issues in adulthood, disproportionately affecting younger individuals [7]. Approximately 60% of all deaths in this age group are due to infectious diseases and nearly half of these deaths are due to diarrheal diseases and pneumonia [8]. Through annual health screenings and regular health monitoring, many health risks can be avoided. This is a common practice in developed countries, where annual compulsory health checks for all students are the norm. For example, in Japan, parents from seven local municipalities with 49 junior-high schools (N = 4,081) were invited to answer a survey. The results showed that 63.1% believed the health reports improved attention toward child health, and over 80% agreed to use health records for health promotion and disease prevention [9].

Towards the establishment of school-based annual health checkups and regular health monitoring, this study presents a case where a social business model is adopted to run these services for educational institutes in Bangladesh. The objective of the study is to evaluate the feasibility and effectiveness of implementing a social business approach to enhance school health services.

The research questions are:

- How can social business model be effectively implemented in school-based healthcare programs in Bangladesh?
- What are the challenges and opportunities associated towards implementing school health services?
- How do stakeholders (students, parents, teachers) perceive and respond to the introduction of school-based health checkups and monitoring?

Addressing these health risks through school-based preventive healthcare programs is crucial for the well-being of young people in developing countries.

II. Methodology

This research employs a case study approach to demonstrate the implementation and impact of a social business

model aimed at transforming school-based health services in Bangladesh. The methodology is divided into three main phases: conceptual model development, implementation of the health checkup program, and evaluation through stakeholder surveys.

A. Conceptual Model Development

The first phase involved the development of a conceptual model for a social business designed to provide sustainable school-based health services. This model was tailored to the specific needs and constraints of educational institutions in Bangladesh, considering factors such as funding, infrastructure, and local healthcare resources. Key components of the model include:

Funding Mechanism: Identification of potential revenue streams and funding sources, including partnerships with local businesses, NGOs, and government agencies.

Service Delivery Framework: Design of a comprehensive health checkup program encompassing physical examinations, mental health assessments, and preventive care education.

Stakeholder Engagement: Strategies for engaging students, parents, teachers, and healthcare providers in the program to ensure buy-in and active participation.

B. Implementation of the Health Checkup Program

The second phase involved the practical implementation of the health checkup program in a selected school in Bangladesh. This included: **Selection of the School:** Choosing a school that represents typical conditions in urban to ensure the generalizability of the findings.

Program Execution: Conducting comprehensive health checkups for the students, facilitated by trained healthcare professionals. The checkups included physical health assessments, mental health screenings, and health education sessions.

Data Collection: Recording health data for each student to create individual health profiles and aggregate health statistics for the school.

C. Evaluation Through Stakeholder Surveys

The third phase focused on evaluating the impact of the health checkup program through surveys distributed to key stakeholders:

Survey Design: Developed four questionnaires targeting school administration, school staff, students, and guardians. The surveys covered areas such as awareness of health issues, perceived benefits of the health checkup program, and willingness to support ongoing health monitoring.

Data Collection: Administered the surveys to stakeholders immediately following the health checkup program. A total of 30 participants took part in the survey, including 1 school administrator, 5 school staff members, 15 students, and 9 guardians.

Data Analysis: Analyzed the survey responses using both statistical methods and qualitative analysis techniques to identify trends, patterns, and significant findings. The quantitative analysis focused on measuring the program's effectiveness in improving health awareness and promoting preventive care behaviors, while the qualitative analysis provided deeper insights into stakeholder perceptions and experiences.

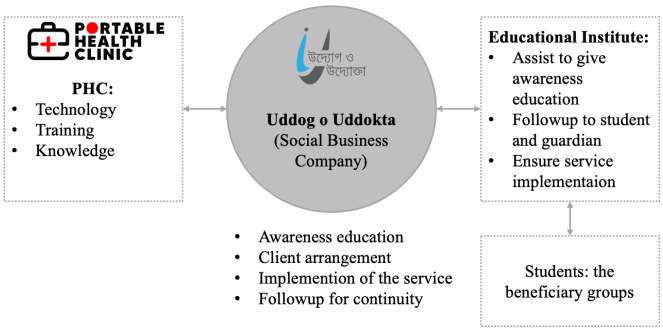

Fig. 1. Our approach in social business model for school health transformation

III. Our Approach: Social Business to Increase Access to Preventive Healthcare

A. Overview of Social Business:

Social business, as defined by Nobel Peace Prize laureate Professor Muhammad Yunus, represents a transformative approach to addressing social issues through business practices. In his books, Yunus describes a social business as one that is created and designed to solve a specific social problem, functioning as a non-loss, non-dividend company. This means that the business is financially self-sustainable, with any profits being reinvested into the business itself to expand its reach, improve its products or services, or support other social businesses. Unlike profit-maximizing businesses, the primary goal of a social business is not to maximize profits for shareholders but to generate positive social impact. Furthermore, unlike non-profits that rely on donations and grants, social businesses sustain themselves through their operations, ensuring ongoing and scalable impact. Yunus emphasizes that while traditional charity funds are spent once, funds invested in social businesses are recycled indefinitely, enhancing the business's ability to address social issues continuously. Philosophically, social business integrates the dual human motives of selfishness and selflessness, seeking profits not for personal gain but to serve societal needs [10] [11] [12].

B. Our Approach:

By following the social business concept, an approach was conceptualized to transform school health services in Bangladesh. Figure 1 shows the conceptual model. To implement the service, "Uddog o Uddokta" functions as a social business company. It collaborates with another company that provides the technology for digital healthcare services and maintains patient healthcare data in the cloud. This partnering company offers technology, trained healthcare workers, and knowledge support.

"Uddog o Uddokta" focuses on raising awareness about this service and attracting clients to utilize it. Once client service

requirements are gathered, they are designed and shared with the partnering company that owns the digital health system, the Portable Health Clinic [13] [14] [15]. The implementing company coordinates with the partnering company to ensure smooth service delivery and, on the other hand, assists the client organizations (schools) by helping them design funding strategies and educating their students and parents about the healthcare services.

C. Role of Social Business and Technology

To increase access to healthcare services in all types of educational institutes in Bangladesh, it is essential to make the process easy and affordable. The integration of a digital health system will facilitate this goal. Through a digital health system, doctors and mental health counselors can join remotely, reducing travel costs and overall expenses. Data can be easily accessible and manageable through this system, allowing for the maintenance of lifelong medical histories for students [16] [17].

The social business ideology ensures that the business focus is on creating a larger social impact rather than profit maximization. Owners of "Uddog o Uddokta" will not take any dividends from the business profits. Instead, the profits will be reinvested to provide similar healthcare services to other educational institutes. Additionally, the pricing of the services will be determined by calculating a nominal profit margin, sufficient only for organizational sustainability. This approach ensures that the services remain affordable while maintaining the financial health of the organization.

IV. Case Study

A. Overview of the Service

After developing the conceptual business model, Uddog o Uddokta took the initiative to implement the service. The first service was implemented on April 28, 2024, at The Radius International School, Dhaka, Bangladesh, a private school in an urban area. Following several discussions with school administrators and guardians, the service was introduced. The service included a total of 17 items, including telemedicine doctor consultations, mental health screening and counseling, and health data management. Guardians paid for the cost of these services. Not all students and staff participated in the health checkup; the numbers are shown in Table I. It was not compulsory to attend the health checkup. The importance of preventive health checkups was explained to all students and staff, and they were allowed to decide on their own whether to participate. The package price was very nominal at BDT 1500 (approximately USD 13).

Among the 73 people who did not attend the health checkup, 42 did not provide a reason for their absence. The remaining 31 individuals cited various reasons for not participating, which are stated in Table II.

B. Findings from the Interview with the Administrator

Following the health checkups, an interview was conducted with the head of the institution to gather insights through a survey. The administrator highlighted several key points. Firstly, the motivation for adopting the healthcare service was primarily due to its alignment with the school's values. However, the major challenges faced included resistance from both staff and guardians/students. To ensure active participation in future health screening initiatives, the administrator noted that making participation mandatory would be necessary. Regarding support from the service providers, the administrator expressed a need for more services to be included in the health checkup package to enhance its effectiveness. The administrator also identified multiple ways in which the health screening service adds value to the school. These benefits include improved student health and well-being, enhanced school reputation and credibility, increased parent and guardian satisfaction, and the early detection and prevention of health issues.

TABLE I
Ratio of attendance in health checkups

Groups	Total	Attended in Health Checkup	Not Attended in Health Checkup
Teachers	24	6	18
Admin/Other Staffs	5	5	0
Male Students	40	13	27
Female Students	39	11	28
Total	**108**	**35 (32.41%)**	**73 (67.59%)**

TABLE II
Reasons for Not Joining the Health Checkups and Number of People

Sl.	Reasons	Number of People
1	Age is too low (3.5 years)	2
2	Has own diagnostic Center/ Hospital	6
3	Has regular Doctor	1
4	Recently finished check-up	5
5	Has Special Health Issue	3
6	Does regular check-up with personal doctor	6
7	Student Fears	3
8	Exam Running	5

C. Findings from the Interview with Staffs

There were 18 staff members in total, including faculty members, and 10 participated in the survey. They were asked, "How do you perceive the importance of health screening programs for student well-being?" The graph in Figure 2 illustrates the perception among respondents, categorized into five levels: Very Important, Important, Somewhat Important, Not Important, and Not Sure. The results show that 80% of respondents consider health screening programs very important, 10% find them important, and another 10% believe they are not important. No respondents rated the programs as somewhat important or expressed uncertainty, indicating a strong consensus on the importance of these programs.

Regarding enhancing the program to better meet the needs of students and staff, the responses were as follows: 43.75% of respondents suggested more awareness campaigns, 12.5% advocated for longer preparation time, 6.25% mentioned im-

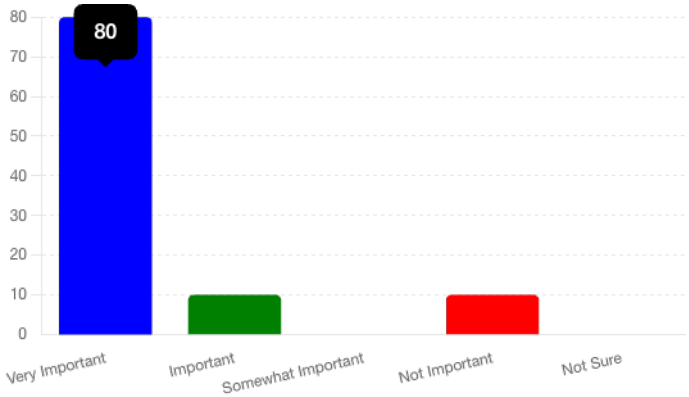

Fig. 2. Perception about the importance of health screening

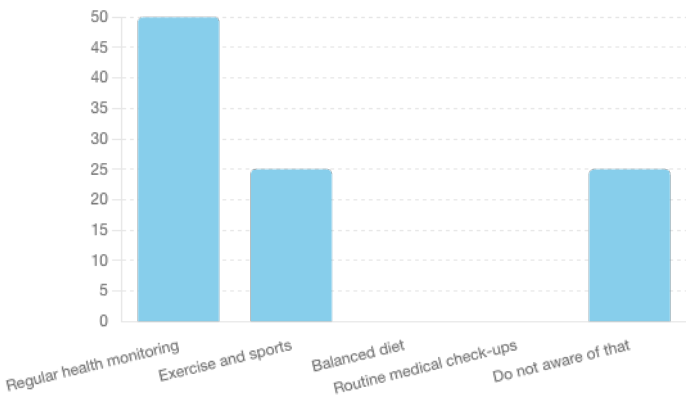

Fig. 3. Preventive healthcare practices in family

proved service quality, and 37.5% highlighted the need for better resources and equipment.

When asked about challenges associated with program implementation, 42.86% of respondents identified limited funding and resources, while 57.14% noted resistance from guardians or students.

D. Findings from the Interview with Guardians

In total, only four guardians participated in the survey responses. All respondents (100%) agreed that they would allow their children to attend health check-ups, recognizing the importance of health management. When asked, "How do you feel about the inclusion of healthcare services within the school environment?" responses were evenly split, with 50% being supportive and 50% remaining neutral.

As illustrated in Figure 3, the graph shows how respondents maintain preventive healthcare practices within their families, revealing a varied distribution of methods. A significant 50% of respondents rely on regular health monitoring as their primary preventive measure. Exercise and sports are practiced by 25% of the respondents, indicating a moderate level of physical activity for health maintenance. Interestingly, none of the respondents reported maintaining a balanced diet or engaging in routine medical check-ups, highlighting a gap in these critical areas of preventive care. Additionally, 25% of the respondents are not aware of any preventive healthcare practices, underscoring the need for increased awareness and education on maintaining health through proactive measures.

E. Findings from the Interview with Students

Among the students, 15 responded to the survey. It appears that they are not fully comfortable with the school health check-up program, as this is a new concept for them, and most of them are not aware of health screening and preventive healthcare. For future health check-ups, they suggested shorter wait times, more comfortable facilities, and clear instructions.

For the question about rating the overall experience of the health screening program, the majority of respondents (73.33%) rated it as "Good," while 18.75% found it "Fair," and only 20% rated it as "Excellent". No respondents rated

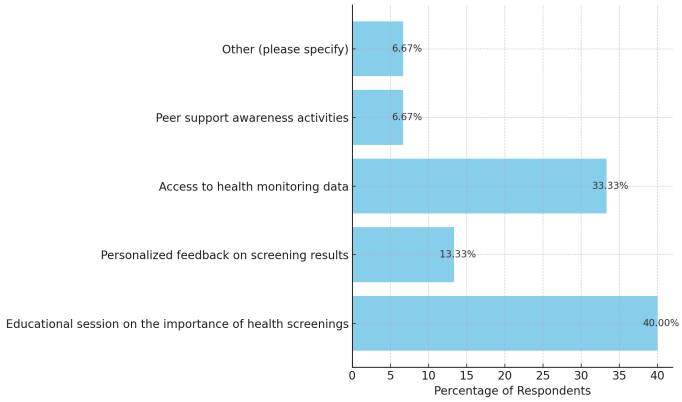

Fig. 4. Preferred approaches to understand preventive healthcare practices

the experience as "Poor" or "Very Poor", indicating general satisfaction with the program.

Regarding interest in managing lifelong medical history through a web-based application, responses varied: 40% were "Moderately interested," 26.67% were "Slightly interested," 20% were "Not at all interested," and 13.33% were "Very interested". No respondents expressed being "Extremely interested", suggesting a moderate level of interest overall, with some resistance or lack of enthusiasm towards digital health management tools.

When asked about preferred approaches to better understand the importance of preventive healthcare practices and health screenings, 40% of respondents favored "Educational sessions on the importance of health screenings," indicating a preference for informational and educational methods. "Access to health monitoring data" was preferred by 33.33%, reflecting a desire for data-driven insights. Personalized feedback on screening results was selected by 13.33%, while 6.67% each preferred "Peer support awareness activities" and other unspecified methods, highlighting a diverse range of preferences for understanding and engaging with preventive healthcare practices. The responses are shown in Figure 4.

V. Discussion

This study explores the implementation of a social business model for school-based healthcare programs in Bangladesh, focusing on feasibility, challenges, opportunities, and stakeholder perceptions. Findings indicate that such a model can effectively integrate healthcare services within schools through strategic partnerships, sustainable funding, and active stakeholder engagement.

Effective Implementation: Strategic partnerships with technology providers, sustainable funding via nominal guardian fees, and awareness campaigns emerged as critical factors for effective implementation.

Challenges and Opportunities: Identified challenges include staff and guardian resistance, logistical issues, and technical difficulties. However, opportunities such as improved student health outcomes, enhanced school reputation, and increased parent satisfaction were also noted.

Stakeholder Perceptions: Stakeholders generally held positive perceptions, with students mostly satisfied but suggesting areas for improvement. Parents unanimously supported health check-ups, although opinions on integrating these services into schools varied. Teachers acknowledged the importance of health screenings for student well-being.

In summary, this research underscores the feasibility and benefits of implementing school-based healthcare programs through a social business model. It also identifies opportunities for improving stakeholder engagement and logistical coordination.

VI. Conclusion

The implementation of a social business model for school-based healthcare services in Bangladesh has shown promising results, demonstrating its potential to improve student health outcomes and enhance the credibility of educational institutions. Despite challenges such as stakeholder resistance, the findings emphasize the importance of stakeholder engagement, awareness programs, and sustainable funding mechanisms. Future initiatives should address these challenges, enhance awareness and education on preventive healthcare, and explore scalable models for various educational settings. By leveraging technology and fostering health awareness, schools can significantly contribute to better health outcomes and quality of life for young people in developing countries.

Acknowledgment

Expressing gratitude to The Radius International School, Bangladesh, SocialTech Lab, Kyushu University, Japan, and Uddog o Uddokta, Bangladesh, for their cooperation in conducting the health screening program and their assistance in this study.

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Feasibility of LLM based Generative AI for Transformation of the UI/UX of mHealth applications

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***Abstract*—This exploratory study investigates the feasibility of using LLM-based generative AI to redesign a mobile e-health application interface for an aging population. ChatGPT and DALL-E were used with prompt engineering to recreate a single screen from a popular medication reminder application. To evaluate the redesigned UI's effectiveness, we conducted heuristic evaluations with five UI/UX designers with experience in healthcare IT UI design. The results indicate that the designs were well received and aligned with heuristic principles, and the introduction of generative AI in the UI design workflow can help overcome important challenges in the healthcare IT UI design process.**

Index Terms*—*user interface design, mobile health applications, aging population, heuristic evaluation, ChatGPT, DALL-E, usability engineering, UI/UX Design, e-health, digital health technology, human-computer interaction, design co-creation, medication reminder application

I. Introduction

The increased use of mobile phones has led to the widespread adoption of mobile healthcare applications, commonly referred to as "mHealth" applications. These applications can have a significant impact on the health of older adults – applications such as Vivifrail have demonstrated great advantages in the health of the elderly by improving adherence to exercise regimens [1]. Numerous studies and global statistics have indicated that the percentage of the elderly population is rapidly increasing worldwide, particularly in developed countries where the use of mobile phones is prevalent [2]. The oldest segment of the elderly population is growing at the fastest rate, with an eleven-fold increase observed between 1900 and 1994, compared to a three-fold increase in the non-elderly population during the same period [3].

These applications offer significant advantages to elderly users, who often require self-monitoring of health. mHealth applications can provide timely interventions and positively impact health outcomes [4]. However, mobile phone user interfaces are designed primarily for younger populations [5]. Enhancing the usability of mHealth applications for the elderly necessitates the application of Human-Computer Interaction (HCI) principles in a context-dependent manner. UI / UX tailored for the elderly can increase adherence, such as in the case of Vivifrail indirectly having an impact on the health of the elderly. Despite all of the advantages, time and budget constraints often hinder companies from prioritizing these adaptations due to the extensive user testing required and the difficulty in application of HCI principles tailored to context [6].

Nielsen's heuristics can enhance usability for the elderly, but their generic nature and wide interpretation make research on their application time-consuming. Leveraging large language model (LLM)-based generative AI offers a potential solution to this challenge. Introducing generative AI to help develop adaptive user experiences shows promise [7]. Investigating whether LLM-based generative AI can bridge the budget and time gap through an adaptive framework diverges from previous research that focuses only on singular avenues such as introduction of AI agents into the creative design process or on UI design for the elderly rather than the combined problem. This framework could assist UI/UX designers in applying established HCI principles to design mHealth applications that are more suitable for elderly users.

The paper is structured as follows: In section 2 a description of Nielsen's heuristic and the applicability of the heuristic evaluation for this study is presented. In Section 3 a prompt engineering technique is explained. In Section 4 the results are reported, and Section 5 is a conclusion.

II. NIELSEN'S HEURISTICS

A. Heuristic evaluation of user interfaces

Heuristic evaluation is a method for assessing user interfaces where evaluators review a UI design and provide feedback. While a single evaluator can conduct the assessment, results indicate that a single evaluator identifies only a limited number of issues. It is recommended to use multiple evaluators, with three to five being sufficient to yield robust results, as additional evaluators beyond ten do not significantly improve outcomes [8]. Given that multiple evaluators can detect interface errors with an accuracy of 55% to 90% (depending on the number of evaluators), we selected heuristic evaluation to assess designs produced by generative artificial intelligence. For this method to be effective, the heuristics must be simplified to enable practical evaluation [8]. Thus, we chose Nielsen's heuristics, aligning with well-established research. For this study, we utilized the latest set of heuristics published in 2005

[9]. The heuristics are detailed in the following table, tailored to the use case of a medication reminder application for the elderly. We used the **myTherapy** application, a popular medication reminder app, as our reference mHealth application. The focus of our redesign was solely on the home screen, applying the selected heuristics to enhance usability for elderly users .

TABLE I
NIELSEN'S HEURISTICS

Heuristic principle	Implementation description
Visibility of system status	The system should identify to the user its status and condition.
Match between system and real world	Linguistics are important, the system should speak to the user using a language that they are familiar with. A previous paper has identified this as an important characteristic for the elderly.
User control and freedom	Platform conventions should be followed so that users spend less time figuring out actions. In the case of the elderly, it is beneficial to see what actions they are familiar with already.
Consistency and Standards	Accessibility and usability standards need to be followed.
Error prevention	It becomes important to prevent errors when it comes to elderly users.
Flexibility and efficiency of use	Shortcuts for expert users that speeds up interactions between the user and the system.
Aesthetic and minimalist design	The design should only contain relevant information. Any extra information may cause difficulties for the user.
Recognition rather than recall	The user should be able to recognize patterns and the cognitive load should be lowered.
Help users recognize, diagnose, and recover from errors	Error messages should be understandable to the user. The message should identify the problem and suggest an appropriate solution.
Help and documentation	There should be enough help and documentation and should be appropriately explained so that it can be implemented.

III. PROMPT ENGINEERING

Prompt engineering involves developing and optimizing prompts for large language models to achieve desired outcomes. As a relatively new field, it is rapidly gaining traction with the widespread adoption of generative AI [10]. Prompt engineering includes systematic methods, but extensive exploratory research is still ongoing. In this study, we initially adopted an exploratory approach, repeating it multiple times to identify effective methods and ensure consistent results. From this exploratory phase, we theorized a model with specific assumptions and aims, as illustrated in the figure [Fig.1].

A. Prompt Chaining

Prompt chaining involves using the output of one LLM as the input for another, enhancing knowledge aggregation [11]. Given the complexity of optimizing prompts, we employed LLMs to streamline the prompt optimization process for DALL-E, the image generation LLM used in the final step of our study.

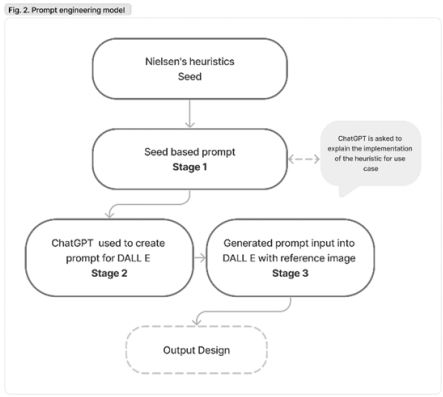

Fig. 1. Proposed prompt engineering model

B. Prompt Engineering Theory

Two approaches based on prompt engineering theory were employed, using ChatGPT 3.5 and ChatGPT 4. In the first experiment, we prompted ChatGPT 3.5 ten times to describe each heuristic for our use case in the first stage, then generated a prompt for DALL-E in the second stage. The third stage involved prompting DALL-E with the output from ChatGPT 3.5, with minor optimizations. This experiment was repeated twice, following a structured method for the first stage prompt. In the second experiment, a different prompt engineer used ChatGPT 4, limiting iterations to two and allowing independent prompting without a structured form in the first stage. The summary is provided in table 2.

In the first variation of the experiment, we modeled the prompt in the form of an equation during the first stage to systematize the process and evaluate its effectiveness compared to freestyle prompting.

$$D + H + C = p$$

In the first experiment, the prompt was structured as an equation: $D(H, C) = p$, where D represents keywords (e.g., describe, detail, explain), H is the heuristic, C is the contextual object, and p is the resulting prompt. This structured method was compared to the freestyle approach used in the second experiment.

The results from each stage are too lengthy to include in full. Instead, we provide an overview and a single example from the first experiment. In the first stage, ChatGPT 3.5 expanded on each heuristic within the established context. For example, for the heuristic 'Match between System and Real World,' ChatGPT 3.5 suggested: "Design the application with familiar terminology and visual metaphors that align with the real-world experiences of elderly users. For instance, use imagery of pill bottles or medical symbols to represent medication reminders, making it easier for users to understand

TABLE II
SUMMARY OF INPUT PROMPT ENGINEERING EXPERIMENTS

Experiment	Stage	Prompt	Model
Variation 1	1	Can you describe the usability principle of match between system and the real world in the context of UI design for a mobile application for elderly users?	GPT 3.5
	2	Design a prompt for DALL E to redesign a UI in dark mode for a medication reminder application for which I will provide a reference image.	GPT 3.5
Variation 2	1	Read the following UI/UX Usability principle and explain them in context for healthcare application: (Description of Nielsen's heuristics is followed)	GPT 4
	2	Based on your previous response, help me create a DALLE text-prompt for enhancing the design of 'myTherapy,' a mobile health app for elderly users. The design should follow all principles you described previously, making navigation intuitive and feedback clear. NOTE: "I need a descriptive user prompt only. Must cover entire description written in your previous response."	GPT 4

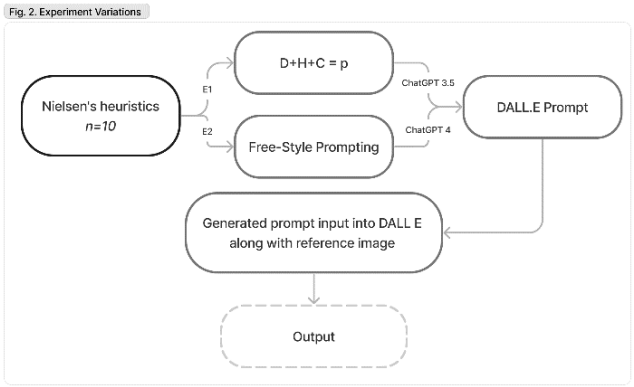

Fig. 2. Proposed prompt engineering model

the application's purpose and function." This output served as the input for the second stage, which was then summarized into a single prompt for DALL-E in the third stage. The results from the second variation were like the first, showing consistency in the outcomes, with minor differences in UI element placement.

IV. OUR APPROACH

Through post-analysis of common industry prompt engineering approaches, we identified the methods used in our experiments. We summarized the results in the following table, providing justifications for each approach. The methods were consistent across both variations of the experiment and were classified according to the input and output stages.

TABLE III
PROMPT ENGINEERING MODEL

Stage	Prompt method	Reasoning
Input	Few shot prompt	A basic guideline to refer to is provide
Input	Directional stimulus prompting	A specific output is demanded from ChatGPT (to create a prompt for DALL-E).
Output	Zero shot prompt	DALL-E does not have any knowledge or reference of a UI that has been designed previously in this context.
Overall	Chain of thought prompting	The prompting was done via a particular thought process

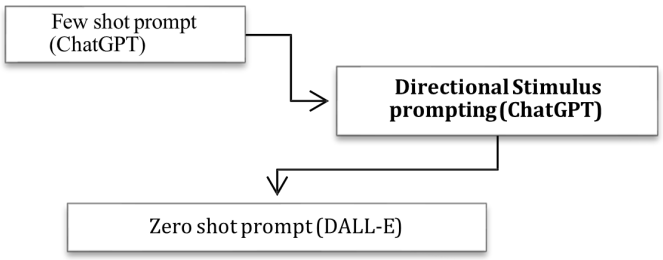

Fig. 3. Prompt engineering model abstraction

V. RESULTS AND OBSERVATIONS

To evaluate the images generated by DALL-E, we performed a heuristic evaluation with five evaluators ($n = 5$) with 2-20 years of experience in UI / UX design, including HCI researchers and professional designers, all of whom had extensive experience in the design of UI of healthcare IT applications. The reviewers independently conducted their evaluations without communication with each other.

A. DALL-E output

As a result of the output from the prompt engineering model, a total of three designs were produced.

Fig. 4. Example of the output from the prompt engineering model from the first variation

Fig. 5. Example of the results from the second variation of the experiment

Heuristic principle	Satisfaction		Comments
	Low	*High*	
Visibility of system status	☐	☑	Multiple indicators for each medication
Match between system and real world	☑	☐	Monotone theme doesn't bring any resemblance to realworld
User control and freedom	☑	☐	Little control for the user, user has fixed options
Consistency and Standards	☐	☑	bottom nav bar is non-standard, however rest of the UI has good contrast and large button touch areas
Error prevention	☑	☐	Very little error prevention mechanisms
Recognition rather than recall	☑	☐	Non standard UI elements it difficult to rely on recognition
Flexibility and efficiency of use	☑	☐	Very few flexible options
Aesthetic and minimalist design	☐	☑	Aesthetic color scheme and minimal design elements
Help users recognize, diagnose, recover from errors	☐	☑	Many help buttons in quick access
Help and documentation	☐	☑	Documentation each to access across multiple pages

Fig. 7. Evaluator's feedback form

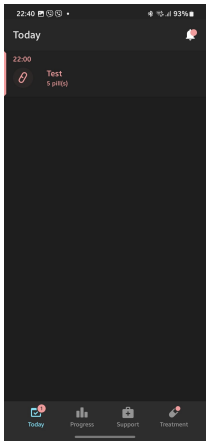

Fig. 6. The original reference image from the myTherapy application

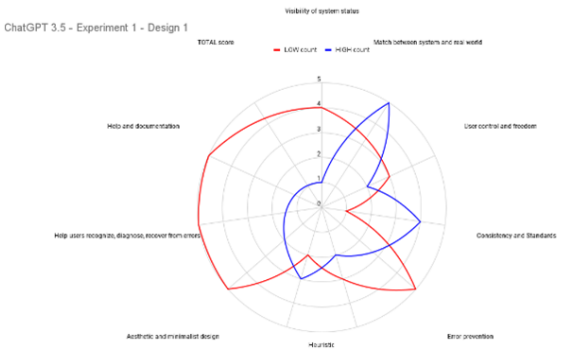

Fig. 8. Results from the heuristics evaluation of Experiment 1 – Design 1 using ChatGPT 3.5

B. Results of heuristic evaluation

The heuristic evaluation used a questionnaire for each design, with evaluators rating their satisfaction on a dichotomous scale: 0 for 'Low' and 1 for 'High', due to its higher reliability [12]. Furthermore, a Likert scale question (1-5) assessed the similarity of the designs of the independent experiments. Evaluators also provided a binary answer and comments on whether this process could aid UI design of mHealth applications for the elderly, addressing time and budget constraints.

Evaluators rated three designs from each experiment variation, providing comments for each heuristic. They were informed that the designs were generated by AI and intended as low-fidelity guidelines, similar to paper prototyping, for the final UI design. Detailed instructions emphasized considering this aspect during the evaluation.

ChatGPT-4 outperformed ChatGPT-3.5 in the evaluation results. Experiment 2 scored higher than Experiment 1, indicating that freestyle prompting for the stage 1 input is superior to a structured approach. Experiment 2 received 37 'High'

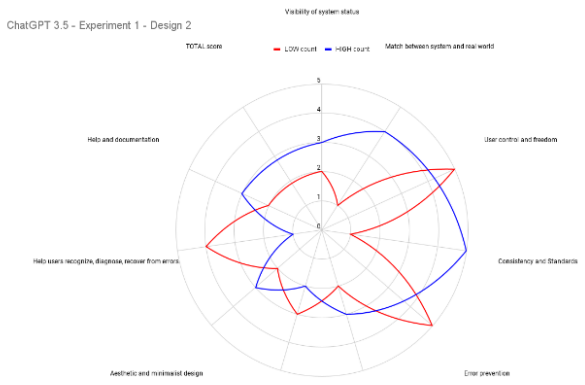

Fig. 9. Results from the heuristics evaluation of Experiment 1 – Design 2 using ChatGPT 3.5

Fig. 10. Results from the heuristics evaluation of Experiment 2 – Design 1 using ChatGPT 4

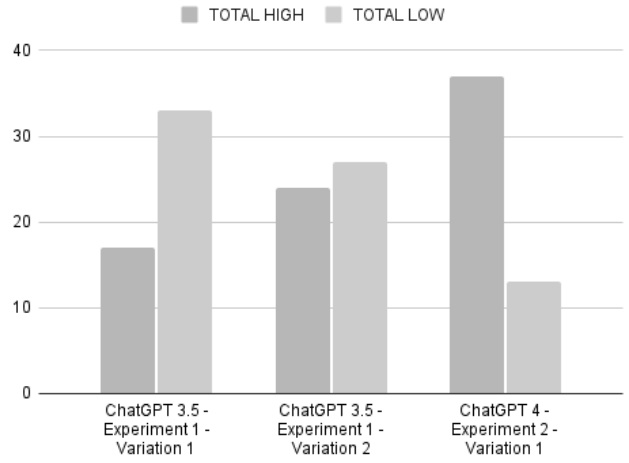

Fig. 11. Overall results compared across experiments

ratings versus 13 'Low' ratings, indicating strong compliance with heuristics. In contrast, the first design of Experiment 1 received only 17 'high' ratings versus 33 'low' ratings, while the second design had 24 'high' and 27 'low' ratings, still below the performance of Experiment 2. The average similarity score across all experiments was 2.4, indicating moderate similarity.

All evaluators (100%) agreed that this process can save time when designing a UI for elderly mobile users. Common themes from feedback included 'starting point', 'initial design', 'basic UI structure', and 'initial idea', suggesting that this approach can expedite the design process and support design co-creation with LLMs.

VI. Conclusion

Evidence suggests that using prompt engineering with LLMs can expedite the UI co-creation process for challenging use cases, such as the one in this study. This domain merits further research and collaboration between industry and academia to enhance usability engineering using generative AI in mHealth technology for the elderly. Limitations of this study included the scope of the assessment of the feasibility to only one screen of a popular mHealth application and the heuristic evaluation being conducted of low fidelity wireframes. Future research is recommended to expand the scope of the study to include feedback from not only UI designers and researchers but also end users using a technology evaluation model such as TAM by using the converted low-fidelity wireframes created by generative AI into functional prototypes. This will provide deeper evaluation into the capabilities of generative AI to create effective UI design for mHealth applications.

VII. Acknowledgements

The authors acknowledge and thank the myTherapy application for providing permission to use the application in this research. We also wish to thank the evaluators for taking their time in helping with this research. ChatGPT 4o was used for language improvement.

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Understanding the Reach of Telemedicine: Awareness and Usage Among Bangladesh's Rural and Urban Populations

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***Abstract*—This study investigates the awareness, usage patterns, and perceptions of telemedicine services among rural (Gopalganj) and urban (Dhaka) populations in Bangladesh. A survey of 75 respondents revealed that 44% were aware of telemedicine, primarily through the internet and healthcare providers, but only 20% had used it. Barriers to adoption included lack of awareness, preference for in-person visits, privacy concerns, and lack of necessary technology. While 64% indicated a likelihood of using telemedicine in the future, concerns about quality, privacy, and technology reliability remain. The study highlights the need for targeted awareness campaigns, educational initiatives, and technological improvements to enhance telemedicine adoption and effectiveness in Bangladesh.**

***Index Terms*—Telemedicine, Telemedicine in Bangladesh, Developing Country, Digital Health**

I. Introduction

Bangladesh, a densely populated and developing country, faces significant challenges in its healthcare system. There is a severe shortage of doctors relative to the demands of both rural and urban patients. According to the World Health Organization (WHO), Bangladesh has only 7 doctors per 10,000 patients as of 2021, whereas the WHO recommendation is 10 per 10,000 patients [1], [2]. The situation is even more concerning in rural areas, with only 1.1 doctors per 10,000 population, compared to 18.2 per 10,000 in urban areas [3].

In rural areas, many people face difficulties in visiting certified physicians due to the unavailability of doctors, high consultation fees, transportation costs, and other issues. This often pushes them to consult untrained and unqualified village doctors or pharmacists, who are not licensed to provide necessary medical advice. This practice often results in the consumption of unexamined and potentially harmful medications, gradually diminishing the population's immune strength. According to Mahmood et al., around 44% of villagers suffered from an illness during the 14 days preceding their survey, and of these, 47% sought treatment for their ailment. A significant 65% of patients consulted village doctors, with village doctors being the first line of care for 67% of patients. In contrast, consultation with MBBS doctors was low at 14% [4]. This highlights the heavy reliance on non-licensed village doctors in rural areas. While village doctors can serve as a first line of care for primary health screening or basic advice, they often practice beyond their qualifications, and people in rural areas are predominantly dependent on them.

To address the shortage of healthcare workers and accelerate the provision of quality healthcare services, digital health interventions have made significant improvements. Telemedicine, the practice of providing medical treatment through certified doctors using the internet, mobile phones, and other electronic devices, offers a promising solution to these healthcare challenges. Telemedicine can reach unreached communities in an affordable manner, providing quality healthcare services. Additionally, by aligning with digital health management, we can ensure preventive healthcare for the population [5]–[7].

Telemedicine services have existed for a long time but were not effective or widely used [8], [9]. The COVID-19 pandemic caused a seismic shift in the healthcare delivery system, accelerating the adoption of digital health solutions at record speed and putting telemedicine (i.e., telehealth) at center stage. Amid the highly contagious COVID-19, telemedicine transitioned from being an optional service to an essential one [10].

If effectively promoted and adopted, telemedicine has the potential to revolutionize healthcare in Bangladesh. The primary objective of this study is to investigate the awareness and usage of telemedicine services in rural and urban areas of Bangladesh, aiming to understand the barriers and opportunities for broader adoption. The specific objectives are:

- To assess the level of awareness of telemedicine services among rural and urban populations in Bangladesh.
- To evaluate the usage patterns of telemedicine services in rural and urban areas.
- To identify the gaps between awareness and usage of telemedicine services.
- To explore the perceptions and attitudes toward telemedicine among rural and urban residents.

This study has the following research questions:

- What is the level of awareness of telemedicine services among rural and urban populations in Bangladesh?
- How frequently and in what ways do rural and urban populations in Bangladesh use telemedicine services?
- What are the differences between awareness and actual usage of telemedicine services in rural and urban areas?
- What are the perceptions and attitudes of rural and urban residents towards telemedicine services?

By addressing these objectives and research questions, this study aims to provide valuable insights that can help in designing effective strategies to promote and enhance the adoption of telemedicine services across Bangladesh, ultimately improving access to quality healthcare for all.

II. Methodology

The following methodological approach was taken to conduct this study:

Study Design: This study employs a cross-sectional survey design to assess the awareness, usage patterns, and perceptions of telemedicine services among the rural and urban populations of Bangladesh. The survey aims to identify the barriers to and opportunities for the broader adoption of telemedicine services.

Study Area: The study was conducted in two distinct areas of Bangladesh:

- Rural Area: Gopalganj
- Urban Area: Dhaka

These areas were randomly selected to represent the rural and urban populations of Bangladesh.

Population and Sampling: The target population for this study includes individuals residing in the rural area of Gopalganj and the urban area of Dhaka. The inclusion criteria were adults aged 18 and above. Participants were selected using random sampling to ensure a representative sample from both areas.

Data Collection Tool: Data were collected using a structured questionnaire. The questionnaire was designed to gather comprehensive information on several aspects related to telemedicine, including:

- Demographics: Age, gender, location (rural or urban), and occupation.
- Awareness of Telemedicine Services: Whether participants have heard of telemedicine services and their sources of information.
- Usage of Telemedicine Services: Whether participants have used telemedicine services, the frequency of usage, and the purposes for which they have used these services.
- Gaps Between Awareness and Usage: Reasons for not using telemedicine services.
- Perceptions and Attitudes Towards Telemedicine: Participants' perceptions of the quality of telemedicine services compared to in-person visits, the benefits and concerns of telemedicine, and their likelihood of using telemedicine in the future.

Data Collection Procedure: The survey was administered online and offline to accommodate participants with varying levels of access to technology. In Gopalganj, field assistants distributed and collected the questionnaires, ensuring participation from those with limited internet access. In Dhaka, the survey was primarily distributed online, followed by a direct interview with the respondents.

Data Analysis: The collected data were entered into a database and analyzed using statistical software. Descriptive statistics were used to summarize the demographic characteristics of the respondents and their responses to the survey questions. Comparative analyses were conducted to identify differences between rural and urban populations regarding their awareness, usage patterns, and perceptions of telemedicine services.

Ethical Considerations: Participation in the survey was voluntary, and informed consent was obtained from all respondents. Confidentiality of the respondents was maintained by anonymizing the data, and the information collected was used solely for academic purposes.

III. Results

The survey included a total of 75 respondents, with 35 from rural Gopalganj and 40 from urban Dhaka. The age distribution showed a majority of respondents between the ages of 18-34, with an almost equal split between male and female participants. Occupations among respondents varied, including students, service workers, self-employed individuals, and housewives.

A. Awareness of Telemedicine

Out of the total respondents, 44% had heard of telemedicine services, while 56% had not. The primary sources of information for those aware of telemedicine were the internet/social media and healthcare service providers. This indicates a significant gap in awareness that needs to be addressed to enhance the reach of telemedicine services.

B. Usage of Telemedicine

Figure 1 shows that only 20% of the respondents reported using telemedicine services. Among these users, the frequency of use varied: 47% used telemedicine only once, 27% used it frequently (monthly), 13% used it occasionally (a few times a year), and 13% used it rarely (once or twice). The primary purposes for using telemedicine included general health consultations and specialist consultations. This limited usage highlights the need for more targeted efforts to promote the benefits and ease of access to telemedicine services.

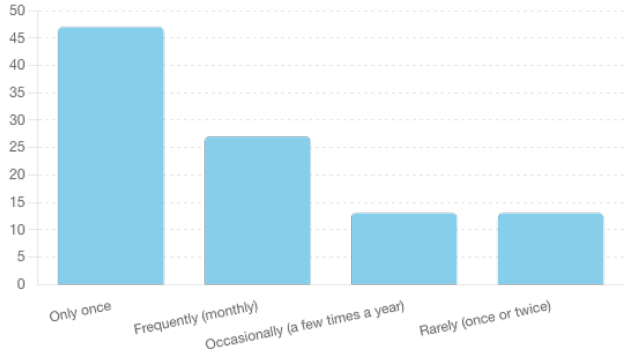

Fig. 1. Frequency of telemedicine usage among users

C. Gaps Between Awareness and Usage

The main reasons for not using telemedicine among respondents included not being aware of how to access the services, preferring in-person visits, concerns about privacy and security, and a lack of necessary technology such as smartphones and internet access. These barriers suggest that increasing education on how to access telemedicine and addressing technological and privacy concerns could significantly boost its adoption.

D. Perceptions and Attitudes

The survey results reveal a range of perceptions and attitudes towards telemedicine among respondents. When asked about their likelihood of using telemedicine in the future, the responses varied on a scale from 1 to 5, with 5 being very likely. A significant portion, 64%, indicated a likelihood of 3 or higher. Specifically, 11% rated their likelihood as very unlikely (1), 9% rated it as 2, 35% rated it as 3, 12% rated it as 4, and 29% rated it as very likely (5).

Regarding the perceived quality of telemedicine compared to in-person visits, opinions were mixed. An equal proportion of respondents (15%) perceived telemedicine as either much better, better, or about the same as in-person visits. Meanwhile, 8% of respondents perceived telemedicine as worse than in-person visits.

The perceived benefits of telemedicine included convenience, time-saving, cost-effectiveness, access to specialists, and reducing the need for travel. However, several concerns were highlighted by the respondents, including the quality of care, privacy and data security, technology reliability, and the lack of personal interaction. Addressing these concerns is crucial for building trust and encouraging the wider adoption of telemedicine services.

Figure 2 below illustrate these findings. The first graph shows the distribution of respondents' likelihood of using telemedicine in the future, while the second graph compares their perceptions of the quality of telemedicine to in-person visits.

E. Effectiveness of Telemedicine

Figure 3 illustrates the perceived effectiveness of telemedicine in addressing healthcare needs in both rural (Gopalganj) and urban (Dhaka) areas. Respondents rated the effectiveness on a scale from 1 to 5, with 5 being the highest rating.

In rural areas, specifically Gopalganj, 63% of respondents rated the effectiveness of telemedicine as either 4 or 5 out of 5. Among these, 22 respondents rated it as 5, and 5 respondents rated it as 4. Lower ratings were less common, with 5 respondents rating it as 1, 2 respondents rating it as 2, and 1 respondent rating it as 3.

In contrast, in urban areas like Dhaka, 42% of respondents rated the effectiveness of telemedicine as either 4 or 5 out of 5. In this group, 9 respondents rated it as 5, and 7 respondents rated it as 4. Ratings of 3, 2, and 1 were more evenly distributed among the urban respondents, with 8 respondents each rating it as 2 and 3, and 7 respondents rating it as 1.

This comparison highlights that while a significant majority in rural areas see telemedicine as highly effective, the urban population is more evenly divided across the effectiveness scale. Despite these differences, the positive perception in both areas indicates a recognition of telemedicine's potential benefits. However, the actual usage remains limited, suggesting that addressing barriers to wider adoption could further enhance both the perceived and actual effectiveness of telemedicine services.

The survey results underscore a significant gap between the awareness and usage of telemedicine services in Bangladesh. Despite recognizing the potential benefits, several barriers, including lack of awareness, technological constraints, and concerns about quality and privacy, hinder broader adoption. Targeted awareness campaigns, educational initiatives, and addressing technological and privacy concerns are essential steps to enhance the adoption and effectiveness of telemedicine services in Bangladesh.

IV. Discussion

This study aimed to investigate the awareness, usage patterns, and perceptions of telemedicine services among rural and urban populations in Bangladesh, focusing on Gopalganj and Dhaka. The findings provide valuable insights into the current state of telemedicine and highlight areas for improvement to enhance its adoption and effectiveness.

Awareness of Telemedicine Services: The first research question addressed the level of awareness of telemedicine services among rural and urban populations. The results showed that 44% of the respondents had heard of telemedicine services. The primary sources of information were the internet/social media and healthcare service providers. This significant gap in awareness underscores the need for targeted awareness campaigns to educate the population about telemedicine services and their benefits.

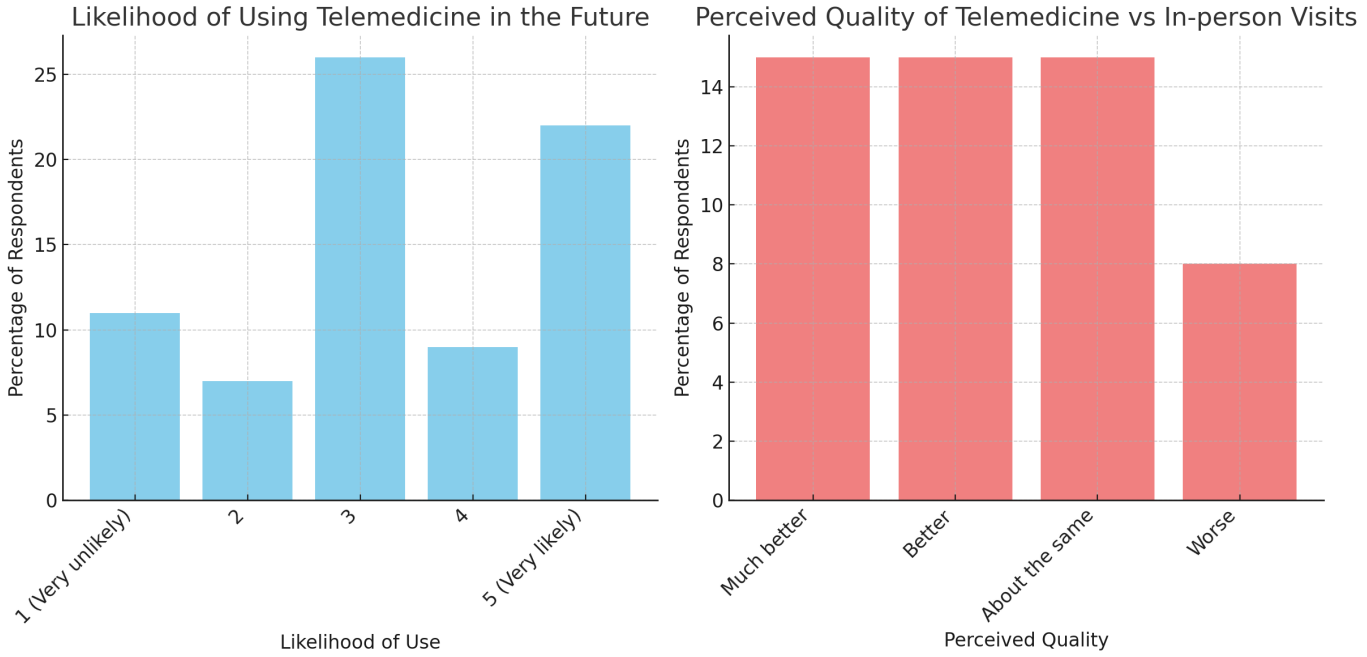

Fig. 2. Likelihood of using telemedicine in the future and Perceived quality of telemedicine vs In-person Visits

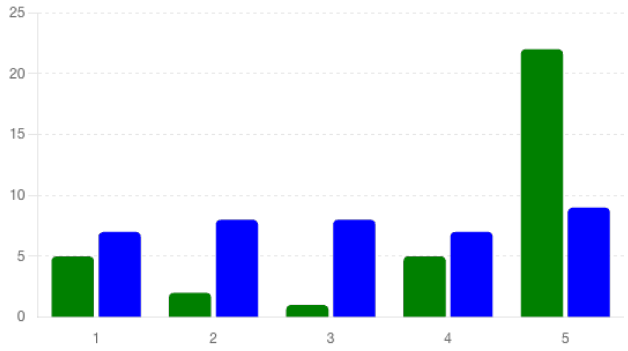

Fig. 3. Effectiveness of telemedicine in rural and urban areas

Usage Patterns of Telemedicine Services: The second research question focused on the frequency and manner in which rural and urban populations use telemedicine services. Only 20% of the respondents reported using telemedicine services. Among these users, 47% used telemedicine only once, 27% used it frequently (monthly), 13% used it occasionally (a few times a year), and 13% used it rarely (once or twice). The primary purposes for using telemedicine included general health consultations and specialist consultations. These findings indicate that while there is some level of usage, it is limited, suggesting that more efforts are needed to promote the regular use of telemedicine.

Gaps Between Awareness and Usage: The third research question examined the differences between awareness and actual usage of telemedicine services. The main reasons for not using telemedicine included not being aware of how to access the services, preferring in-person visits, concerns about privacy and security, and a lack of necessary technology such as smartphones and internet access. Addressing these barriers through education on how to access telemedicine services and improving technological infrastructure could significantly boost its adoption.

Perceptions and Attitudes Towards Telemedicine: The fourth research question explored the perceptions and attitudes of rural and urban residents towards telemedicine services. The survey revealed that 64% of respondents indicated a likelihood of 3 or higher on a scale of 1 to 5 for using telemedicine in the future. Regarding the quality of telemedicine compared to in-person visits, opinions were mixed, with 15% perceiving it as much better, 15% as better, 15% as about the same, and 8% as worse. The perceived benefits of telemedicine included convenience, time-saving, cost-effectiveness, access to specialists, and reducing the need for travel. However, concerns about the quality of care, privacy and data security, technology reliability, and the lack of personal interaction were prominent. Addressing these concerns is crucial for building trust and encouraging the wider adoption of telemedicine services.

V. Conclusion

This study highlights the potential of telemedicine to improve healthcare access in Bangladesh, especially in underserved rural areas. Despite recognizing its benefits, the adoption of telemedicine is hindered by a lack of awareness, technological constraints, and concerns about quality and privacy. To fully realize the benefits of telemedicine, targeted awareness campaigns, educational initiatives, and

improvements in technological infrastructure are essential. By addressing these barriers, telemedicine can become a vital tool in providing accessible and quality healthcare to all populations in Bangladesh.

In conclusion, the findings from this study provide a clear roadmap for enhancing the adoption and effectiveness of telemedicine services in Bangladesh. Through strategic initiatives aimed at increasing awareness, improving technology access, and addressing concerns about privacy and quality, telemedicine can significantly contribute to the country's healthcare system.

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Islamic Social Finance with Social Business to Tackle Health Inequities

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***Abstract*— This paper proposes an integrated social business model incorporating Islamic social finance (ISF) to augment equitable healthcare services for underprivileged people. The model comprises ISF instruments, namely *Qardul Hassan* (benevolent loan) and *Waqf* (endowment), Social Business principles, and Shariah governance (Islamic rulings). Based on logical reasoning, it could be concluded that social businesses coupled with Islamic social finance would be more effective and sustainable in providing equitable healthcare services. In this regard, policy adaptation is deemed necessary.**

***Index Terms*— Social business, Islamic social finance, equitable healthcare, and sustainability**

I. INTRODUCTION

The recent seventy-seventh session of the World Health Assembly was convened under the "All for Health, Health for All" tagline, uplifting the necessity of equitable healthcare [1]. Our long-cherished desire to create an equitable society will never come true until fundamental human rights are preserved. Healthcare is the fourth pivotal human right after food, clothing, and shelter. However, the systematic flaws and socioeconomic anomalies have made the existing healthcare system irrational and inequitable. Healthcare service has been commoditised and made available only for those who are economically nourished and capable of paying for it. Half of the world's population lacks access to comprehensive healthcare services. About two billion people encounter economic hardship due to out-of-pocket healthcare expenditures. Underprivileged communities, including girls and women, ethnic minorities, people with disabilities, and older adults, are exposed to severe deprivation of health services [2]. The social business model could address this issue effectively and efficiently since it is mechanised with non-loss, non-dividend features with the sole priority of attaining social objectives. The efficacy and efficiency of social business could be augmented by integrating it with two Islamic social financial instruments, namely *Waqf* (endowment) and *Qardul Hassan* (benevolent loan). The following sections delineate how this approach can pave the way to equitable healthcare services for underprivileged communities.

II. HEALTH EQUITY

Equity refers to the absence of unfair differences among people if they are diverse socially, economically, demographically, geographically or in any other dimensions such as sex, gender, ethnicity, disability or sexual orientation [3]. It is an ethical principle closely related to human rights principles [4]. In the same vein, health equity is a state where everyone gets fair and just opportunities to attain the highest level of health, overcoming economic, social and other obstacles and, thus, eliminating preventable health disparities [5]. Health equity is considered achieved when everyone can attain their full potential for health and wellbeing [3].

III. ISLAMIC SOCIAL FINANCE (ISF)

Islamic financial system is a Shariah-driven system under the commandments of God stated in the Quran and the sayings and doings of His last apostle, Muhammad (pbuh). This system stands on three fundamental principles: "1) profit comes through accepting and bearing risks, 2) money is only a store of value and medium of exchange, 3) wealth creation must be balanced with wealth transfer and circulation, and assurance of transparency and traceability" [6] (p-104). Along with the commercial financial instruments, it comprises a few social financial tools such as *Zakat* (mandatory alms-giving), *Waqf* (endowment), *Sadaqa* (voluntary donation), and *Qardul Hassan* (benevolent loan) to alleviate inequalities by uplifting the economic standing of the most vulnerable communities while addressing socioeconomic ills like poverty, illiteracy, inequitable healthcare services, etc., [7, 8]. Two of those instruments, *Waqf* (endowment) and *Qardul Hassan* (benevolent loan) are seemingly suitable for integration with social business and, thus, address the inequities in healthcare more sustainably. The following sections discuss an integrated conceptual model (Figure 1) that this paper intends to deal with.

A. Qardul Hassan

Qard Hasan is a benevolent loan that is not tied up with the time value of money principle, which is why it does not seek any risk-adjusted market returns like the interest charged on the loans offered by conventional financial institutions. It can be loaned repeatedly by individuals

and organisations [9]. This instrument aims to ensure social welbeing through social justice, risk sharing and mutual cooperation. Hence, it could utilised in the health sector to enhance equitable healthcare services. Thus, this wealth redistributive instrument will provid significant socioeconomic benefits by enhancing individual and social wellbeing [10].

B. Waqf

Another source of Islamic social funds is *Waqf* (endowment), which embodies the characteristics of perpetuity, irrevocability, and inalienability[11, 12] and could be integrated into Social Business. *This* is basically in two kinds: asset and cash *waqf*. Asset *waqf* has a long-standing history of being utilised for social welfare by building educational institutions, orphanages, hospitals, etc. Cash *waqf* is a trust fund formed with cash to extend service to humanity in the name of God[13]. Cash *waqf* utilisation is comparably easy to invest, manage, and enhance value. It is also convenient for adherent Muslims to be involved by contributing money [14]. Both types of *Waqf* could be incorporated into the social business model. For instance, asset *waqf* could used for facility building and cash *waqf* for purchasing equipment.

Recently, a different kind of *Waqf* has come forth, called corporate *Waqf*, which is issued in the form of shares (*mawquf waqf* asset) and managed by a corporation. It embodies all characteristics of *Waqf* while meeting business and corporate objectives [15]. A *Waqf* administrative body (WAB) issues *waqf* certificates to individuals or institutions. [16]. Once it reaches the targeted amount, a planned social business to provide healthcare services could be initiated. Corporate *Waqf* can address critical social problems by establishing large projects such as hospitals and pharmaceutical companies to produce generic medicine, vaccines, etc.

IV. ISLAMIC SOCIAL FINANCE, SOCIAL BUSINESS, AND HEALTH EQUITY

Yunusian Social Business is a non-dividend and non-loss profit-driven business model. This type of business generates profit for attaining operational viability and economic sustainability. However, it offers no dividends to the investors. They can only recope the capital amount after a stipulated time [17]. Investors are incentivised with mental satisfaction and the 'Joy' of achieving social objectives. Philanthropists, benevolent-minded individuals, and corporations contribute to this kind of concessionary investment. For this reason, the start-up capital for social businesses is somewhat uncertain. Incorporating the aforesaid two social funds could ensure the start-up funds for social businesses. As a result, social business would grow faster and provide healthcare services to underprivileged people more sustainably.

Further, social business has proven tremendously effective in providing health services. For example, Grameen Healthcare, Grameen Green Childen Eye Hospital, and many others are to be exemplified as very successful healthcare service providers to those in need. In the same vein, if healthcare centres and pharmaceutical companies are built using *Waqf* assets as a social business model, it will bring significant benefits to caregivers as well as care receivers by reducing costs and increasing efficiency. The performance will be enhanced if the *Qardul Hassan* fund is added for operational capital, and it will significantly reduce the service cost due to the zero cost of capital, which will positively contribute to improving quality as well. Since social business is market-driven, it will be able to pay the start-up capital (Qardul Hassan) back from the generated income after a certain period (Fig 1). By virtue, it will remain economically self-reliant and operationally sustainable because of its market-driven nature and Seven Operational Principles (see the appendix. The main concern of Islamic finance and Social Business is the operational principles. Islamic Financing principles must look into Shariah investment compliance, while social business will focus on the Seven Principles prescribed by Nobel Peace Laureate Professor Muhammad Yunus (see the appendix). Nonetheless, Yunusian principles do not contradict Shariah's principles. Therefore, the principles of Social Business and Shariah financial rules can coexist in Social business operations. Further, the value proposition, value constellation, and profit equation of social business or Islamic social finance-based equity healthcare services complement each other. Therefore, incorporating Islamic social finance with social business has no technical and ethical barriers and hench; this alliance will augment social business performance to ensure equitable healthcare service.

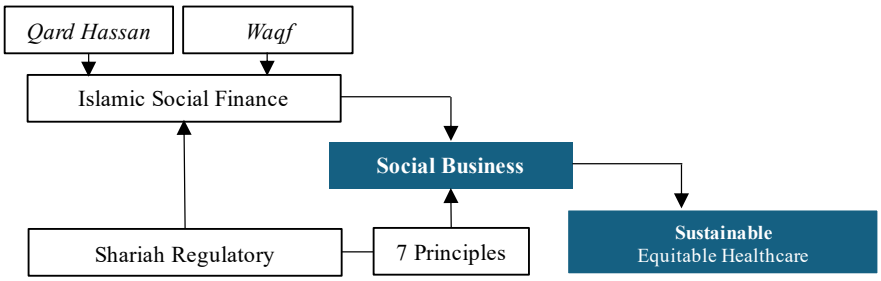

Fig 1: ISF, SB, and Sustainable Equitable Healthcare

V. VALUE PROPOSITION, VALUE CONSTELLATION, AND PROFIT EQUATION OF ISLAMIC SOCIAL FINANCE-BASED SOCIAL BUSINESS

Value Proposition refers to a social business venture's unique values that offer equitable healthcare services to an amenable group. The value constellation means the orchestration of partners, resources and activities that collectively function to create and deliver the value proposition. Finally, the profit equation denotes the revenue stream, cost structure, and profitability, including the social return on investment (SROI) and sustainability [18]. Table (1) below demonstrates these three components.

TABLE 1

ISLAMIC SOCIAL FINANCE-BASED SOCIAL BUSINESS MODEL

Value Proposition *(Beneficiaries and Product & Services)*	***Value Constellation*** *(Internal and External Value Chain)*	***Profit Equation*** *(Revenue, cost structure, and capital employed)*
Amenable Group • Underprivileged people **Products and Services** • Access to Healthcare • Quality Care • Preventive Services • Generic medicines and health supplements • Holistic Approach	**Partnerships:** • Health Organizations • Islamic Financial and Charitable Organisations • Government Agencies • NGOs and Community Groups • Educational Institutions • Private Sector **Resources:** • Health Professionals • *Qardul Hassan* • *Waqf* Endowments • Technological Resources • Physical Resources **Activities:** • Primary and Preventive Care • Specialised Medical Services • Community Outreach • Training and Capacity Building • Research and Innovation • Profit Equation	**Revenue Streams:** • *Waqf* Returns • Service Fees • Public-Private Partnerships **Cost Structure:** • Operational Costs • Medical Supplies and Equipment • Outreach and Education • Research and Development • Technology and Infrastructure **Profitability:** • Break-Even Point • Reinvestment • Social Return on Investment (SROI) • Operational sustainability

VI. CONCLUSION

In conclusion, Islamic social funds are dedicated to social wellbeing; whereas social business has the same motto. In this case, these two entities can complement each other. *Waqf* assets, cash or corporate *waqf,* could be used for health facilities such as hospitals or pharmaceutical industry buildings; *Quardul Hassan* could be used to purchase equipment or operational capital (buying raw materials, paying wages and salaries, utilities, etc.). As a result, Islamic social finance-led social business ventures will obtain higher production efficiency and product quality due to the zero cost of capital (*Quardul Hassan*) and endowment (*waqf*). Therefore, equitable health service provision will be better possible and more sustainable.

Particular policies are required to make this model Shariah-compliant while practising the seven operational principles that Professor Yunus advocates. The policy must clearly define the roles of governments, non-governmental organisations, and stakeholders, such as social impact-seeking purchasers, channels of capital, and sources of capital in attaining equitable healthcare. In that case, further research is needed.

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Appendix: Seven Principles of Socia l Business Prescribed by Professor Yunus [17]

1. Business objective will be to overcome poverty, or one or more problems (such as education, health, technology access, and environment) which threaten people and society; not profit maximization.
2. Financial and economic sustainability
3. Investors get back their investment amount only. No dividend is given beyond investment money
4. When investment amount is paid back, company profit stays with the company for expansion and improvement
5. Gender sensitive and environmentally conscious
6. Workforce gets market wage with better working conditions
7. ...do it with joy

Issues in Crowd-Sourced Healthcare Data and a Machine Learning based Approach to Enhance the Data Quality

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***Abstract*—In the realm of crowd-sourced healthcare data, challenges arise from inaccuracies introduced by users, including uploading irrelevant or misleading documents. This paper addresses two critical challenges: the upload of non-medical or fake documents and the potential misattribution of information to the wrong individual. Our proposed solution involves the development of machine learning algorithms to filter out irrelevant documents and unnecessary information, ensuring the accuracy of the Personal Health Record (PHR). Additionally, we introduce a method to identify the true owner of the information, mitigating the risk of misguidance. Our system effectively identifies and filters out irrelevant documents with a 98% accuracy rate, providing a robust foundation for accurate PHR construction. Ongoing efforts focus on enhancing the model's capability to precisely identify the document owner. Through these advancements, our developed system aims to eliminate common user errors, fostering the creation of reliable and trustworthy crowd-sourced healthcare data.**

***Index Terms*—Natural Language Processing, Medical Document Classification, Electronic Health Records (EHR), Transformer Models, Large Language and Vision Assistant (LLAVA), Large Language Model (LLAMA)**

I. Background

In the ever-changing global healthcare landscape, Electronic Health Records (EHR) systems have emerged as a transformative force [1]. The shift from traditional analog health records to digital EHR technology holds great promise for advancing healthcare data management, accessibility, and efficiency [2]. As part of this digital transformation, individuals increasingly possess a mix of historical medical records in both analog and digital formats [3].

The transition from analog to digital medical records opens avenues for easier access and utilization of lifelong health records [4], [5]. This improvement can enhance healthcare services, assist doctors in decision-making, and potentially reduce the cost and time required for healthcare resources. However, the collection and digitization of paper-based medical records to adapt to the digital health system pose challenges [6], [7], [8]. Analog data, including printed prescriptions and medical test reports still play a crucial role, particularly in developing countries. Even in partially digitized healthcare settings, manual input remains common for transferring data from paper-based documents to Electronic Medical Records (EMR) or EHR. When users upload their medical data, unintentional inclusions of unrelated documents alongside authentic medical records are common. Individuals may lack the necessary education or awareness to effectively manage healthcare data. These unintentional inclusions introduce noise into EHR databases, leading to reduced accuracy and reliability of machine learning models relying on this data.

While extensive research focuses on medical data extraction and analysis in EHRs, a substantial gap exists in effectively distinguishing non-medical documents from authentic medical records. The presence of irrelevant, non-medical data complicates accurate and meaningful analysis, challenging the core objectives of EHR systems aimed at enhancing patient care and healthcare research through data-driven insights.

This study aims to bridge this critical gap by presenting a pioneering approach harnessing the power of machine learning and deep learning techniques. The transition to a digital healthcare era has revolutionized the way medical records are managed and accessed. Traditionally, healthcare documents were handled and uploaded by professionals, ensuring accuracy and relevance. However, the democratization of technology has enabled patients to upload their own documents, which, while increasing accessibility, also introduces the risk of irrelevant or incorrect data entering the system. This noisy data can significantly affect the reliability of patient records and the efficiency of healthcare services. Digital healthcare promises improved patient outcomes, better data accessibility, and enhanced patient engagement. However, with the proliferation of user-generated content, ensuring the accuracy and relevance of medical documents is paramount. The challenges include verifying the authenticity of documents, ensuring they belong to the correct patient, and maintaining a high level of data integrity. The consequences of noisy data in healthcare can be severe, ranging from incorrect patient treatment to flawed medical research. Therefore, robust methods are needed to filter out irrelevant documents and ensure only the correct patient's records are stored.

II. Literature Review

The exploration of document classification, encompassing both textual content and images, has been extensively undertaken within the realms of computer science and information technology [9]. In this domain, various text classification

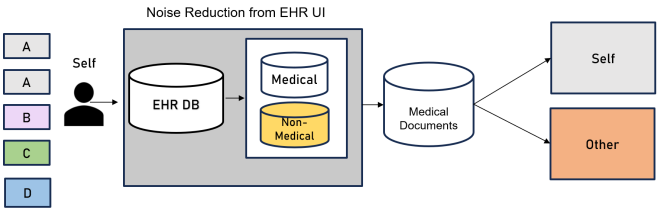

Fig. 1. Crowd Sourced Healthcare Data

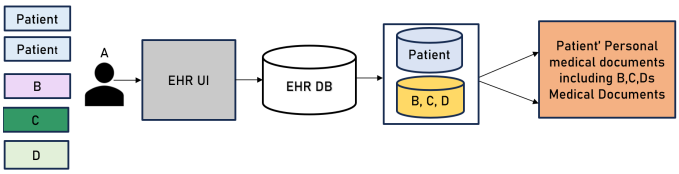

Fig. 2. EHR in New Era

algorithms play a significant role by accepting different types of data and providing output in the form of class labels describing the data.

A thorough examination of cutting-edge deep learning algorithms, such as Deep Neural Networks (DNN), Recurrent Neural Networks (RNN), Convolutional Neural Networks (CNN), Recurrent Convolutional Neural Networks (RCNN), and Random Multimodel Deep Learning (RMDL), within the domain of biomedical text document classification was presented by [10]. Their comprehensive exploration involved experimenting with various datasets.

In the context of text classification, [11] conducted an extensive survey covering a range of machine learning and deep learning algorithms, along with their corresponding evaluation metrics. Additionally, a bag-of-concepts approach to document representation was introduced by [12], who employed machine learning algorithms, including Support Vector Machines (SVM), for the classification of biomedical documents.

The utilization of Recurrent Neural Networks (RNN) and Long Short-Term Memory (LSTM) networks to automatically assign ICD-9 labels to medical records was explored by [13], with a primary focus on medical notes authored by healthcare professionals. Furthermore, [14] introduced a novel medical text classification approach that leveraged two innovative deep learning architectures: a quad-channel hybrid long short-term memory (QC-LSTM) achieving an accuracy of 96.72%, and a hybrid bidirectional gated recurrent unit (BiGRU) with 95.76% accuracy.

Despite the wealth of research in document classification, there has been a limited amount of focus on the integration of scanned documents within Electronic Health Records (EHRs). [15] delved into this area by examining the effectiveness of Optical Character Recognition (OCR) and text classification models. These models were trained on manually categorized documents to assess their reliability in classifying scanned documents within an Electronic Health Record (EHR) system. Notably, ClinicalBERT emerged as the top-performing model, achieving an accuracy of 97.3%.

Present studies predominantly concentrate on handling medical data in EHRs but encounter challenges in accurately differentiating non-medical documents. This study aims to address this gap by proposing a smart document sorting system capable of automatically recognizing and categorizing the true owner of the medical document within EHRs. The application of advanced machine learning and deep learning techniques in this study seeks to enhance the efficiency of document classification, contributing to the broader field of healthcare data management, and improving the accuracy of document sorting within EHR systems.

III. Objective

The primary objective of this research is to develop and evaluate effective methods for identifying and filtering irrelevant medical documents in digital healthcare systems. The goal is to ensure that only documents pertinent to a particular patient are stored, thereby enhancing the reliability and accuracy of patient records.

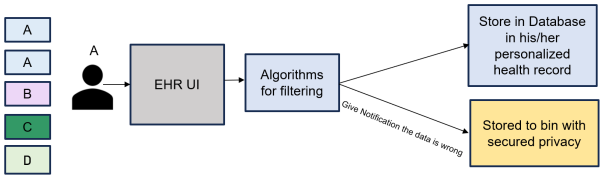

Fig. 3. A sample figure

This objective is important for several reasons:

Improved Patient Care

Accurate records ensure that healthcare providers have access to correct information, leading to better diagnosis and treatment.

Data Integrity

Maintaining high-quality data is essential for reliable healthcare analytics and research.

User Trust

Patients need to trust that their personal health information is managed accurately and securely.

Achieving these objectives requires the development of sophisticated algorithms that can handle the complexity and variability of medical documents, accurately extract relevant features, and classify documents correctly

IV. Technical Problem

The shift to user-uploaded healthcare documents introduces a significant technical problem: the high likelihood of irrelevant or noisy data being uploaded. This data could include documents from other individuals, outdated records, or non-medical documents mistakenly uploaded.

Specific challenges include:

Identifying Relevant Documents

Distinguishing between relevant and irrelevant documents requires sophisticated algorithms capable of understanding the context and content of each document.

Extracting Accurate Information

Optical Character Recognition (OCR) technology must accurately extract text from scanned documents, but it often misidentifies text, leading to errors.

Differentiating Entities

Names and other attributes may refer to multiple individuals (e.g., patient vs. doctor), complicating the identification process.

The technical problem is compounded by the variability in document formats, handwriting styles, and quality of scans. Each of these factors can introduce additional noise into the data extraction process, making it challenging to achieve high accuracy.

V. Methodology

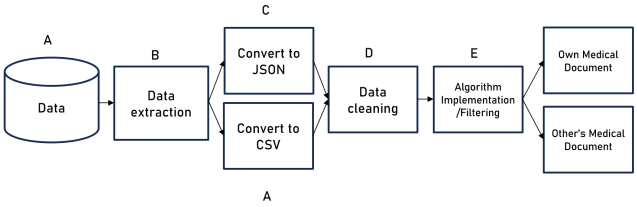

Fig. 4. Methodology for True owner detection

To tackle these challenges, we implemented and compared three distinct approaches:

Approach1: Simple Filtering and Document Matching Algorithm This approach involves basic filtering techniques to match documents based on extracted features such as the patient's name, age, height, and weight. The algorithm performs the following steps: OCR Extraction: Extract text from documents using OCR. Feature Extraction: Identify key features (name, age, height, weight) from the extracted text. Matching Algorithm: Compare extracted features with known patient data to determine relevance. The simplicity of this approach makes it easy to implement but limits its effectiveness in handling complex cases where feature extraction errors occur.

Approach2: Supervised Machine Learning Approach:

Supervised learning models are trained on labeled datasets where each document is marked as belonging to a specific patient or not. The following algorithms were applied: Logistic Regression: A statistical method for binary classification. Support Vector Machine (SVM): A robust classifier that finds the optimal hyperplane for separating classes. Random Forest: An ensemble learning method using multiple decision trees. Naive Bayes: A probabilistic classifier based on Bayes' theorem. These models require a significant amount of labeled training data to perform well but can achieve high accuracy when trained properly.

Approach 3: Unsupervised Machine Learning Approach:

Unsupervised learning methods, such as clustering, group documents based on their features without predefined labels. We used: K-Means Clustering: Partitions documents into K clusters based on feature similarity. Hierarchical Clustering: Builds a tree of clusters based on document similarities. These approaches do not require labeled data, making them suitable for scenarios where labeled data is scarce. However, their performance depends heavily on the quality of feature extraction and the inherent clustering of the data.

A. Data Collection

A total of 500 documents were collected from Kaggle which is publicly available. The medical data, comprising health records, reports, and prescriptions were included.

B. Data Extraction

data extraction and preprocessing phase, OCR technniques and LLAMA 2 were utilized to extract textual content from PDF documents which were then converted into JSON and CSV data

C. Data Preprocessing

Following the preprocessing step, lemmatization, the removal of punctuation marks, the elimination of stop words, the extraction of alphanumeric characters, and the stripping of HTML tags were carried out. These steps are intended to enhance the quality and usability of textual data for subsequent analysis and classification. In Subsequently, a series of operations were conducted, including the removal of accented characters, numbers, punctuation marks, stopwords, and excess white spaces. Additionally, concatenated words were addressed, and the entire text was converted to lowercase for consistency.

VI. Results

6. Results Simple Filtering and Document Matching Algorithm The simple filtering approach provided initial filtration but struggled with accuracy due to noise in the OCR-extracted data. Misidentifications were common, particularly in distinguishing between patients and doctors. The algorithm was able to achieve a baseline level of filtering but was not sufficient for high-accuracy requirements. Supervised Machine Learning Approach The supervised learning models demonstrated high accuracy: Logistic Regression: Achieved an accuracy of 96%, showing its effectiveness in binary classification tasks. Support Vector Machine: Also achieved 96% accuracy, demonstrating robustness in handling the variability of document features. Random Forest: Performed similarly with 96% accuracy, benefiting from its ensemble approach to reduce overfitting. Naive Bayes: Showed slightly lower accuracy but still performed well, highlighting its efficiency in handling probabilistic relationships between features. These results indicate that supervised learning approaches are highly effective in identifying

relevant documents when sufficient labeled data is available. Unsupervised Machine Learning Approach The unsupervised clustering approach achieved 51% accuracy with K-Means clustering. While lower than supervised methods, it highlights the potential for clustering algorithms to identify document groups based on feature similarity. Hierarchical clustering provided similar results, emphasizing the need for further refinement and combination with other techniques to improve performance.

VII. Discussion

The supervised learning approaches significantly outperformed the simple filtering and unsupervised methods. The high accuracy of these models makes them viable for immediate implementation in digital healthcare systems. However, challenges remain in accurately extracting structured data, particularly in distinguishing between entities like patients and doctors. The clustering approach, while less accurate, offers a foundational method for further development, particularly in environments with less labeled data. The results demonstrate the importance of high-quality data preprocessing and feature extraction. Even with advanced algorithms, the accuracy of the system is heavily dependent on the initial quality of the extracted data. Future work should focus on improving OCR accuracy and developing more sophisticated feature extraction techniques.

VIII. Future Works

Future research will focus on several areas: Algorithm Enhancement: Developing more sophisticated algorithms for identity matching, potentially combining supervised and unsupervised approaches to leverage the strengths of both. Dataset Expansion: Increasing the size and diversity of the dataset to improve model robustness and generalizability. This includes incorporating more varied document types and formats to simulate real-world scenarios. Exploring Clustering Techniques: Investigating additional clustering algorithms, such as DBSCAN or Gaussian Mixture Models, to enhance the performance of the unsupervised approach. Live Environment Testing: Implementing and testing the models in a live healthcare environment to evaluate real-world performance. This step is crucial for understanding the practical challenges and limitations of the proposed methods. These future directions aim to refine the methodologies, enhance accuracy, and ensure the reliable identification of patient-specific documents in digital healthcare systems. By addressing these challenges, we can move closer to realizing the full potential of digital healthcare and ensuring the integrity of patient records.

IX. Conclusion

In this study, we explored various approaches to address the challenge of filtering irrelevant medical documents in the digital healthcare era, where users rather than professionals upload documents. The need for accurate identification of a patient's own documents and removal of irrelevant ones is critical for maintaining data integrity in healthcare systems.

We employed LLAMA 2 for text extraction from PDFs, followed by OCR techniques and extensive data preprocessing to prepare the data for analysis. Three distinct approaches were applied: a simple filtering and document matching algorithm, supervised machine learning methods, and unsupervised machine learning techniques.

The simple filtering approach provided a baseline filtration method but was limited by the noise and variability in the data. Supervised machine learning models, including logistic regression, support vector machine, random forest, and naive Bayes, demonstrated high accuracy, each achieving around 96%. These results underscore the effectiveness of supervised learning in accurately classifying documents when sufficient labeled data is available. In contrast, the unsupervised clustering approach achieved a lower accuracy of 51%, indicating the potential for improvement but also highlighting the challenges of working with unlabeled data.

Our findings emphasize the importance of high-quality data preprocessing and feature extraction. Accurate and reliable OCR processes are crucial for ensuring that the subsequent classification models can perform effectively. While supervised learning models are highly effective, future work should focus on improving unsupervised methods to handle scenarios with limited labeled data.

Future research will aim to enhance the algorithms, expand the dataset, explore additional clustering techniques, and test the models in live healthcare environments. These efforts are essential to developing robust systems capable of maintaining the integrity of digital healthcare records, ultimately improving patient care and trust in healthcare information systems.

By addressing these challenges, we move closer to realizing the full potential of digital healthcare, ensuring that patient records are accurate, reliable, and secure. The continued development and refinement of these methodologies will be critical in adapting to the evolving landscape of healthcare data management.

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Prospects and Challenges of Digital Health-Enabled Preventive Care in a Rural Area of Bangladesh

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***Abstract*—In recent years, digital health technologies have emerged as vital tools in transforming healthcare delivery, particularly in rural and underserved areas. This study explores the prospects and challenges of implementing a digital health system for regular health screening and health data management in a rural area of Bangladesh. A structured survey was conducted among 150 respondents to capture demographic information, technology access, awareness, and usage of digital health technologies, as well as perceptions regarding preventive healthcare expenditures. The results indicate that younger individuals, males, and those with higher education levels are more willing to pay for the digital health service. Despite a high level of awareness (60%) about digital health technologies, actual usage remains low at 20%, highlighting significant gaps between awareness and adoption. Barriers such as lack of access, digital literacy, and trust issues were identified. The findings underscore the need for targeted interventions to address these barriers and promote the adoption of digital health technologies. By enhancing digital literacy and building trust through community engagement and education campaigns, it is possible to improve preventive healthcare outcomes in rural communities. This study provides valuable insights for policymakers, healthcare providers, and health entrepreneurs aiming to enhance rural healthcare in Bangladesh.**

***Index Terms*—digital health, preventive healthcare, developing country, health awareness, public health, technology adoption, telemedicine**

I. Introduction

In recent years, digital health technologies have emerged as essential tools in transforming healthcare delivery, particularly in rural and underserved areas. These technologies offer innovative solutions for enhancing access to medical services, improving patient outcomes, and optimizing healthcare resource utilization [1]–[3].

Preventive care, encompassing measures such as regular health screenings, vaccinations, and lifestyle interventions, plays a crucial role in reducing the burden of disease and improving population health. The healthcare system has inadequately promoted preventive care, mainly due to poor reimbursement for preventive care and fragmentation of care [4]. Primary care interventions that enhance the delivery of preventive services are an important part of a public health strategy to contain the health and economic consequences of preventable morbidity and mortality [5], [6].

However, rural areas in Bangladesh face numerous obstacles in providing effective preventive care. These challenges include inadequate healthcare facilities, a shortage of trained medical professionals, and logistical barriers that hinder the timely delivery of healthcare services [7], [8]. Digital health technologies, including telemedicine, mobile health (mHealth) applications, and electronic health records (EHRs), present promising opportunities to address these issues [9]–[11].

The objective of this study is to explore the prospects and challenges of implementing digital health intervention to enhance preventive care in rural communities in Bangladesh. By evaluating the perspective of the rural inhabitants, identifying opportunities, and analyzing barriers, this study aims to provide insights that will benefit future health entrepreneurs, innovators, policymakers, healthcare providers, and stakeholders invested in enhancing rural healthcare in Bangladesh.

II. Methodology

Following methodology has been conducted for this study:

Survey Design and Sampling: To understand the prospects and challenges of digital health-enabled preventive care in a rural area of Bangladesh, we designed a structured survey. The survey aimed to capture demographic information, access to technology, awareness and usage of digital health technologies, and perceptions regarding preventive healthcare expenditures. The survey included both closed-ended and open-ended questions, which were designed to elicit quantitative and qualitative responses. The questions covered various aspects such as age, gender, occupation, education level, smartphone and computer ownership, internet usage, electricity availability, awareness and usage of digital health technologies, preferences for health record-keeping, and willingness to pay for preventive health checkups.

Sample Selection: The sample for the survey was selected using a stratified random sampling method. This method was chosen to ensure that different subgroups within the rural population were adequately represented, thereby increasing the generalizability of the findings. The population was stratified based on key demographic variables such as age, gender, and occupation. Within each stratum, respondents were randomly selected to participate in the survey. Stratified random sampling was justified as it allows for greater precision in

estimating population parameters and ensures that specific subgroups are represented proportionately. According to Cochran (1977), this method is particularly effective in studies where the population is heterogeneous, as it reduces sampling bias and improves the accuracy of the results [12].

Data Collection: Data was collected through online forms over a period of one month from May 1, 2024, to May 31, 2024. The target population included residents of a rural area in Bangladesh, with an emphasis on ensuring a diverse representation across different age groups, genders, occupations, and education levels. A total of 150 respondents participated in the survey. To ensure the reliability and validity of the responses, surveyors were trained to provide clarification on any questions that respondents found difficult to understand. Additionally, respondents were assured of the confidentiality and anonymity of their responses to encourage honest and accurate reporting.

Data Analysis: The collected data was entered into an Excel spreadsheet and cleaned for any inconsistencies or missing values. Descriptive statistics were used to analyze the demographic characteristics of the respondents, their access to technology, and their awareness and usage of digital health technologies. Percentages were calculated to represent the distribution of responses for each survey question. Graphical representations, including bar charts, were used to visualize key findings. These visualizations helped in identifying trends and patterns in the data, providing a clear picture of the current state of digital health awareness and technology usage in the rural area surveyed.

Ethical Considerations: The study adhered to ethical guidelines to protect the rights and welfare of the participants. Informed consent was obtained from all respondents prior to their participation in the survey. Participants were informed about the purpose of the study, the voluntary nature of their participation, and their right to withdraw from the study at any time without any consequences. Data privacy and confidentiality were strictly maintained throughout the study. All collected data was anonymized and stored securely to prevent unauthorized access. The findings of the study were reported in aggregate form, ensuring that no individual respondent could be identified.

III. Results

The survey conducted among 150 respondents from a rural area in Bangladesh (Manirampur, Jashore) yielded insightful results regarding the demographics, technology access, awareness, and perceptions of digital health-enabled preventive care. The findings highlight the current state of technology usage, awareness of digital health technologies, and the willingness of the population to engage with and invest in preventive healthcare solutions. The detailed analysis of the survey responses provides a comprehensive understanding of the potential and challenges faced in the adoption of digital health systems in rural Bangladesh.

A. Demographics

The survey respondents ranged in age from 18 to 56 years old, with the majority (29.3%) being between 18-25 years old. Gender distribution was relatively balanced, with 52.7% male and 47.3% female respondents. The survey captured a diverse range of occupations, including students, housewives, farmers, and self-employed individuals. In terms of education level, respondents varied from primary to higher education, with the majority (60%) having secondary education (10th grade).

B. Technology Access and Usage

Figure1 presents a visual representation of various aspects related to technology ownership and usage among a specific population. The data is illustrated using a horizontal bar chart, where each bar represents a different category of technology access or usage, and the length of the bar corresponds to the percentage of individuals within the population who fall into that category.

The first category, "Smartphone Ownership," shows that 70% of the population owns a smartphone, indicating a high level of mobile connectivity. The second category, "Computer/Laptop Ownership," indicates that 50% of the population owns a computer or laptop in their family, reflecting moderate access to more traditional forms of digital technology. The third category, "Daily Internet Usage," highlights that 60% of the population uses the internet daily, suggesting significant engagement with online resources and activities.

Contrastingly, the category "No Internet Usage" reveals that 30% of the population does not use the internet at all, pointing to a notable digital divide within the community. The final category, "Daily Load Shedding (1-4 hours)," indicates that 100% of the population experiences daily load shedding for 1 to 4 hours, highlighting a critical infrastructure challenge that impacts the reliability of technology usage.

Overall, the graph effectively shows the levels of technology access and usage, as well as the challenges faced by the population, providing valuable insights for stakeholders and policymakers aiming to improve digital inclusion and infrastructure reliability.

C. Awareness and Usage of Digital Health Technologies

The Following two bar charts illustrates the awareness and usage of digital health technologies among the survey respondents.

Figure 2 represents the awareness of digital health technologies, such as mobile health apps and telemedicine. The chart shows that a significant majority of respondents (60%) are aware of these technologies, indicating a good level of exposure to digital health concepts. However, 40% of the respondents are still not aware of these technologies, suggesting that there is room for improvement in spreading awareness about digital health tools and their potential benefits.

Figure 3 depicts the actual usage of digital health technologies among the respondents. Despite the high awareness level, only 20% of the respondents reported using any form of digital health technology. This discrepancy highlights a significant

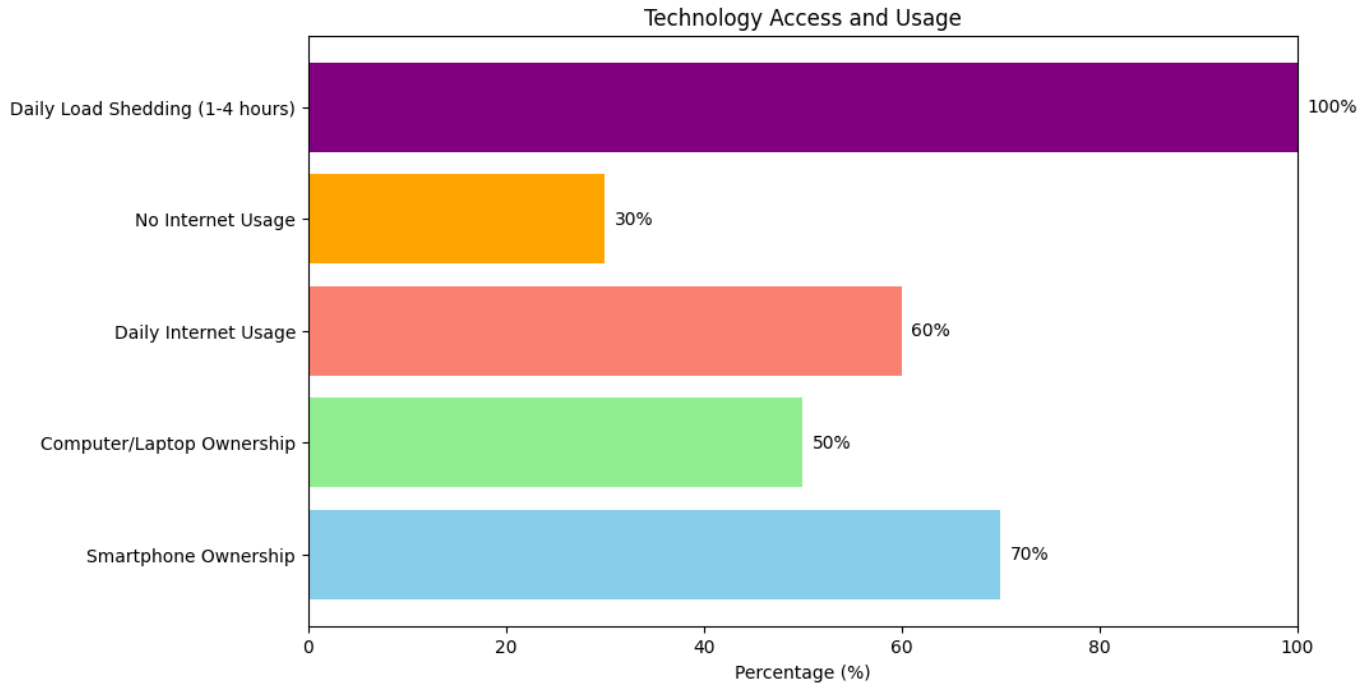

Fig. 1. Technology access and usages by the rural population

gap between awareness and actual adoption. The remaining 80% of respondents do not use digital health technologies, which could be due to various barriers such as lack of access, digital literacy, or trust in these technologies.

The graphs collectively highlight a crucial aspect of digital health implementation in rural areas. While awareness is relatively high, the actual usage lags significantly. This suggests that efforts should not only focus on increasing awareness but also on addressing the barriers to adoption and usage of digital health technologies. Interventions could include providing better access to digital tools, offering training to improve digital literacy, and building trust in digital health solutions through community engagement and education campaigns.

D. Perceptions and Challenges

The survey revealed diverse perceptions and challenges regarding the adoption of digital health technologies. In terms of record-keeping, the respondents were evenly split. Half of the respondents preferred digital health records, citing their accessibility and ease of maintenance as key advantages. The other half continued to rely on paper records, mainly due to a lack of trust in digital systems or insufficient knowledge about digital health technologies.

Regarding health expenditure, 40% of the respondents reported spending between BDT 1,000-5,000 annually on healthcare. Another 30% of the respondents indicated that their annual healthcare expenses ranged between BDT 5,001-10,000. This expenditure data highlights the financial burden of healthcare on rural populations and the variability in healthcare costs among households.

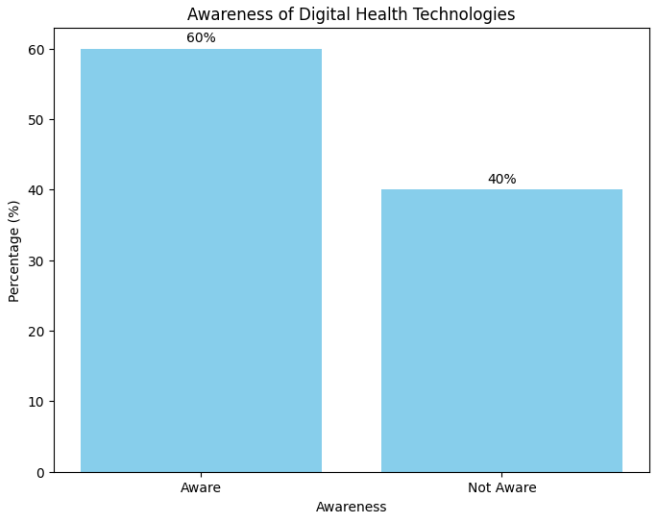

Fig. 2. Awareness of digital health technologies

When it comes to preventive health measures, the respondents showed mixed willingness to invest. While 40% were willing to spend up to BDT 2,000 annually on preventive health checkups, an equal proportion of respondents were not inclined to spend any money on preventive measures. This reluctance could be attributed to financial constraints or a lack of awareness about the long-term benefits of preventive healthcare. These findings underscore the need for targeted education and financial support to encourage the adoption of preventive health practices.

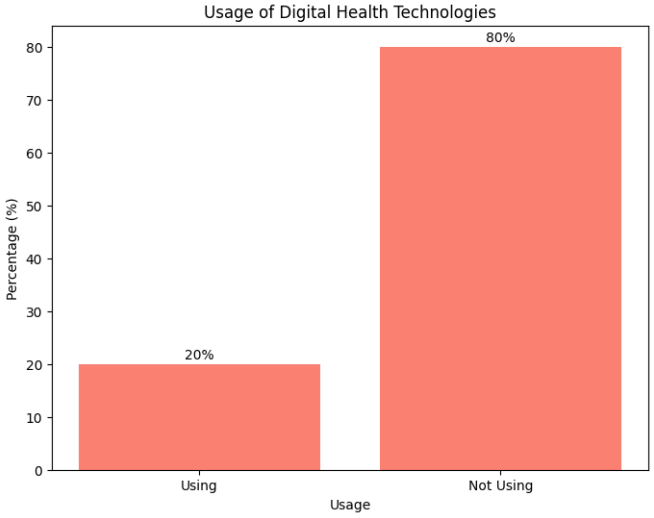

Fig. 3. Usage of digital health technologies

To determine the prospects of using the new digital health system like Portable Health Clinic with life-long medical history management system for regular health screening and health data management, this study aimed to identify what kind of users are willing to pay [13], [14]. To achieve this, the response trends from the survey data were analyzed.

Figure 4 shows the age distribution of respondents willing to pay up to BDT 2,000 for using the new digital health system for regular health screening and health data management. The figure indicates that younger people are more interested in paying for this kind of service. This trend suggests that younger individuals, possibly due to their familiarity with technology and awareness of preventive healthcare, are more inclined towards investing in regular health screenings.

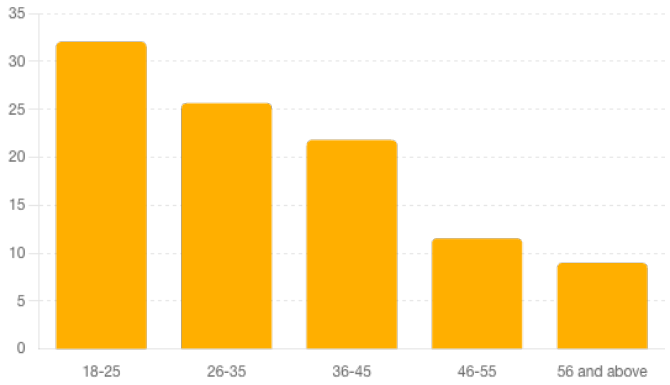

Fig. 4. Age distribution of respondents willing to pay for adoption of a new digital health service

Figure 5 shows that male respondents are more interested in paying up to BDT 2,000 for using the new digital health system compared to female respondents. This trend is not uncommon in developing countries where men are often the primary earners and the main decision-makers for financial issues within families. Therefore, men's higher willingness to pay reflects their role in financial decisions, including healthcare spending.

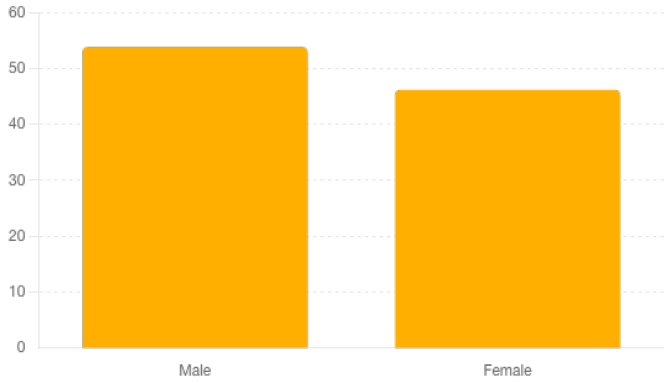

Fig. 5. Gender distribution of respondents willing to pay for adoption of a new digital health service

Figure 6 shows the education level distribution of respondents willing to pay up to BDT 2,000 for using the new digital health system for regular health screening and health data management. The figure highlights that individuals with higher education levels are more likely to pay for preventive care services. This trend is expected, as more educated individuals are generally more aware of the benefits of preventive healthcare and are therefore more willing to invest in it.

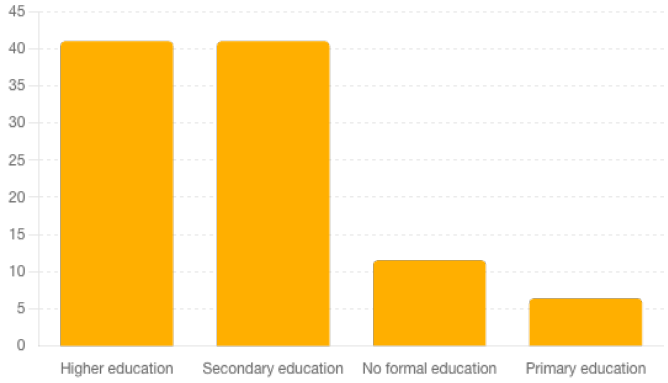

Fig. 6. Education level distribution of respondents willing to pay for adoption of a new digital health service

IV. Discussion

The objective of this study was to identify the types of users willing to pay for a new digital health system for regular health screening and health data management in a rural area of Bangladesh. To achieve this, the response trends from the survey data were analyzed.

The age distribution, shown in Figure 4, indicates that younger people are more interested in paying for the digital health service. This trend suggests that younger individuals, possibly due to their familiarity with technology and awareness of preventive healthcare, are more inclined towards investing in regular health screenings. This finding aligns with the global

trend where younger populations are generally more adaptable to new technologies and preventive health measures.

The gender distribution, depicted in Figure 5, reveals that male respondents are more interested in paying for the digital health service compared to female respondents. This trend is common in developing countries where men are often the primary earners and the main decision-makers for financial issues within families. Therefore, men's higher willingness to pay reflects their role in financial decisions, including healthcare spending. This insight is crucial for policymakers and health entrepreneurs who aim to target the primary decision-makers in households to increase the adoption of digital health technologies.

The education level distribution, illustrated in Figure 6, highlights that individuals with higher education levels are more likely to pay for preventive care services. This trend is expected, as more educated individuals are generally more aware of the benefits of preventive healthcare and are therefore more willing to invest in it. This finding underscores the importance of educational initiatives to raise awareness about the benefits of preventive healthcare among less educated populations.

The study also highlighted significant gaps between awareness and actual usage of digital health technologies. While 60% of respondents are aware of digital health technologies, only 20% reported using them. This discrepancy suggests that efforts should not only focus on increasing awareness but also on addressing the barriers to adoption and usage of digital health technologies. Potential barriers could include lack of access, digital literacy, or trust in these technologies. Interventions such as providing better access to digital tools, offering training to improve digital literacy, and building trust through community engagement and education campaigns could bridge this gap.

V. Conclusion

This study explored the prospects and challenges of implementing a digital health system for regular health screening and health data management in a rural area of Bangladesh. The findings indicate that younger individuals, males, and those with higher education levels are more willing to pay for such services. Despite high awareness of digital health technologies, actual usage remains low, highlighting the need for targeted interventions to address barriers to adoption.

The insights gained from this study can inform the development of targeted strategies to promote the adoption of digital health technologies in rural areas. Policymakers, healthcare providers, and health entrepreneurs can leverage these findings to design and implement effective digital health interventions that cater to the specific needs and preferences of the rural population. By addressing the identified barriers and enhancing digital literacy, it is possible to increase the uptake of digital health technologies and improve preventive healthcare outcomes in rural communities.

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Can We Use Graph Neural Networks (GNNs) in Personal Health Records (PHRs)- Literature Survey

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***Abstract*— A health record that includes personal health information collected by individuals, on top of medical information provided by medical institutions, that is collected, managed, and used by that individual throughout his or her life, is called a Personal Health Record (PHR). In contrast, an Electronic Health Record (EHR) is an electronic record of medical information that can be shared and used with other medical institutions. A data representation in which data is represented as nodes and the relationships between data are represented as edges is called a graph. A method of learning this graph representation with an artificial neural network to solve various tasks is called a graph neural network (GNN). Very little publicly available research exists on the use of GNNs in PHRs. This study aims to find the effectiveness of GNNs in PHRs by investigating examples of GNN use in EHRs, which have already been studied in some details. The results of the study suggest that research using GNNs based on EHR datasets produced superior results compared to existing models that do not use graph representations, and so we conclude that GNNs can be fully used in PHRs, which link heterogeneous data similar to EHRs.**

***Index Terms*—PHR, Personal Health Record, EHR, Electronic Health Record, GNN, Graph Neural Network**

I. Introduction

The use of AI in medicine has been attracting attention. With calls for the promotion of digital transformations in the medical field in Japan, medical institutions are making moves to build data utilization infrastructure. In addition, the spread of smart devices and the use of electronic prescription records and health management apps have led individuals to manage their own health data, and interest is also growing in the use of Personal Health Record (PHR). As it is predicted that various services will be created based on PHRs in the future, the medical and health information of each individual will take on various data formats, and so how to utilize data becomes important. In this study, we investigated existing literature on Electronic Health Record (EHR) and Graph Neural Network (GNN) research to see how PHRs can be utilized using GNN, which are a set of methods that aim to apply deep neural networks to graph-structured data. Graphs describe pair-wise relations between entities, and are essential representations for real-world data from many different domains, including social science, linguistics, chemistry, biology, and physics and thus, are used to obtain various insights from the data.

II. Research Background

A. Personal Health Record, and Electronic Health Record

According to a survey by Kim J, Jung H, and Bates DW, the specific area that PHR refers to has seen continued mixed usage with phrases such as EMR or EHR, and few papers clearly distinguish between the two [1]. Therefore, we investigated the definitions of EHR (Electronic Health Record) and PHR (Personal Health Record). ISO/DTR20514 defines EHR as follows: "The Integrated Care EHR is defined as a repository of information regarding the health of a subject of care in computer processable form, stored and transmitted securely, and accessible by multiple authorised users. It has a commonly agreed logical information model which is independent of EHR systems. Its primary purpose is the support of continuing, efficient and quality integrated health care and it contains information which is retrospective, concurrent and prospective. A system for individuals and their families to accurately grasp health and other information, such as the results of personal health examinations and medication history, in the form of electronic records." On the other hands, in Japan, where the author is based, PHR has not been strictly defined. Therefore, the following definition given by the Ministry of Health, Labour and Welfare (MHLW) in its "Study Group on the Promotion of PHR for National Health Promotion (1st meeting)" is adopted: "A system for individuals and their families to accurately grasp health and other information, such as the results of personal health examinations and medication history, in the form of electronic records." At the third meeting, MHLW made the following three points to keep in mind when considering PHR from the viewpoint of the public and patients: The aim of PHR is for the health and medical information of individuals to be utilized by themselves for prevention and health promotion, and for it to be utilized in medical and nursing care settings with the consent of the individuals. By providing personal health and medical information in a form that is easy for individuals to understand, such as in the form of a summary or history, it will be possible to link these to their own health management and preventive actions, and also to have them consult with doctors, etc. at their request. In addition, the aim is to utilize the data so that everyone can enjoy better healthcare, regardless of age, gender, disability, etc. Through public health policies and health projects by the national and local governments, emergency use such as during national disasters, including for disabled children and adults, who require medical care, and secondary use for research in the health care field [2].

From the above, we interpret the following: EHR is a lifetime electronic record of all medical information generated by medical institutions that can be shared and utilized by other medical institutions. PHR is a health record that includes medical information provided by medical institutions, as well as health information collected by individuals, and is accumulated, managed, and utilized by the individual throughout their lifetime.

B. Graph Neural Network (GNN)

A graph is expressed as $\mathcal{G} = \{\mathcal{V}, \mathcal{E}\}$, where each piece of data

is represented by a node $\mathcal{V}$ and the relationships between data are represented by edges $\mathcal{E}$. A graph represented by one type of node and one type of edge is called a simple graph. However, in the real world, there is a wide variety of data and relationships, so a graph represented by associating types with nodes and edges is called a Heterogeneous Graph. A data structure such as a PHR or EHR, in which a wide variety of data is associated with a node called a patient in a wide variety of relationships, can be considered a Heterogeneous Graph. Applying deep neural networks to graph data like the above is called a graph neural network (GNN), which solves analytical tasks such as node classification, link prediction, and graph classification. In various studies on GNN, various graph embedding methods (i.e., mapping each node of a graph to a low-dimensional vector representation), as well as graph filtering and pooling methods, are adopted [3].

III. Material and Methods

A. Research Questions

We conducted our research with a focus on the following points:

- Literature survey on EHR and GNNs
- Are datasets or benchmarks publicly available?
- Does it include a description of the algorithm, or is the source code publicly available and reproducible?

B. Search Strategy

Initially, we searched for academic papers on PHRs and GNNs, but the number of hits was too few, and even after examining the search results closely, there were only brief references to PHRs, which were not the focus of the research. Therefore, we changed direction to research using GNN methods on EHRs, which have been studied in more details and may be applicable to PHRs. The following query was used for the search to comprehensively output literature containing both "EHR" and "GNN".

("EHR" OR "Electronic Health Record")

AND ("GNN" OR "Graph Neural Network")

The search engine used was IEEE Xplore, an internationally available, widely used and historically important repository of academic articles in Electrical and Electronic Engineering. The search was also conducted with membership privileges enabling us to pick up articles from our wide subscription base using search terms from the text.

C. Selection Criteria

We prioritized papers published in peer reviewed journals over conferences after defining our scope as described in Section IIIA and by using advanced search techniques as described in section IIIB. We still had a lot of papers to skim through abstracts and conclusions to quickly assess the relevance of each. We prioritized more recent papers and considered the reputation of the authors and their affiliations.

IV. Literature Review

C. Su, S. Gao and S. Li proposed a novel graph-attention-augmented temporal neural network for medication recommendation based on Electronic Health Records (EHRs). Medication recommendation is a crucial task in healthcare, aiming to provide personalized prescription recommendations for patients. Existing methods often suffer from limitations due to the selection bias, as they primarily utilize longitudinal EHRs from patients with multiple visits, ignoring those with only a single visit. They claim to enhance medication recommend-dation by incorporating graph-attention mechanisms and temporal modeling, leading to more accurate and personalized prescriptions based on patient records [4].

To address the limitations of drug combination prediction accuracy due to the complexity and uncertainty of clinical situations, H. Wang et al. proposed a new prediction model called TAMSGC, combining two key components; TAM captures the temporal sequence information in medical records and the simple graph convolution (SGC) extracts medication knowledge from complex combinations [5]. Experiments on a real dataset demonstrated that TAMSGC outperforms baseline models in predicting medication combinations.

Most existing models for predicting specific diseases, readmission times, and patient diagnoses utilizing EHR temporal features cannot fully utilize EHR data due to the inherent lack of labels for supervised training of some temporal events. Moreover, existing methods have difficulty simultaneously providing general and personalized interpret-ability. To address these challenges, C. Lu, C. K. Reddy and Y. Ning proposed Sherbet, a self-supervised graph learning framework with hyperbolic embedding for temporal health event prediction [6].

In EHR-based clinical risk prediction, existing solutions usually focus on the inherent relationships between temporal features or clinical event variables, or extract both information in two separate phases, that usually results in insufficient patient feature information and poor prediction performance. Moreover, existing methods based on heterogeneous graph neural networks usually require manual selection of appropriate meta-paths. To solve these problems, Y. Xu et al. proposed the Time-aware Context-Gated Graph Attention Network (T-ContextGGAN) [7].

S. Tang et al. proposed a multimodal, spatiotemporal graph neural network (MM-STGNN) for prediction of 30-day all-cause hospital readmission, which fuses in-patient multimodal, longitudinal data and models patient similarity using a graph [8].

Many recent studies in medication combination prediction (MCP) focus on patient representations from past medical records, but ignore the value of medical knowledge such as prior knowledge and medication knowledge. Chao Gao et al. developed a medical knowledge-based graph neural network (MK-GNN) model that incorporates patient representations and medical knowledge into a neural network [9].

Medical ontologies are often small and coarse-grained, and therefore, many diagnoses and medical concepts as well as various relationships between these concepts are missing. L. Wang et al. proposed to incorporate the existing large-scale medical knowledge graphs (KGs) into diagnosis prediction and devised a stage-aware hierarchical attention relation network (HAR) to overcome this limitation [10].

Q. Liu et al. proposed a knowledge graph-based explainable and personalized cognitive reasoning model (CRKG) that can

utilize EHRs and knowledge graphs to provide personalized diagnoses, perform decision-making in general practice, and simulate human thinking modes [11].

Most studies of EHR prediction tasks using GNN methods adopt a simple structure of the GNN model in a single prediction task, but fail to fully utilize the potential of EHR representations. Compared with previous work, the multi-task prediction could utilize the latent information of concealed correlations between different prediction tasks. In addition, self-contrastive learning on graphs could improve the representation learned by GNN. Y. Cao, Q. Wang, X. Wang, D. Peng and P. Li proposed a multi-gate mixture of multi-view graph contrastive learning (MMMGCL) method, aiming to get a more reasonable EHR representation and improve the performances of downstream tasks [12].

Current drug recommendation methods only model patient health status from EHR data, ignoring the rich relationships within the data. To address this issue, H. Zhang, X. Yang, L. Bai and J. Liang developed a graph representation learning method that utilizes heterogeneous information networks (HINs) to represent EHRs and perform drug recommendation [13].

G. Wang, X. Lou, F. Guo, D. Kwok and C. Cao proposed a novel heterogeneous graph convolutional network method for classifying EHR texts. The EHR-HGCN method comprises three main components: word embedding, heterogeneous graph construction, and heterogeneous graph classification [14].

Existing methods may lack the completeness of recommended medication packages and have difficulty delving into physicians' decision-making processes. To address these issues, F. Zhu, X. Zhang, B. Zhang, Y. Xu and L. Cui proposed DIAGNN, a dual-level interaction-aware heterogeneous graph neural network for medication package recommendation. DIAGNN leverages heterogeneous graphs to explicitly model interactions of medical entities in EHRs at two levels: individual medications and medication packages [15].

Z. Xu et al. presented a novel approach for predicting interventions for patients in the intensive care unit using a multi variate time series graph convolutional neural network [16].

M. Postiglione, D. Bean, Z. Kraljevic, R. J. Dobson and V. Moscato proposed MedTKG, a Temporal Knowledge Graph (TKG) framework that incorporates both the dynamic information of patient clinical histories and the static information of medical ontologies [17].

TABLE I
LIST OF DATASETS AND ALGORITHMS RELATED TO OUR SELECTED REFERENCE ARTICLES

Reference No.	Methods/Algorithms	Datasets/ Benchmarks	Comparison Baseline Model	Algorithm Description
[4]	a novel graph attention-augmented temporal neural network that can capture both the structural and temporal aspects of patient data	MIMIC-III	Logistic Regression (LR), Learn to Prescribe (Leap), Reverse Time AttentIon Model (RETAIN), Graph Augmented Memory Networks (GAMENet), G-Bert	Included
[5]	TAMSGC is based on the temporal attention mechanism (TAM) and the simple graph convolution (SGC)	MIMIC-III TWOSIDES	RETAIN, RNN, LEAP, DMNC, GAMENet, CompNet, G-BERT,	Included
[6]	Sherbet, a self-supervised graph learning framework with hyperbolic embeddings for temporal health event prediction.	MIMIC-III eICU	MLP, DoctorAI, RETAIN, Deepr, GRAM, Dipole, Timeline, G-BERT, HiTANet	Included
[7]	the Time-aware Context-Gated Graph Attention Network (T-ContextGGAN)	MIMIC-IV eICU	SVM, LR, LSTM, T-LSTM, Retain, MedGCN, ConCare, HiTANet	Code available on GitHub
[8]	a multimodal, spatiotemporal graph neural network (MM-STGNN)	MIMIC-IV Not public internal data sets	XGBoost, Gradient Boosting, LR, Naive Bayes, RF, MLP, GraphSAGE, LSTM	Not included
[9]	a medical-knowledge-based GNN model extracts patient features from medical records in different feature subspaces and links them for comprehensive patient representation	MIMIC-III	PKANet, ARMR, AMANet, GATE, G-BERT, GAMENet, TAMSGC, RETAIN, LEAP, SARMR, SafeDrug	Included & Code available on GitHub
[10]	a stage-aware hierarchical attention relation network (HAR) model extracts personalized sub-Knowledge Graphs from existing medical Knowledge Graphs for each patient visit	MIMIC-III MIMIC-IV SemMed: A Public Knowledge Graph	LSTM, Dipole, RETAIN, RAIM, StageNet, HiTANet	Included & Code available on GitHub
[11]	a knowledge graph-based explainable and personalized cognitive reasoning model (CRKG)	Not public internal data sets	RippleNet, KGAT, ECFKG, NFM	Included
[12]	a multi-gate mixture of multi-view graph contrastive learning (MMMGCL) method	MIMIC-III eICU	SVM, KNN, GAT, GCN, GraphSAGE, MLP, Transformer	Not included
[13]	Proposing a bi-channel heterogeneous local structural encoder to decouple and extract diverse information in the EHR's heterogeneous information networks (HINs)	MIMIC-III TWOSIDES	Deepwalk, Node2vec, GCN, GAT, Metapath2vec, HAN, CKD, LEAP, RETAIN, DMNC, GAMENet, COGNet	Included & Code available on GitHub
[14]	EHR-HGCN treats text classification as a graph classification task, allowing it to better capture the structural information of the document, then classifies it based on its graph representation using a heterogeneous GCNN.	20-Newsgroups（20NG） R8 R52 from Reuters 21578 OHSUMED, Movie Review (MR)	CNN, LSTM, Bi-LSTM, FastText, TextGCN	Not included
[15]	a dual-level interaction-aware heterogeneous graph neural network for medication package recommendation (DIAGNN)	MIMIC-III	LR, RETAIN, LEAP, GAMENet, SafeDrug, 4SDrug	Included
[16]	multivariate time series GCNN analyzes real-world ICU records from MIMIC-III dataset	MIMIC-III	RF, LR, CNN, LSTM	Not included
[17]	MedTKG aims to forecast future medical outcomes by identifying potential disorders in a patient's future	MIMIC-III	CNN, RNN, RETAIN, Transformer, TCN, AdaCare, ConCare, StageNet, Dr. Agent, GRASP	Not included

V. Results of Literature Review

We initially found 124 articles using the search strategy in IIIB. We then narrowed them down to "Journals" and "Early Access Articles" to get the most recent, strictly peer-reviewed content, scrutinized that content to determine whether it was research related to EHR, PHR and GNN, and ultimately narrowed them down to 14 articles to review in more details.

VI. Discussions

Three representative references were selected, and a SWOT analysis was conducted on each of these three to evaluate how they could contribute in light of the external environment surrounding PHR.

TABLE II discusses SWOT analysis for reference [6] for example. TABLE III discusses SWOT analysis for reference [10] and TABLE IV discusses SWOT analysis for reference [14]. We also took note for a few other references, like for [18], opportunities include Medical ontologies gaining more attention, such as the adoption of ontologies from ICD-11. However, Ontology construction is labor intensive and slow which can be categorized as a Threat.

These Tables suggest that the studies using GNNs can be applied to tasks using PHRs. However, the lack of data sets and other issues such as underdevelopment of the environment for PHR utilization and scalability are issues that need to be addressed in the future.

As a result of the research and review we have done, studies using GNNs based on EHR datasets cover a wide range of areas, including medication recommendations, drug combination prediction, and readmission prediction, and suggest that by expressing the connections between different data in a graph, such as by relating each clinical event to a knowledge graph, added via learning with a neural network, yields superior results compared to existing models that do not use graph representations.

TABLE II
SWOT Analysis for Reference [6]

	The external environment surrounding PHR	
	Opportunity It is desirable to detect complications even in newly added PHRs with poor historical records.	***Threat*** Lack of a decent PHR data set.
Strength Incorporating all admissions, including both single and the final records of multiple admission patients, without omissions, it is possible to detect disease complications in all admissions.	This study could be applied to tasks such as detecting hidden diseases even in newly added PHR records with poor historical records.	It could be applied by training on an existing EHR data set and repeating self-supervised graph learning by applying it to PHR data as well.
Weakness It only utilizes disease codes in patients' admission records.	Since it depends on training data, it may not be able to adequately detect the disease if past medical history data is scarce.	Due to lack of decent PHR data sets, it is difficult to verify if it is also effective for PHR.

TABLE III
SWOT Analysis for Reference [10]

	The external environment surrounding PHR	
	Opportunity Medical ontologies are gaining more attention, such as the adoption of ontologies from ICD-11.	***Threat*** Ontology construction is labor intensive and slow
Strength Incorporating a large-scale medical knowledge graph (SemMed), it enables diagnostic predictions that takes into account the specific stage of a patient's disease progression.	The adoption of ontologies in ICD-11 will enable a more international standard of medical care to predict diagnosis.	The model must incorporate the existing large-scale medical knowledge graph, and must be validated and applied to PHRs.
Weakness Considered to depend on the knowledge graph used to determine what tasks can be solved.	If ICD-11 could be incorporated into the model as a knowledge graph, a more internationally standardized diagnostic prediction model could be realized.	If the knowledge graph of the existing medical ontology is not updated, diagnoses may also rely on outdated information.

TABLE IV
SWOT Analysis for Reference [14]

	The external environment surrounding PHR	
	Opportunity PHR contains a variety of field data, including numerical and image data, and text-based data may be included in the PHR.	***Threat*** PHR is sensitive data and therefore scarce in datasets that can be used for training.
Strength Obtaining word- and sentence-level embeddings from documents, documents are represented as heterogeneous graphs and classified using a graph convolution network (GCN), which adds depth and context to text classification.	Text classification that adds more depth and context to the text data would enable the task to be solved with a high degree of accuracy in combination with other data in different formats contained in the PHR.	Validation of text data contained in PHR is a possible future task due to the scarcity of training data sets.
Weakness The computational complexity of EHR-HGCN scales as $O(\|V\|^2)$. This poses challenges in its application to large-scale benchmarks.	Scalability issues arise depending on the amount of text in the text data. While following up on future research to resolve scalability, it will be necessary to take measures such as setting input character limits.	Scalability issues could be examined using existing benchmarks such as those listed in "TABLE I."

Researchers have developed graph-based methods to cluster similar patients using basic patient information (such as age, gender) and diagnoses. These patient clusters form a network-like structure that can be analyzed using GNNs. GNNs help

identify relevant medical procedures associated with specific patient clusters.

Regarding datasets, many studies used MIMIC-III datasets, MIMIC-IV datasets, eICU datasets, etc. Many of the articles described the algorithms, and some even stated that the code was posted on GitHub, and the reproducibility was excellent.

As mentioned above in some details and from our analysis of literature survey, GNNs have produced excellent results in tasks such as predicting associations between heterogeneous data and making recommendations, we can safely conclude that it can be fully utilized not only in EHRs but also in PHRs, which are data formats that link health data accumulated by individuals.

VII. Conclusion

Currently, in Japan, the data utilization infrastructure for PHR is being developed in conjunction with the "My Number Card." However, PHR data is extremely sensitive data, and at the same time, data may be missing or inconsistent due to the variety of data linked to patients. In addition, data that can be used for learning is difficult to obtain because the infrastructure is still in the process of being developed.

In order to investigate the effectiveness of using GNNs in PHRs, we reviewed studies that used GNNs in EHRs, which have been researched extensively, suggesting the possibility that GNNs can be fully used in PHRs as well. In the future, when PHRs become more widespread in society and the infrastructure for their use becomes solid, it is expected that the use of GNNs will further improve the quality of medical care and contribute to improving Quality of Life. While continuing to follow research on the application of GNNs to PHRs and EHRs, we would like to continue to study further ways to use GNNs and contribute to medical care.

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Real-Time Data Retrieval from Life-long Medical History Using Small Language Model

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***Abstract*—This study addresses the challenges of managing and visualizing comprehensive medical histories in resource-limited healthcare settings. The Smart Health Gantt Chart (SHGC) system is introduced to improve healthcare delivery by enabling efficient management and sharing of digital medical records. However, current systems face significant obstacles in extracting relevant information from large volumes of data for clinical decision-making. To overcome these issues, the paper proposes a novel approach for the integration of Small Language Models and custom CoVeMedRAG technique to generate real-time, contextual insights from patient histories. The proposed solution includes advanced natural language processing for prompt generation, hybrid retrieval methods, and the use of compact, efficient language models such as phi-3 and TinyLlama. The expected outcomes include improved healthcare provider efficiency, enhanced quality of care, and optimized healthcare operations through real-time data retrieval and visualization. The paper also discusses the challenges of implementing these technologies, such as data complexity and model limitations, and suggests future directions for research and development in smart healthcare technologies and governance.**

***Index Terms*—Smart Health Gantt Chart, Small Language Models, Digital Health Management System, Digital Health, Real-Time Data Retrieval, Healthcare in Developing Countries**

I. Introduction

The integration of advance technological solution in healthcare sector presents a promising avenue for significant challenges, particularly in remote, rural, and undeveloped areas. In these regions, the scarcity of medical resources and low ration of healthcare providers to patient exacerbate the difficulty of delivering quality medical care. This issue can be observed in Bangladesh, where patients receive an average of merely 48 seconds of consultation time per visit [1]. This situation underscores the critical need for efficient systems capable of managing and visualizing comprehensive health histories to enhance healthcare service performance. Recognizing the importance of maintaining detailed patient records, the Smart Health Gantt Chart (SHGC) system emerges as a pivotal innovation designed to support healthcare providers in resource-limited environments. This enables physicians to manage their time and resources more effectively and facilitates patients in maintaining digital medical records that can be easily shared with different healthcare stakeholders. Despite its benefits, the SHGC encounters significant obstacles in leveraging the full potential of digital records, particularly in assisting physicians to pinpoint relevant disease markers within expansive medical histories. The overwhelming volume of data, coupled with the exigency for precise and timely information retrieval, presents substantial challenges in distilling essential details for medical decision-making [2]. Existing systems often struggle to efficiently process large amount of data to deliver essential insights critical for informed clinical judgements, although they provide a feasible visual ascent but on relevance of context. [3] [4].

In response to these challenges, this paper proposes to explore and advance methodologies that can generate real-time contextual insights from patient histories. The objective is to significantly enhance the visualization capabilities of medical histories, employing state-of-the-art technology Language Models and Retrieval-Augmented Generation techniques. By integrating relevant case precedents and current patient data, this approach aims to facilitate superior clinical decision-making processes. This research not only seeks to refine the functionality of systems like the SHGC but also aims to provide a template for future innovations in smart healthcare technologies, enhancing the overall efficacy of medical services.

II. Challenges of medical visual system

In the healthcare sector, efficient access, accurate interpretation and relevant content of medical records are paramount for effective patient management and treatment decisions. However, healthcare providers frequently encounter significant hurdle in navigating through extensive medical records, particularly when it comes to reviewing dense chart points and addressing diagnosis-specific issues. A notable 82% of doctors have reported challenges in comprehensively analyzing patient records, primarily due to the inadequacy of current visualization tools [5]. Such deficiencies in visualization and data quality complicate the interpretation and utilization of patient information, leading to time-consuming processes and the potential oversight of critical details.

1) **Lack of Real-time Contextual Assistance**: Modern medical visualization systems often fail to provide real-time, contextual assistance that adapts to the users' needs. This lack of assistance can hinder the ability of healthcare providers to make informed decisions swiftly. Context-aware systems that adapt to user queries and provide relevant information could significantly enhance decision-making efficiency [6].

2) **Inflexible Data Interaction**: The interaction mechanisms available in many medical history visualization tools are rigid, offering limited options for data manipulation. This inflexibility can prevent healthcare providers from exploring patient data in more insightful ways.
3) **Overwhelming Diagnosis Points**: Another significant issue is the excessive complexity and volume of diagnosis points presented, which can overwhelm users. This complexity often leads to cognitive overload, hindering the ability to quickly comprehend a patient's medical history [7].
4) **Summarization of Patient History**: Effective summarization of patient history is lacking in many systems, making it challenging for healthcare providers to gain quick insights into a patient's medical background [8].

Current visualization systems lack real-time understanding of doctor-patient conversations, crucial for dynamic graph updates based on ongoing interactions as mentioned in Figure 1. Furthermore, these systems struggle to generate concise patient text summaries relevant to current conversations and medical history. This gap hinders seamless integration into healthcare workflows, where providers need real-time assistance and accurate summaries for informed clinical decisions.

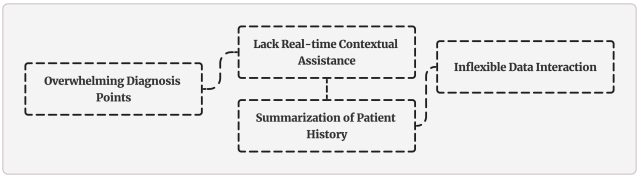

Fig. 1. Noticeable Challenges in Medical History Visualization Systems

III. Existing Work

In recent years, significant advancements have been made in various areas of natural language processing, including the development of Small Language Models (SLMs), Retrieval Augmented Generation (RAG), and Chain of Verification Prompting (CoV). These technologies have shown promising results in enhancing the efficiency, accuracy, and reliability of language models in medical and other specialized domains.

A. Small Language Model

Small Language Models (SLMs) are efficient and require lower computational resources compared to larger models. Characterized by fewer parameters and streamlined training data, SLMs have shown enhanced reasoning skills from medical textbooks. As evidenced by, SLMs trained on comprehensive medical literature can achieve performance levels comparable to larger models while maintaining efficiency [9].

B. Retrieval Augmented Generation

Retrieval Augmented Generation (RAG) combines retrieval-based and generative models to enhance NLP and reduce Hallucination. Researchers have used RAG for processing unstructured medical data and developed robust summarization systems. One study introduced LogicSumm, an evaluation pipeline for RAG-augmented summarization across seven scenarios, aiming to improve robustness and performance through training dialogues and model fine-tuning [10].

C. Chain of Verification Prompting

Prompt engineering has become crucial for enhancing pre-trained model capabilities. The Chain of Verification (CoV) is a prompt engineering method designed to reduce hallucinations and ensure response reliability in language models. A study by [11] explores CoV's implementation to mitigate hallucinations in large language models, showing that incorporating a verification step, where responses are cross-checked against reliable sources, significantly improves accuracy and trustworthiness.

IV. Our Approach

Our solution introduces a novel approach using Small Language Models (SLMs), a Prompt Generator, and CoVeMedRAG. We will experiment with open-source SLMs such as phi-3, TinyLlama, and Meerkat-7B. Various retrieval strategies will be discussed to ensure the accuracy and credibility of generated text, using the Portable Healthcare Clinic dataset as an external database. Our aim is to integrate these models into broader systems to enhance reasoning capabilities and content summarization in the medical domain. This exploration seeks to improve graph visualization and patient-trial matching, focusing on the relevance of patient medical history. Figure 2 shows the concept-level diagram.

A. Prompt Generator

The essential module before the data retrieval process is prompt generator. It systematically transforms raw queries from healthcare professionals into refined, contextually enriched prompts. This module, referred to as the is pivotal for ensuring that the queries are precisely tailored to elicit the most relevant and accurate information from the vast repositories of medical data. Utilizing advanced techniques such as the Automatic Prompt Engineer and Rephrase and Respond Prompting. It acts as a sophisticated front-end processor that refines and contextualizes user inputs.

Automatic Prompt Engineer (APE): The APE is designed to automate the creation and refinement of prompts based on the specific requirements of the medical context [12]. By dynamically generating tailored prompts, the APE ensures that the retrieval system focuses precisely on the relevant aspects of medical knowledge bases, thus enhancing the efficiency and relevance of the retrieved data. This automated engineering of prompts is crucial, especially in scenarios where the input data varies significantly in terms of specificity and detail.

Rephrase and Respond (RaR) Prompting: The RaR technique complements the APE by further refining the prompts to ensure they match the expected input format of the retrieval system. It rephrases user queries into a structured format that is more likely to generate precise and useful responses from

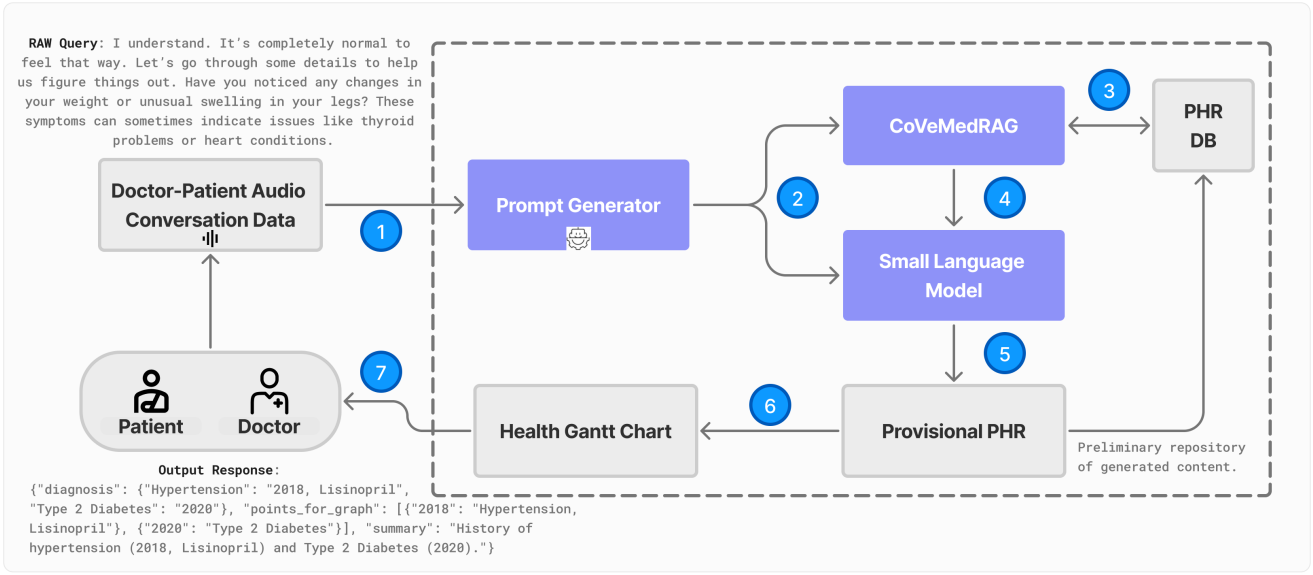

Fig. 2. Integration of SLM with advanced RAG technology in processing doctor-patient conversations to generate actionable health data visualizations and personalized health records

the Modular RAG system [13]. This not only improves the user experience by providing more accurate responses but also significantly reduces the likelihood of retrieving irrelevant or incorrect information, a critical factor in medical applications.

Additionally, the module utilizes query rewriting strategies to rephrase and reorder query components, improving alignment with database indexing systems and enhancing search result precision. This holistic approach streamlines the retrieval process, significantly increasing the accuracy and relevance of information provided to healthcare professionals, thereby supporting more informed clinical decisions and enhancing patient care outcomes.

B. CoVeMedRAG

The core module is CoVeMedRAG. It introduces an advanced framework for integrating the CoVe with Advanced RAG to improve the accuracy and reliability of AI-generated medical texts. This approach emphasizes precision and verification in a field where the stakes of misinformation are high. RAG is an framework that improves language model performance by integrating retrieval processes directly into the text generation pipeline. The process comprises three primary stages: indexing, retrieval, and generation. For indexing, the Facebook AI Similarity Search (FAISS) is utilized, allowing for the efficient retrieval of relevant information [14]. Subsequently, the retrieved data is used in the generation phase to dynamically incorporate external data into the text generation process [15]. This stage benefits significantly from the context provided by the retrieved data, leading to outputs that are not only relevant but also rich in detail and grounded in factual information .

The core encompasses a comprehensive spectrum of retrieval activities—Pre-Retrieval, Retrieval, and Post-Retrieval—which are enhanced by the integration with CoVe and specifically tailored for use with the Portable Health Clinic dataset [16]. Unlike the traditional Native RAG, it dynamically and more effectively integrates external data during the text generation. Furthermore, research has demonstrated that RAG optimizes language models and offers a more advantageous strategy compared to traditional fine-tuning of large language models [17].

1) Pre-Retrieval: The native-RAG encountered issues with data indexing, crucial for ingestion, chunking, and embedding of text. This component has been enhanced through several optimization techniques: data granularity enhancement, index structure optimization, metadata addition, alignment optimization, and mixed retrieval. These improvements result in superior indexed data quality and more accurate retrievals [15].

The process initiates with **enhancing data granularity**, segmenting documents into smaller, pertinent chunks to increase the specificity and relevance of retrieved information. **Optimizing index structures** involves deploying advanced data structures such as inverted indexes and vector databases, which facilitate efficient high-dimensional searches, thus elevating retrieval speed and accuracy. The integration of **metadata** adds layers of context (timestamps, author information, tags), enhancing the precision in identifying and retrieving relevant information. **Alignment optimization** adjusts the semantic alignment of indexed data with retrieval models by fine-tuning embedding to capture domain-specific nuances. **Mixed retrieval** strategies, blending keyword-based and semantic

searches, significantly enhance the robustness and comprehensiveness of the retrieval outcomes.

2) Retrieval: This part aim to improve by optimizing the embedding model itself which directly impacts the quality of the chunks that make up the context. This can be done by fine-tuning the embedding to optimize retrieval relevance or employing dynamic embedding that better capture contextual understanding. For better word extraction, we will consider a dual approach where both semantic and keyword-based retrieval methods are used to fetch data. Semantic retrieval involves understanding the context and meanings behind the query, often using machine learning models to find documents that conceptually match the query. Keyword-based retrieval, on the other hand, looks for exact or close matches to the words in the query within the indexed documents.

3) Post-Retrieval: This part focus on avoiding context window limits and dealing with noisy or potentially distracting information. It involves several critical steps designed to filter and organize the retrieved content for optimal integration with large language models. One of the primary techniques used is **re-ranking**, where retrieved document chunks are rearranged based on their relevance and importance to the query. This ensures that the most pertinent information is prioritized, significantly improving the contextual alignment of the generated responses. Re-ranking typically employs advanced algorithms to reassess the semantic similarity between the query and the retrieved data, effectively filtering out less relevant content. Additionally, **Context window management** is another essential aspect, addressing the limitations of language models regarding input size. Finally, **noise reduction** strategies are employed to eliminate irrelevant information from the retrieved data. By recalculating the semantic relevance and filtering out non-essential chunks, the system can maintain a high signal-to-noise ratio [17].

C. Small Language Model

The compact pre-trained models are designed for natural language processing tasks, characterized by their relatively small size, typically ranging from a few million to a few billion parameters. The concept of SLMs emerged as a response to the increasing computational demands and resource constraints associated with LLMs, which can have hundreds of billions of parameters. The development of SLMs aims to balance computational efficiency with high performance in specific tasks, making them suitable for environments with limited hardware capabilities and low latency. These models need are build in specialized domains where tailored datasets can improve content relevance. Techniques like model compression, knowledge distillation, and transfer learning are often employed to optimize them. DaSLaM framework which uses fine-tuning SLMs to coordinate with larger models [18], which uses a 13B parameter model to decompose complex problems into simpler sub problems that can be solved more efficiently. The Phi series of models developed by Microsoft Research exemplifies the power of SLMs. The Phi-2 model, with 2.7B parameters, achieves state-of-the-art performance on several benchmarks, outperforming models up to 25 times larger [19]. Soon after, they introduce phi-3 Family models, varying from 3.8B, 7B and 14B parameters [20]. TinyLlama was introduce as an open-source project with approximately 1.1B parameters. It was pretrained on around 1T tokens over approximately three epochs, leveraging the architecture and tokenizer of Llama 2. The model incorporates several advanced techniques from the open-source community, such as FlashAttention and Lit-GPT.

V. Expected Outcome

The implementation of the proposed system in developing countries, particularly in resource-limited settings like subcontinent is anticipated to yield several significant social and financial benefits.

A. Social Benefits

Improved Healthcare Access: It will enhance access to healthcare by providing digital medical records that can be easily shared among healthcare providers. This is particularly beneficial in rural and remote areas where access to healthcare is limited.

Enhanced Quality of Care: With comprehensive and easily accessible medical histories, healthcare providers can offer more informed and timely medical decisions, leading to improved patient outcomes.

Continuity of Care: The proposed system facilitates seamless transitions of care by maintaining up-to-date and accurate medical histories, which is crucial for patients with chronic conditions requiring long-term management.

B. Financial Benefits

Cost Savings: The system is expected to reduce healthcare costs by minimizing redundant tests and procedures through better information sharing and coordination among healthcare providers.

Increased Productivity: The reduction in time spent on administrative tasks and manual record-keeping will increase the productivity of healthcare providers, allowing them to focus more on patient care.

C. Technological Advancements

Enhanced Data Visualization: The proposed system will incorporate advanced data visualization tools, such as the Smart Health Gantt Chart (SHGC), to provide clear and actionable insights from patient data.

Real-Time Data Retrieval: Leveraging smaller models with CoVeMedRA, the system will offer real-time contextual insights, improving the decision-making process for healthcare providers.

Scalability and Adaptability: The use of compact, efficient models like SLMs ensures that the system can be scaled and adapted to various settings, including those with limited computational resources.

VI. Challenges and Limitation

While compact models like Phi-3 have surpassed GPT-3.5 in certain academic benchmarks [20], their application in real-world scenarios presents several challenges that require thorough consideration and strategic mitigation. Key challenges include:

- *Data Complexity and Volume*: Compact models may struggle with processing and synthesizing large volumes of unstructured medical texts due to their limited capacity for embedding and comprehending the deep contextual nuances of medical data. This limitation could compromise the quality of the generated content and potentially omit critical information.
- *Factual Knowledge and Domain Specificity*: Given that these models are trained on domain-specific datasets with fewer parameters, they may lack the multi-step reasoning capabilities necessary for addressing complex medical issues effectively.
- *In-accurate information*: Similar to larger language models, compact models are also prone to produce hallucinations and unbiased content.
- Language Restrictions: Due to the nature of models pre-training, it does not inherently support multiple languages unless specifically trained on multilingual datasets.

VII. Conclusion

In this paper, we have presented a novel concept approach for real-time data retrieval from a patient's medical history using the capabilities of small language models, integrated with retrieval-augmented generation techniques. Our aim to streamline the summarize the extensive medical histories into actionable insights, dynamically reflecting updates in a health graph. While the practical implementation of these technologies is in its conceptual stages, the expected outcomes include enhanced accuracy and speed in accessing and summarizing patient histories, which could significantly aid healthcare professionals in decision-making processes. The theoretical framework suggests that utilizing small language models can provide a balance between performance and computational resources. Future work will involve rigorous simulation and testing on the ground truth generated to evaluate its reliability. Since our primary focus are on open-source models data privacy, transparency, and integration with existing healthcare systems won't be a hurdle.

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Use of Extended Reality on Patient Education and its Impact: A Systematic Review

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***Abstract*—This study provides a systematic overview of the current research on the use of extended reality (XR) in patient education. The study followed the well-known PRISMA guideline and ultimately selected 8 papers for review after applying exclusion criteria. The findings indicate that virtual reality (VR) is a feasible and acceptable educational tool in healthcare, potentially enhancing patients' knowledge about their illness and increasing satisfaction with treatment. Most VR studies utilized Oculus headsets, with 360-degree VR being the predominant format. Augmented reality (AR) and mixed reality (MR) also demonstrated positive outcomes in patient education. While XR shows promise in effectively communicating medical information to patients, further research is necessary to fully establish its benefits.**

***Index Terms*—Extended Reality (XR), Patient Education, Systematic Review, AR, VR, MR**

I. Introduction

Patient education refers to a set of intentional informational materials aimed at enhancing a patient's understanding of their illness, treatment, and health-promoting behaviors [1]. Effective patient education equips patients with the knowledge needed to make informed healthcare decisions, promoting autonomy. The best possible patient education and communication can lead to greater patient satisfaction, improved adherence to treatment, and more positive results in terms of health [2]. Thus, individuals who are given Patients who get good patient education are more likely to comprehend medical information and feel more like patients empowered [3], [4]. Patient education can also reduce medical costs by decreasing treatment time.

A review indicated that between 40% and 60% of patients cannot correctly recall the information provided by their healthcare provider 10–80 minutes after consultation [5]. Additionally, 60% of patients misunderstood the information given regarding prescribed medication immediately after consultation [5]. This misunderstanding may be due to a lack of involvement and how medical information is typically presented to patients.

Research suggests that individuals can better retain new scientific concepts through 'learning by doing' [6]. A potential solution to improve the effectiveness of patient education is the use of Extended Reality (XR) technologies, as these can aid in visualizing medical information. Utilizing 3D models in patient education may enhance patients' understanding of their disease and serve as a tool to align the perspectives of patients and professionals on the disease.

A growing body of evidence suggests the potential of Extended Reality (XR) technologies, such as Virtual Reality (VR) and Augmented Reality (AR), in enhancing patient education. Several systematic and scoping reviews have highlighted the effectiveness of XR applications in improving patient satisfaction, knowledge retention, and reducing anxiety across various medical contexts.

This study conducted a systematic review of recent advancements in patient education using extended reality. Section II discusses the methodology used for this review. The study results and findings are summarized in Section III. Section IV highlights the future work including a suitable method to be used in our proposed PHC framework.

II. Materials and Methods

This systematic literature review used the following methods to find and explain significant research papers.

A. Literature search methods

This systematic literature review was conducted following the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines as shows in Figure1. The PICO(T) strategy was defined as follows: the population consisted of patients or their substitutes; the intervention involved XR-based educational tools; the control group was not specified as a criterion for selecting studies; the outcomes focused on the effects on patient education, perceived knowledge gain, patient satisfaction, and health literacy and capturing the timeframe of the study.

B. Identifying relevant studies

A comprehensive literature search was conducted on Google Scholar on June 10, 2024. Initially, a keyword-based search was performed using "Extended Reality in Healthcare Education," which yielded a total of 18,900 results. The search was then refined by including the exact phrase "Patient Education" and limiting the date range to 2015-2024, reducing the results to 17,300. Next, Boolean terms 'OR' and 'AND' were used to combine terms such as XR, AR, VR, and MR with the keywords, narrowing the results to 86. After excluding review papers, the final count of relevant articles was 74.

C. Selection of eligible studies

All studies were initially identified, and through manual selection, 15 studies were chosen. Manual selection was

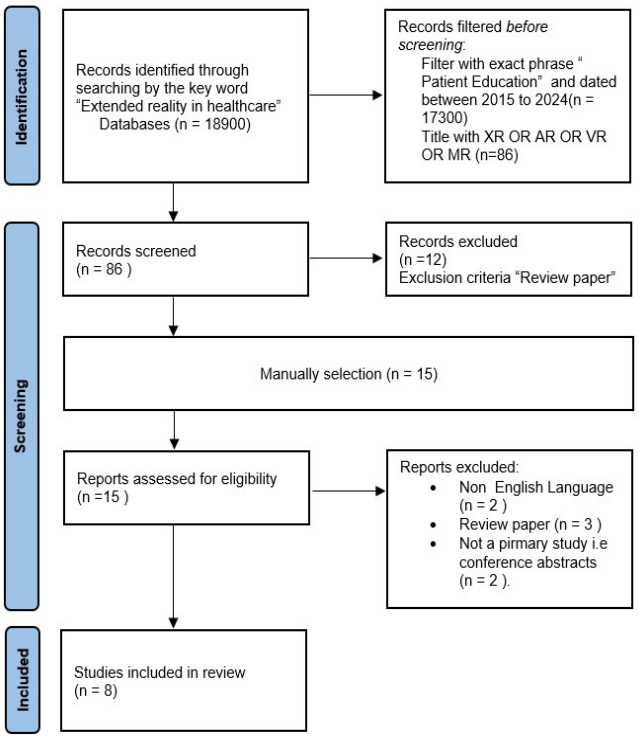

Fig. 1. PRISMA flow diagram of study selection.

proposed by the authors and verified by an expert. To be eligible, studies needed to be in English. Two papers were in German, so they were excluded. Additionally, three were review papers, and two of these were not primary studies but conference abstracts, so they were also excluded. This left us with eight papers that met our eligibility criteria. These studies used human participants or patients, focused on XR technology, targeted patient education outcomes, had a proper study design, and were written in English. Table I, provides an overview of inclusion and exclusion criteria.

D. Data extraction and synthesis

Data were extracted from studies that met the inclusion criteria. Both quantitative and qualitative data were entered into a Microsoft Excel spreadsheet and categorized accordingly. The extracted data included information on the author, year of publication, country of study, study design, aim of the study, sample size, average age, study population, study outcomes, most relevant findings, recommendations for future studies, device used, duration and frequency of use, place of use, and type of content used.

III. Review Results

A. Study characteristics

Initially, a total of 18,900 articles were identified. The most common reasons for exclusion were related to relevance to patient education and recency of publication. Following the PRISMA guideline, 8 papers were selected for review. Three of them were randomized controlled trials (RCTs), one was a cross-over RCT [7], three were pilot studies, one was a pre-test study [8], and one was a pre-test and post-test study [9].

TABLE I
Inclusion and Exclusion Criteria

Criterion	Inclusion Criteria	Exclusion Criteria
Language	English	Non-English
Type of Study	Primary studies using human participants or patients	Review papers, conference abstracts
Technology Focus	XR technology (e.g., AR, VR, MR)	Studies not focusing on XR technology
Outcome Focus	Patient education (e.g., information recall, knowledge gain)	Studies not focusing on patient education
Study Design	Properly designed studies	Studies with inadequate or unclear study designs

B. Patient characteristics

The studies addressed a variety of populations, ages, and conditions. The number of participants ranged from 8 to 182, with a mean age ranging from 43.3 to 68.5 years. Each study included both male and female patients. Additional information is provided in the table II.

C. Geographical context

Two of the papers are from Germany [9], [10], two are from the USA [8], [13], one is from Iran [7], one is from Thailand [12], one is from Czechia [14], and one did not specify the location but was conducted somewhere in Europe [11].

D. hardware and software

We are reviewing the entire XR domain in healthcare education, encompassing a variety of hardware and software. Three studies used 360-degree virtual reality [7], [11], [14], two used virtual reality technology [9], [12], two utilized augmented reality [8], [13], and one employed mixed reality [10]. Consequently, the hardware and software differed among the studies.

For hardware, one study used Magic Leap 1 with a personal computer [10], two studies used Oculus Quest 2 [12], [14], one used Cardboard VR [11], and one study also incorporated a 3D printer [9]. The augmented reality-based studies used tablets and mobile phones [8], [13], while one study did not specify the hardware used [7].

Regarding software, the following were utilized: DICOM Dataset [8], [10], [13], Elements Viewer [10], IBM SPSS [9], [11], [14], Power Analysis Sample Size (PASS) [7], 3DSlicer [8], MeshLab [8], Blender [8], [9], SiraMedical [8], Unity [9], and GraphPad Prism [9]. Additional information is provided in the table II.

TABLE II
REVIEW SUMMARY: PART 1

Author year	Study design	Participants	Experiment group	Control group	Technology	Hardware	Software
Johannes et al., 2023 [10]	Pilot Study,RCT	Total participant n = 50, Male n = 44, Female n = 6, Mean age = 68.5	n = 25	n = 25	MR	Magic Leap-1, Personal Computer	Elements Viewer software
Astrid et al., 2023 [11]	RCT	Total participant n = 134, Male n = 83, Female n = 51, Mean age = 66	n = 68	n = 66	360 degree VR	Oculus Go, Cardboard VR	IBM SPSS Version 28
Surachet et al., 2024 [12]	RCT	Total participant n = 107, Male n = 38, Female n = 69, Mean age = 58	n = 58	n = 49	VR	Oculus Quest 2	Not specified
Fatemeh et al., 2023 [7]	Cross-Over RCT	Total participant n = 150, Male n = 22, Female n = 122, experimental group Mean age = 43.85, Distraction Group mean age = 41.02, control group mean age = 47	Education Group n = 50, Distraction Group n = 50	n = 50	360 degree Virtual reality	Not specified	Power Analysis Sample Size (PASS)
David et al., 2024 [8]	Post-test survey	Total participant n = 8, Male n = 4, Female n = 4, Mean age = 57	n/a	n/a	AR	Tab	3DSlicer, MeshLab, Blender, SiraMedical
Maximilian et al., 2023 [9]	Pre-test and post-test	Total participant n = 99, Male n = 87, Female n = 12, Mean age = 64.8	VR Group n = 31, 3D print group n = 34	n = 34	VR	3D printer(Agilista), Oculus Quest 2	Blender, Unity, GraphPad Prism software, SPSS
Liam et al., 2024 [13]	Pitot study	Total participant n = 75, Male n = 25, Female n = 50, Mean age = 64.4	n/a	n/a	AR	Mobile Phone	Not specified
Bogna et al., 2023 [14]	Randomized Pilot Study	Total participant n = 182, Male n = 99, Female n = 83, Mean age = 66	n = 94	n = 88	360 degree VR	Oculus quest 2	SPSS® Statistics software

E. Education provided

All studies aimed to educate patients on different types of programs, such as atrial fibrillation [11], abdominal aortic aneurysm (AAA) [2], esophagogastroduodenoscopy (EGD) [12], laparoscopic cholecystectomy [7], spine fracture [8], cardiac surgery [9], and radiation oncology [13].However, most studies primarily focused on reducing patient anxiety through education [7], [11], [12], [14] Three of the studies used 360-degree video to educate patients about laparoscopic cholecystectomy [7], fibrillation ablation [11], and hypertension [14]. Among these, one study also used 360-degree images of nature, space, and the ocean to reduce anxiety [7]. Two studies used 3D content and models for education [9], [12], with one of these also incorporating 3D printed models [9]. Two studies used mobile phones to augment 3D models for discussing spine anatomy [8] and simulating radiation treatment [13]. One study used mixed reality to educate about abdominal aortic aneurysm [10]. Additional information is provided in table III.

F. Outcome measures

The method of assessing patient understanding was evaluated using various surveys. Seven studies used the Likert scale [7]–[12], [14]. Three studies used the Visual Analog Scale (VAS) [7], [9], [12]. Additionally, some focused methods were employed to achieve outcomes, such as the Amsterdam Preoperative Anxiety and Information Scale (APAIS) [11], State-Trait Anxiety Inventory (STAI) [9], [12], Spielberger's State Anxiety Inventory [7], McGill Pain Questionnaire [7], Trait-Anxiety-Score (TAI) [9], German short version of the STAI [9], and basic patient surveys.

G. Patient understanding and satisfaction

Four studies measured patient anxiety and information gain simultaneously [7], [9], [11], [12]. One study found no significant difference between the MR group and the control group in informational gain (MR group: 1.4±1.8; Control group: 1.4±1.8; p=0.5) or patient satisfaction scores (MR group: 18.3/21 points (±3.7); Control group: 17/21 points (±3.6); p=0.1). However, 92% of patients reported that the HMD helped them understand the disease, and 96% agreed it improved their understanding of complications [10].

Another study showed that fewer patients were worried about the ablation procedure in the VR group compared to the control group [13 (19.1%) vs. 27 (40.9%), P=0.006]. Specifically, fewer patients under 65 years were worried in the VR group compared to controls [7 (21.2%) vs. 13 (50.0%), P=0.020]. Patients aged 65 years in the VR group felt better informed about the catheterization laboratory environment compared to controls [29 (82.9%) vs. 22 (55.0%), P=0.010] [11].

A study on VR-assisted patient education before EGD did not significantly reduce anxiety but did improve memory and understanding of the procedure for non-sedated EGD patients

TABLE III
REVIEW SUMMARY:PART 2

Author	Study Duration	Education Provided	Outcome Measure	Result
Johannes et al., 2023 [10]	June 2021 to July 2022	A virtual 3D model of a patient's abdominal aortic aneurysm(AAA) based on CT angiography, viewable and interactive via a head-mounted display for learning about AAA.	Patient survey, Likert scale	Both groups improved their Informational Gain Questionnaire (IGQ) scores after education (MR group: 6.5±1.8 to 7.9±1.5; Control group: 6.2±1.8 to 7.6±1.6; p¡0.01). No significant difference was found between groups in informational gain (both 1.4±1.8; p=0.5) or patient satisfaction (MR: 18.3±3.7; Control: 17±3.6; p=0.1). Multiple regression showed no correlation between MR use and informational gain or patient satisfaction.
Astrid et al., 2023 [11]	January 2020 to August 2021	The study used VR video. It included preparation advice, an overview of the ablation procedure, catheterization environment, and post-procedural self-care tips. The video provided a 360° tour of the hospital ward and operating room.	Patient survey (Amsterdam Preoperative Anxiety and Information Scale (APAIS)), Likert scale	Fewer patients in the VR group were worried about the ablation procedure compared to the control group [13 (19.1%) vs. 27 (40.9%), P=0.006].
Surachet et al., 2024 [12]	November 2021 to January 2023	Teach about upper gastrointestinal endoscopy, specifically esophagogastroduodenoscopy (EGD), and reduce anxiety.	State–Trait Anxiety Inventory (STAI) , 10-point Visual Analogue Scale (VAS), Likert scale	VR-assisted patient education before EGD did not significantly reduce anxiety but may improve memory and understanding of the procedure for patients undergoing non-sedated EGD. Mean anxiety scores before the education program were 41.4 ± 9.6 (VR group) and 41.9 ± 7.7 (control group). Post-program, scores were 37.1 ± 10.8 (VR) and 38.9 ± 8.07 (control) (P = 0.354). The change in scores was 4.2 ± 5.6 (VR) and 2.9 ± 5.1 (control) (P = 0.230).
Fatemeh et al., 2023 [7]	August 2020 to February 2021	Teaching about laparoscopic cholecystectomy using VR.	Spielberger's State Anxiety Inventory, Visual Analog Scale(VAS), McGill Pain Questionnaire	The results showed a significant reduction in preoperative anxiety mean scores in both VR groups compared to the control group ($p < 0.001$). Additionally, a significant decrease was observed in postoperative pain scores among patients in the intervention groups compared to the control group (p = .001).
David et al., 2024 [8]	June 2021 to July 2022	A 3D spine model was presented to patients via augmented reality (AR) by a resident, covering spinal anatomy, injuries, treatment options, and potential complications.	Likert-scale	All patients rated the AR software's ability to enhance understanding of specific anatomy, injury, treatment plan, and complications as the maximum score of "great help."
Maximilian et al., 2023 [9]	December 2019 to March 2022	Teaching about cardiac surgery using VR and 3D printing.	Likert scale, VAS(1–10), STAI, Trait-Anxiety-Score (TAI), German short version of the STAI	Significant anxiety reduction, measured by Visual Analog Scale, was achieved after patient education with virtual reality models (5.00 to 4.32, -0.68, $p < 0.001$).
Liam et al., 2024 [13]	May 2021 to January 2023	Teaching about radiation oncology using augmented reality (AR).	Likert Scale.	After the AR session, 95% reported improved understanding of radiotherapy treatment (p = 0.38). Among the 35 initially anxious patients, 60% indicated reduced anxiety following the AR session.
Bogna et al., 2023 [14]	Not specified	Teaching about hypertension using virtual reality (VR).	post-intervention survey,likert scale	Median objective scores were significantly higher for VR (14, IQR 3) compared to traditional education (10, IQR 5), $p < 0.001$.

[12]. Another study reported a significant reduction in preoperative anxiety scores in VR groups compared to the control group (p ¡ .001). All patient scores were at maximum (4—great help) for the AR software's effectiveness in understanding anatomy, injury, treatment plan, and complications [8].

A different study achieved a significant reduction in anxiety measured by the Visual Analog Scale after patient education with VR models. Procedural knowledge increased significantly in all groups, with the highest ratings for visualization and satisfaction in the VR group compared to conventional paper sheets [9]. Lastly, a single-arm prospective study found that a simplified, low-cost tablet-based personalized AR simulation can be a helpful educational tool for cancer patients undergoing radiotherapy [13].

IV. DISCUSSION

This systematic review aimed to explore the current literature on the use of extended reality (XR) as a patient education tool. Eight studies were identified that utilized various XR tools to educate patients or communicate medical knowledge.

The findings suggest that XR has the potential to positively impact patient education, satisfaction, and anxiety levels.

The majority of the studies employed randomized controlled trials (RCTs), dividing participants into experimental and control groups. These studies indicated that, following the intervention, levels of anxiety, distress, and systolic blood pressure significantly decreased, while satisfaction and knowledge significantly increased in the intervention group compared to the control group, across both pediatric and adult patients.

AR, VR, and MR all demonstrated strong performance, with most studies utilizing 360-degree VR. However, the research was often time-consuming, with study duration ranging from 6 to 30 months. A limitation of this review is that, due to resource constraints, the reviewer independently screened and extracted data from only a portion of the papers. Additionally, there is a lack of research focused on general patient education, which is another limitation.

Our lab has developed Portable Health Clinic (PHC), a remote healthcare solution that integrates eHealth and telemedicine functions [15]. This study will use this platform to educate the human resources e.g. healthcare workers, patients and doctors to evaluate the impact of using XR in healthcare in PHC system.

V. Conclusion

This systematic review reveals that extended reality (XR) technologies, including virtual reality (VR), augmented reality (AR), and mixed reality (MR), have significant potential as patient education tools in healthcare. The reviewed studies demonstrated that XR can effectively enhance patient knowledge, improve satisfaction with treatment, and reduce anxiety. Most of the studies focused on VR, particularly using Oculus headsets and 360-degree VR formats, which showed positive results. AR and MR also yielded promising outcomes in patient education. However, the current body of research is still limited, and further studies are needed to explore the long-term benefits, identify the most effective applications, and assess the scalability of XR technologies in diverse healthcare settings. Future research should also consider the specific needs of developing countries to ensure that XR can be effectively utilized in patient education globally.

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Innovative Social Business Strategies for HIV and STI Screening and Counseling: Transforming Healthcare through Digital Solutions

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***Abstract*—Approximately 25% of new global HIV transmissions occur in Asia and the Pacific, accompanied by challenges with HBV, HCV, and STIs. To address these issues and aim to end AIDS by 2030, this guide—developed from a consultative process with Thai community-based organizations (CBOs) from July to December 2023—emphasizes a people-centered and social business approach, prioritizing financial independence and sustainability for long-term impact. It explores innovative strategies for financing and expanding testing, treatment, prevention, and counseling services, focusing on at-risk, marginalized, and economically disadvantaged populations. The guide examines social business innovations to deliver affordable, scalable, and user-friendly solutions, introducing task shifting, resource efficiency, streamlined operations, and consumer education. It underscores the importance of non-financial support in scaling public health outcomes, such as training and mentorship, and offers recommendations including economic analyses, policy development, private finance mobilization, and capacity development for health service providers. While centered on Thailand, the guide's principles are adaptable globally, serving as a roadmap for tailoring social business models to end AIDS worldwide.**

***Index Terms*—Social Business, HIV/AIDS Prevention, Public Health Innovation, Community-Based Organizations (CBOs), Sustainable Healthcare Solutions**

I. Introduction

Nearly a quarter of new HIV infections in the world occur in Asia and the Pacific, a region with the second-highest number of people living with HIV. Other infections including some sexually transmitted (STIs), such as syphilis, hepatitis B virus (HBV), hepatitis C virus (HCV), Chlamydia trachomatis (CT), Neisseria gonorrhoeae (NG), Mpox, Human Papillomavirus (HPV), and tuberculosis (TB) are of concern from a public health perspective. At-risk populations and groups at the bottom of the socioeconomic pyramid face a range of challenges to access HIV and other health services including stigma and discrimination. The prevalence of HIV among at-risk populations globally ranges from four to fourteen times higher than other sexually active groups in 2022. With the aim of ending the AIDS epidemic by 2030, a global effort has focused on screening and testing for HIV as a core component in diagnosing people living with HIV, providing timely treatment and prevention, and suppressing HIV viral loads to undetectable levels.

Whereas Thailand has made significant advancements to reduce HIV infections and reach the 95-95-95 targets, there were an estimated 6500 new HIV infections in 2021 [1] [2]. Critically, half of all new infections occur among young people between ages 15 and 24, most of them among people in key population communities [1] [2]. A combination of public health initiatives from government, community and key-population led organizations, and private sector clinics providing screening and testing for HIV and other STIs has been at the forefront of Thailand's success in diagnosing approximately 90% of people living with HIV (PLHIV). These initiatives have relied significantly on international finance such as from the Global Fund to fight AIDS, Tuberculosis, and Malaria, and Thailand's National Health Security Office (NHSO), among others, while also many for-profit private sector clinics have exclusionary pricing structures for many key populations. The incidence of HIV is significantly higher among groups that also face stigma and discrimination by society. Bottom of the pyramid and risk populations such as undocumented migrants, LGBTQ+, sex workers, and people who use drugs often face difficulties in accessing health services that meet their needs in a safe environment [3]. A series of community-based and key-population led interventions have been developed both in Thailand and elsewhere, as a successful model to reach and recruit at-risk groups for HIV and STIs testing while confronting stigma and discrimination. These initiatives include informing and counseling in testing service delivery approaches.

In the race to end AIDS by 2030, identifying and implementing innovative approaches to finance and scale the provision of HIV and STIs testing, treatment and prevention, and counseling services in Thailand is needed. This study aims to contextualize and present practical innovations and opportunities to do so from a social business perspective, which strive to follow the principles of non-loss to ensure financial independence and sustainability, and non-dividend to enable financing the expansion to scale long-term impact.

Whereas this guide hones into the Thai context, it may also inform others.

II. Addressing the needs of at-risk and marginalized populations

This guide was drafted following a consultative process with community based organizations (CBOs) delivering HIV and other STI related health services in Thailand [4] [5] [6]. There is extensive evidence on the benefits of CBOs to reach and recruit at-risk individuals. Some of these point to higher rates of early diagnosis of new infections.

A. Adolescents & Youth

Despite longer risks of infection, awareness and knowledge levels among youth are a function of varied access to sexual health education. Many youth turn to peers and digital sources for information and counseling.

B. Eliminating Stigma and Discrimination Against Sex Worker

Stigma, legal barriers, and marginalization of the sex industry often hinder sex worker access to adequate healthcare. In Thailand, a significant number of sex workers are also economic migrants from neighboring countries, who face multiple access barriers and layers of discrimination.

C. Mainstreaming Sexual Health Among Men

Thailand's Ministry of Public Health reports that whereas nearly 60% of PLHIV in 2020 are men, approximately 80% of new HIV cases are among men. Risk groups include Gay men or other men who have sex with men (MSM) and male sex workers (MSW). More recently, the prevalence of Hepatitis C has been observed to increase, especially among MSM groups and particularly those infected with syphilis, engaging in chemsex, having multiple sex partners, and prisoners.

D. Ensuring Friendly and Judgment Free Services for People Who Use Drugs

People who inject drugs (PWID) are at high risk of HIV and Hepatitis C and yet some report experiencing discrimination including health workers denying access to health care facilities and services. Other forms of risk behavior while under the influence of drug and substance abuse, also referred to as chemsex, increase risk of transmission. Location-based test services are often preferred by PWID given the direct availability of counseling, care, and treatment. According to estimates by UNAIDS, there are approximately 57 600 adults who inject drugs in Thailand.

E. Sexual and Reproductive Health Services for Women and Girls

Whereas this guide focuses less on mother-to-child HIV and STI transmissions, it is important to note ongoing efforts to enhance access to sexual and reproductive health services and education to reduce teen pregnancies in Thailand and ensure safe and accessible support for family planning among women and girls while also engaging men and boys.

F. Enabling Access to Health Service for Migrants

Whereas HIV infection rates may be relatively low overall, Hepatitis B, Hepatitis C and Tuberculosis have high prevalence among economic migrants in Thailand, particularly from Myanmar, Cambodia, and Lao PDR [7] [8]. Many of these migrants are undocumented, do not speak the local language, and are not aware of existing support mechanisms for health.

G. Transforming Health Services for Transgender Inclusion

Transgender women and men in Thailand report a range of issues linked to stigma and discrimination. These affect their experience in accessing and navigating healthcare, including for sexual health, gender-affirming care, and counseling. The trans- oriented Tangerine Clinic in Bangkok reports that approximately 15% of visitors are unemployed and a third show symptoms of depression. Beyond external access barriers, internal factors affecting the health and wellbeing of trans individuals include internalized stigma, low levels of awareness, and misconceptions drug interactions.

III. Leveraging partnership and other support to scale social business approaches

A. Public Partnerships

Public entities may provide financial and non-financial support for social business innovation and operations. In some cases, public-private partnership (PPP) models can facilitate collaboration, private investment, and risk-sharing. In others, integrating approaches with public programs can provide social businesses with competitive advantages to manage interventions efficiently [9].

B. Private Partnerships

Private sector support for HIV and STI screening can help reduce costs of operation while enabling new revenue streams. Collaboration with insurance companies and employers to include HIV and STI screening and counseling support yield revenue while contributing to workforce wellbeing. In other cases, leveraging corporate social responsibility finance to bridge investment needs, purchase of equipment, and optimize operations can deliver mutual benefits. In-kind contributions of equipment, access to facilities, marketing and communication support, digital support, or favorable rates for products and services can contribute to lean operation expenses.

C. Educational Partnerships

Building partnerships with academic institutions can be pivotal to ensure access to adolescents and youth. They can ensure comprehensive sexual and reproductive health education campaigns, leverage student apprenticeships, and integrate sexual health programs to student life on campus [10]. Though specific avenues may vary depending on institutional needs and contexts, these initiatives can help encourage safe practices, promote open dialogue about sensitive topics, and increase rates of HIV and STIs screening, treatment, and prevention uptake.

D. Sample Financial Support Opportunities

Thailand's National Health and Security Office (NHSO) Medical Reimbursements, Trial Services for In Vitro Diagnostic Medical Devices for Approval by Thailand's Food and Drug Administration.

E. Sample Non-financial Support Opportunities Business Support

Incubators, accelerators, and other forms of business development guidance [11].

F. Pro-Bono or Discounted Services

Marketing, accounting, and legal support (i.e., TrustLaw by Thompson Reuters Foundation) [12].

G. Technology Resources and tools

Examples include TechSoup for nonprofits, Monday.com project management, Free Google Suite and Google Ads.

IV. Recommendations to harness social business contributions to end the HIV/AIDS epidemic and control other STIS.

A. Research and Knowledge exchange

Conduct analysis of the economic case and financial savings on public spending derived from social business initiatives. Conduct market research on new products and services. Conduct multi stakeholder dialogues to build collaborative action plans among stakeholder organizations and including community and key population actors.

B. Business Development & Investment

Seek technical assistance to develop and refine new social business models. Mobilize private finance to deliver activities under social business models. Explore and pilot avenues to leverage public funds for additional outcome-driven finance for social entrepreneurs.

C. Policy and Governance

Develop an enabling environment to support and integrate social business approaches into policies and action plans. Streamline procedures for self testing technology review and approval [13]. Conduct training and capacity development activities among health service providers on social business approaches.

V. Conclusion

Social business approaches can offer an alternative to support the financial sustainability of impact oriented interventions focusing on reaching at-risk, marginalized, and low-income populations to diagnose, treat, and prevent HIV and other sexually transmitted infections. Given the complex nature of facing this challenge, social business approaches should be seen as part of a broader, collective effort to reach the goal of Zero HIV, with special attention on existing gaps and careful consideration to policy developments to determine whether and how social business models can best add value. With an impact and people-oriented social mission that values social inclusion and combats discrimination, focusing on models that deliver public health outcomes is paramount. Given the experimental nature of entrepreneurship, fostering continuous improvement, knowledge exchange, and a collaborative mindset is key to ascertain and accelerate the adoption of impactful and scalable models.

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Methods to Reduce False Negatives without Sacrificing Machine Learning Model Performance

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***Abstract*—Machine learning is getting really popular, but its predictions aren't always accurate. This is a big issue, especially in areas like healthcare, where a wrong prediction can be dangerous. One common mistake is a "false negative" – when a model says someone is healthy when they're actually sick. Our study looks at a way to fix this problem. In this article, we introduce a special method that double-checks those "false negative" cases to see if the model got it wrong. This can detect mistakes, anywhere from 28% to 90% depending on the model. The salient point is that fixing these mistakes didn't make the model worse at its overall performance. The proposed method can make machine learning models more reliable, which is really important for areas like healthcare where mistakes can have serious consequences.**

***Index Terms*—False Negative, Machine learning, Prediction, Remote Healthcare, Developing Countries, SDGs**

I. Introduction

The role of data analysis in health informatics has expanded rapidly over the past decade due to the influx of vast and diverse information [1]. The growing number of publications in fields such as life information science and medical informatics indicate a swiftly increasing interest in machine learning.

A. False Negative in the Healthcare Field

Deep learning models have shown immense promise in health informatics, often rivaling or outperforming traditional approaches. However, the accuracy of their predictions is not always guaranteed, and a rigorous evaluation is essential. In healthcare, false negatives—predicting a healthy status when an individual is actually unwell—carry significant risks. This study explores a novel method that can be applied across various predictive models to minimize false negatives while preserving overall accuracy. By addressing this critical issue, our research aims to enhance the reliability and effectiveness of deep learning models in healthcare applications.

B. Existing Method

Olawale et al. [2] addressed the challenge of class imbalances in health data classification, which often leads to a high rate of false negatives, particularly detrimental in medical diagnoses. The study extensively explored resampling techniques, such as oversampling and undersampling, to balance the dataset. By focusing on enhancing recall and reducing false negatives, the authors developed methods that demonstrated significant improvements in predictive performance. Their findings highlight the effectiveness of these resampling techniques, achieving a better balance between sensitivity and specificity, which is critical in healthcare applications. This study provides a foundational approach to mitigating the issue of false negatives, offering valuable insights and methodologies that can be adapted and extended in various health data prediction scenarios.

C. Research Motivation

In binary classification prediction, there are two types of prediction errors. One is when a positive is predicted but the outcome is actually negative, and the other is when a negative is predicted but the outcome is actually positive. If we consider "unhealthy" as a positive result, the former is called a "False Positive" and the latter a "False Negative." A high occurrence of False Positives leads to unnecessary medical tests, incurring additional healthcare costs as well as financial and temporal costs for patients diagnosed as unhealthy. Conversely, a prevalence of False Negatives increases the likelihood of missing a present illness, which can lead to its aggravation or even transmission to others. Placing an emphasis on accurately predicting a patient's health status, it is deemed more crucial to avoid missing an illness than to minimize time and financial costs. Thus, reducing False Negatives generated by prediction models is considered vital to addressing these challenges, which motivated the present study.

D. Research Objectives

The objective of this study is to reduce False Negatives while maintaining the accuracy of the prediction model. In binary classification predictions, the results are categorized into four patterns using a confusion matrix.

TABLE I
Confusion Matrix

		Prediction	
		Healthy	***Unhealthy***
True	***Healthy***	True Negative(TN)	False Positive(FP)
	Unhealthy	False Negative(FN)	True Positive(TP)

While various evaluation metrics exist depending on which aspects are prioritized, if the sole focus is on improving the metric known as Recall, which emphasizes reducing False Negatives, other metrics can be ignored for ease of implementation. However, this approach would result in a biased model

that could not be considered highly accurate. Therefore, it is crucial to use metrics like **Accuracy** and the **F-score** to assess the overall balance and precision of the prediction model and employ **Recall** along with the **False Negative** reduction rate to monitor False Negatives. This study investigates how much each metric improves before and after applying the proposed method.

II. Method

The overview of the proposed method is described herein "Fig. 1""Fig. 2". The objective of this method is to create a model that reevaluates individuals predicted to be healthy to ensure that no unhealthy individuals have been mistakenly classified. Various factors are inputted as explanatory variables, and the health status determined from these factors is used as the response variable. Subsequently, a model is developed using existing predictive models to forecast health status, which then categorizes the data into predicted healthy and predicted unhealthy groups. False negatives exist only in the data predicted as healthy; therefore, to reduce these, the proposed method is reapplied to this data to predict health status again. As a result, the data are once again output as either healthy or unhealthy. If an individual is actually unhealthy and is predicted as such through the proposed method, the overall rate of false negatives is reduced.

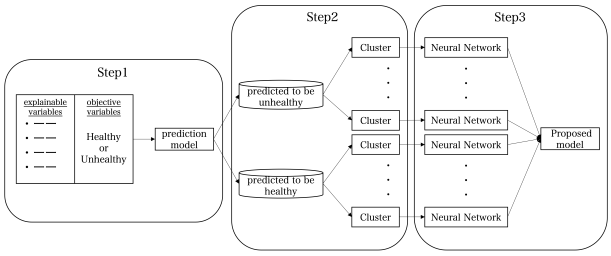

Fig. 1. The workflow of the proposed method 1

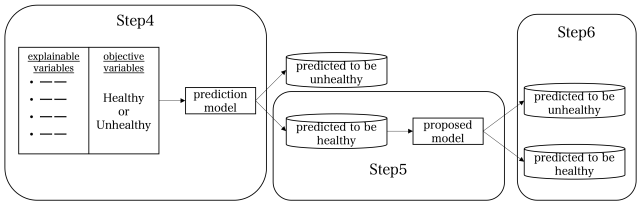

Fig. 2. The workflow of the proposed method 2

- Step1 Firstly, the dataset used in this study is divided into three parts: training data, test data 1, and test data 2, with the proportions being 5:3:2, respectively. A binary classification model is then developed using the training data to predict whether the condition is healthy or unhealthy. This model is subsequently applied to test data 1. Following this, data predicted as healthy are extracted and used for clustering.
- Step2 The binary classification prediction model separates data predicted as healthy into actual healthy data (TN data) and unhealthy data (FN data). Subsequently, clustering is performed on each group of data, and dendrograms are generated. Then, an appropriate similarity threshold is determined, and elements located at distances less than this threshold are divided into clusters containing m and n data points, respectively.
- Step3 We prepare a neural network for each cluster and perform supervised learning for each cluster. For each cluster, all data belonging to the cluster are mixed with either FN data if the cluster consists of TN data, or TN data if the cluster consists of FN data. This mixture is used as the input layer. The target variable is set to 1 for data belonging to the cluster and 0 otherwise, and the network is configured to output 1 if the data belongs to the cluster, and 0 if not.
- Step4 Input the test data 2 into the predictive model created in Step 1 to forecast whether it is healthy.
- Step5 The model developed up to Step 3 is applied to data predicted to be healthy in step 4. During this process, it is assumed that the data belongs to the cluster that yields a value closest to 1. If this cluster consists of TN data, the condition is reclassified as healthy; if it consists of FN data, it is reclassified as unhealthy.
- Step6 Compare the results of step 4 with those obtained by reflecting step 5 in step 4.

III. Experiment

In this study, we constructed a complete dataset from a subset of health screening data obtained via the Portable Health Clinic (hereafter referred to as PHC [3]), and compared the performance before and after applying the proposed method. Additionally, the performance was evaluated using Accuracy, Recall, Precision, F-score, and the reduction rate of False Negatives.

A. About Dataset

1) Preprocessing: The dataset used in this study was collected during an empirical experiment in PHC. It comprises data recorded from 2010 to 2020, including 24,005 male and 20,454 female entries, totaling 44,460 cases (with one case of missing entry). The dataset contains 7 registration items such as test dates and account IDs, as well as 27 clinical data items including waist circumference and blood glucose levels. Appropriate processing was applied to this dataset for use with the proposed method.

2) Select Feature Value: In PHC, when determining the colors that represent the health status of various items, a unique set of criteria called B-logic "Fig. 3" is employed. This dataset includes 34 types of variables, of which, eight items that range in color from green to red according to B-logic, along with gender and age, are used to predict health status. Below, B-logic and the full set of following ten items are presented: (1) gender (2) age (3) bmi (4) oxygenation of blood (5) systolic blood pressure (6) diastolic blood pressure (7) blood glucose (8) blood hemeglobin (9) cholesterol and

(10) uric acid.

PHC B-Logic and Human Acceptable Range									
No.	Parameter	Spec.	Data Type	Lower Warning	Green	Yelow	Orange	Red	Upper Warning
1	Height		dec	<100.0					>200.0
2	Weight (kg)		dec	<25					>100.0
3	BMI		dec		<25	>=25 & <30	>=30 & <35	>=35	
4	Waist (cm)	Male	dec	<40.0	<90.0	>= 90.0	NA	NA	>120.0
		Female	dec	<40.0	<80.0	>= 80.0	NA	NA	>110.0
5	Hip (cm)		dec	<40.0					>120.0
6	Waist Hip Ratio	Male	dec		<0.90	>= 0.90	NA	NA	
		Female	dec		<0.85	>= 0.85	NA	NA	
7	Temperature (C)		dec	<33.0	<37.0	>=37.0 & <37.5	>=37.5	NA	>39.0
10	Urine Sugar				-	+-	Others		
11	Urine Protin				-	+-	Others		
12	Urinary Urobilinogen				+-		Others		
13	Oxygenation of Blood (%)		int	>100	>=96	>=93 & <96	>=90 & <93	<90	<92
14	Blood Pressure (mmHg)	Systolic	int	<70	<130	>=130 & < 140	>=140 & <180	>=180	>220
15		Diastolic	int	<50	<85	>=85 & <90	>=90 & <110	>=110	>140
16	Blood Sugar (mmol/dl)	PBS	dec	<3.0	<7.78	>=7.78 & <11.11	>=11.11 & <16.67	>=16.67	>30.0
17		FBS	dec	<3.0	<5.56	>=5.56 & <7.0	>=7.0 & <11.11	>=11.11	>20.0
18	Blood Hemoglobin (g/dl)		dec	>18.0	>=12.0	>=10.0 & <12.0	>=8.0 & <10.0	<8.0	<6.0
20	Pulse Rate (bit/min)		int	<50	>=60 & <100	>= 50 & <60 or >=100 & <120	<50 OR >=120	NA	>130
21	Arrhythmia				Normal		Others		
22	Blood Cholesterol (mg/dl)		dec	<120.0	<=200.0	>200.0 & <=225.0	>225.0 & <240.0	>=240.0	>300.0
23	Blood Uric Acid (mg/dl)	Male	dec	<3.5	>3.5 & <=7.0		>7.0 &<8.0	>=8.0	>12.0
23		Female	dec	<2.4	>2.4 & <=6.0		>6.0 &<7.0	>=7.0	>12.0

Fig. 3. B-logic a.k.a Bangladesh Logic. A logic set created based on WHO guideline to classify patients in four colors.

However, predicting health status based on the measurement of 10 parameters presents several issues. One significant problem is the cost of measurements. Measuring all 10 items can significantly burden both the patients and the health workers involved. Particularly, an increase in the workload of health workers often leads to more frequent data entry errors and omissions, compromising the accuracy of the data obtained. Indeed, in a dataset of 44,460 records from PHC, numerous missing and anomalous values were observed. Another issue is the inaccessibility of health check-ups for individuals who cannot afford the time or are unable to leave their homes for various reasons. Therefore, this study proposes dividing the aforementioned 10 parameters into those that can be self-measured by patients and those that cannot. The explanatory variables are defined as the self-measurable items, and the dependent variable is set as the health status derived from all 10 parameters.

The challenges associated with self-measurement by patients include the difficulty of handling the equipment, the need for medical knowledge, and the potential inaccuracy of the measurements. Hence, from these criteria, the items that can be easily measured by patients themselves are identified as gender, age, bmi, oxygenation of blood, diastolic blood pressure, and systolic blood pressure. The parameters that are preferable to be measured in medical facilities include blood glucose, blood hemoglobin, cholesterol, and uric acid.

3) Handling Missing Values: As previously mentioned, the data from PHC contain many missing values. For this study, it was necessary to create a dataset without any missing entries; therefore, we employed a listwise deletion method, where any data containing even a single missing variable was removed from the dataset. As a result, out of the original 44,460 records, 1,137 datasets were extracted.

4) Handling Outliers: Similar to missing values, it was discovered that the dataset contained a significant number of outliers. Therefore, outlier processing was conducted for each variable. Using B-logic, values lower than the Lower Warning and higher than the Upper Warning were identified as outliers. Any data containing outliers in any of the ten variables were entirely removed. As a result, 964 data records were extracted from the initial 1,137 records.

B. Evaluation Metrics

When comparing the performance of various methods, we use evaluation metrics based on the confusion matrix such as Accuracy, Recall, Precision, and F-score, along with the FN (False Negative) reduction rate. FN reduction rate is defined as the extent to which False Negatives decrease following the application of the proposed method. A confusion matrix is a table that classifies predictions into four categories by verifying whether the prediction indicates 'healthy' or 'unhealthy' and whether the actual condition is 'healthy' or 'unhealthy', as shown in confusion matrix.

$$Accuracy = \frac{TP + TN}{TP + FP + FN + TN}$$

$$Recall = \frac{TP}{TP + FN}$$

$$Precision = \frac{TP}{TP + FP}$$

$$F - score = \frac{2 \times Precision \times Recall}{Precision + Recall}$$

$$FNreductionrate = \frac{FNbefore - FNafter}{FNbefore}$$

C. About Binary Classification Prediction Models

In this study, we use models created through ensemble learning employing computational methods of bagging, boosting, and stacking to create a model that classifies and predicts health status.

In the bagging model, we use Random Forest, which combines multiple decision trees for classification. Although individual trees may overfit, their combination through majority voting reduces overfitting and enhances overall performance.

In this study, we used XGBoost for boosting. XGBoost iteratively trains decision trees to correct errors from previous iterations. While its serial processing increases computational time, proper hyperparameter tuning enhances accuracy by refining earlier errors.

For stacking, we used logistic regression to make final predictions based on outputs from decision trees, logistic regression, and support vector machines. Stacking leverages the strengths of individual models by using their outputs as new features for a final predictive model.

D. About an Optimization of Models

In this study, the hyperparameters of the binary classification prediction model were tuned to achieve the highest possible Area Under the Curve (AUC). The AUC is a widely used metric that balances the true positive rate and the false positive rate, and it indicates the accuracy of the model. Furthermore, the model's threshold was set to maximize the Accuracy, which represents the rate of correct predictions, thus enhancing the precision for use in this research.

E. About the Valiables Used for Clustering

In the proposed method, clustering is performed by inputting all 10 variables, with the aim of reflecting the trends of the four variables not used as explanatory variables. Additionally, to examine the differences when only the variables used for prediction are input, comparisons are made between scenarios where six variables that patients can easily measure themselves are set as input variables, and where all 10 variables are set.

IV. Results

In this chapter, we predict health status using the methods described in Chapter 2 and present various evaluation metrics mentioned in Chapter 3, comparing the results before and after the application of the proposed method.

A. Results of Each Method

TABLE II
PREDICTION RESULTS OF RANDOM FOREST

	Accuracy	*Recall*	*Precision*	*F-score*	*FN reduction rate*
Before	0.6823	0.7615	**0.7674**	0.7645	
After(6 items)	**0.7083**	**0.8718**	0.7619	**0.8128**	**46.23%**
After(10 items)	0.6736	0.8410	0.7226	0.7772	33.32%

TABLE III
PREDICTION RESULTS OF XGBOOST

	Accuracy	*Recall*	*Precision*	*F-score*	*FN reduction rate*
Before	0.6094	0.6077	**0.7670**	0.6781	
After (6 items)	**0.6493**	0.7180	0.7526	0.7348	28.12%
After (10 items)	0.6459	**0.7487**	0.7339	**0.7411**	**35.94%**

TABLE IV
PREDICTION RESULTS OF STACKING

	Accuracy	*Recall*	*Precision*	*F-score*	*FN reduction rate*
Before	**0.7240**	0.8077	**0.7895**	0.7985	
After (6 items)	0.7222	0.8667	0.7578	0.8086	41.08%
After (10 items)	0.7222	**0.9051**	0.7417	**0.8153**	**50.65%**

B. Comparison of Results

While the trends differed according to the binary classification prediction model used, improvements were observed in Recall and F-measure regardless of the model. Moreover, except for stacking, Accuracy also improved, and the decrease in stacking was minimal. From these results, it can be stated that the proposed method maintains accuracy without deterioration. Although Precision, which is in a trade-off relationship with Recall that is strongly affected by False Negatives, deteriorated, stacking reduced False Negatives by up to approximately 50%.

V. Discussion

In the field of healthcare, False Negatives, a type of error prediction, pose significant risks and are crucial to reduce. However, merely reducing False Negatives without regard to overall accuracy is not meaningful. Therefore, this study proposes and evaluates a method to decrease False Negatives while maintaining accuracy. Furthermore, we approached the issue of reducing the burden on both patients and healthcare workers by predicting health status using only metrics that patients can measure themselves. The results show that it is possible to reduce False Negatives while maintaining balanced indicators such as Accuracy and the F-measure. This approach significantly mitigated the risks of severe complications from undiagnosed illnesses and the spread of infectious diseases. Additionally, by eliminating the need for healthcare workers in the measurement process, not only is it easier for individuals to monitor their health status, but it also serves as a measure against the spread of infections.

A. Future Enhancement

As a future challenge, it is necessary to consider revising the datasets used. The dataset employed in this study contained a predominance of unhealthy data. This may be attributed to the omission of measurements for individuals known to be generally healthy, in an effort to reduce unnecessary costs. Therefore, it would be advisable to modify the methods for handling missing values and ensure a sufficient amount of data before verifying the accuracy. Furthermore, while there was an improvement in Recall, Precision deteriorated. Thus, it is also essential to test whether applying the proposed method, which was only used for data predicted to be healthy, to data predicted to be unhealthy, could enhance the overall accuracy of predictions.

B. Social Impact

Reducing false negatives in machine learning models, particularly in healthcare, can have a profound positive social impact in several ways:

- Improved Healthcare Outcomes: Fewer false negatives mean fewer missed diagnoses. This leads to earlier detection and treatment of diseases, improving patient outcomes and potentially saving lives.
- Reduced Healthcare Costs: Early detection often leads to less invasive and less expensive treatments. This can reduce the overall burden on healthcare systems and make healthcare more accessible.
- Increased Public Trust: Reliable predictive models can increase public trust in healthcare and technology. This can lead to greater adoption of preventive measures and improved health management.
- Enhanced Resource Allocation:By identifying those who truly need care, resources can be better allocated, ensuring that those who are most in need receive timely and appropriate treatment.

- Reduced Anxiety and Uncertainty: False negatives can cause significant anxiety and uncertainty for individuals. Reducing them can lead to better mental health outcomes and peace of mind.
- Fairer Healthcare Access: In some cases, false negatives disproportionately affect certain populations due to biases in data or algorithms. Reducing them can help address health disparities and promote equitable healthcare access.
- Advancements in Medical Research: Reliable models can accelerate medical research by providing accurate data for analysis and hypothesis testing. This can lead to the faster development of new treatments and cures.

Overall, reducing false negatives in machine learning has the potential to create a healthier, more equitable, and more efficient society.

VI. Conclusion

In this study, we propose a method to reassess individuals predicted as healthy to ensure no unhealthy individuals are misclassified. We compared various evaluation metrics before and after applying the method. The results indicate a decrease in False Negatives and a corresponding increase in Recall values. However, False Positives increased, which also led to an decrease in Precision values. There is a trade-off between False Positives and False Negatives, making it quite challenging to reduce both simultaneously. Nevertheless, there was no significant decline in Accuracy and F-measure. Furthermore, it was observed that depending on the model, there is an optimal number of input items for clustering. Regardless, the reduction in False Negatives demonstrates the effectiveness of the proposed method.

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Understanding the Influence of Socioeconomic and Health System Variables on Global Pandemic Management: A Secondary Data Analysis

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***Abstract*— This study examined the impact of socioeconomic conditions and health system infrastructure on the management and outcomes of the COVID-19 pandemic. The key aim of this study was to analyze the influence of socioeconomic status and health systems on pandemic management, with a particular focus on the COVID-19 pandemic. Analyzing the secondary data from 209 countries, we found that regions with higher health spending, better equipped health systems, and higher socioeconomic development experienced higher COVID-19 cases and mortality rates, likely due to improved reporting and detection capabilities. Key health indicators, including health workforce availability and hygiene practices, correlated significantly with pandemic metrics, underscoring the importance of robust health systems. Socioeconomic factors, particularly the Human Development Index (HDI) and GDP per capita, also showed strong positive correlations with COVID-19 metrics, suggesting that higher human development and economic prosperity enabled more effective responses to the pandemic. Conversely, regions with higher poverty rates reported lower COVID-19 incidence and mortality, which may reflect underreporting and limited access to healthcare. Despite the findings, there were limitations, including variability in data quality and possible underreporting in low-income regions. Our findings highlighted the need to invest in health infrastructure and address socioeconomic disparities to improve global pandemic preparedness and response. Future research should focus on the role of government policy, the effectiveness of public health interventions, and improving data accuracy to strengthen global health resilience.**

***Index Terms*—Pandemic, COVID-19, Socioeconomic Factors, Healthcare system, Multivariate analysis**

I. Introduction

For decades, researchers have focused on the connection between socioeconomic conditions, health systems and pandemic management [1]. Historic pandemics such as the 1918 Spanish Flu, the HIV/AIDS epidemic, and the more recent H1N1 influenza outbreak have repeatedly demonstrated the importance of these elements in health outcomes [2]. During the Spanish flu, countries with better funded health systems and higher socioeconomic status were able to adopt more effective public health measures such as quarantine and isolation, dramatically reducing the impact of the virus [2]. However, many low-income countries experienced higher mortality rates due to inadequate health infrastructure and limited access to medical treatment. Likewise, low-income areas and countries with underdeveloped health systems have been disproportionately affected by the HIV/AIDS epidemic [3].

Extensive testing, education and access to antiretroviral medicines have made it possible to control the spread of the disease more effectively in areas with strong public health systems and higher socioeconomic levels [4]. The H1N1 flu pandemic has exacerbated these discrepancies. Countries with well-equipped health systems were able to quickly launch vaccination campaigns and intensively treat affected individuals, but countries with fewer resources struggled to respond adequately [2]. The different preparedness and response capacities underscored the importance of socioeconomic and health system aspects in pandemic management [5].

The COVID-19 pandemic, which began in late 2019, has provided a timely perspective to examine the interplay between socioeconomic status, health systems, and pandemic management [6] [7]. Wealthier countries with higher GDP per capita tended to have more resources to conduct widespread testing, contact tracing and vaccination campaigns. They were also able to provide economic assistance to individuals and businesses affected by lockdowns and other restrictions. Lower-income countries, on the other hand, face significant hurdles, such as limited access to vaccinations, poor testing infrastructure and a lack of funding to fund public health initiatives and social distancing regulations [8]. Health systems have been equally important in dealing with the COVID-19 epidemic. Countries with strong health infrastructure, including sufficient hospital beds, well-trained medical professionals, and comprehensive public health systems, have been more effective in managing spikes in cases and providing vital treatments to affected individuals [1] [6] [8].

The capacity of health systems has a significant impact on the speed and efficiency of vaccine distribution. Countries with centralized health systems and solid logistical frameworks have tended to have more successful vaccination programs [9]. The main objective of this study was to analyze the influence of socioeconomic status and health systems on pandemic

management, with a particular focus on the COVID-19 pandemic. The aim of this study is to identify and quantify the important elements that determine the outcome of a pandemic in different countries. The goal is to provide actionable insights that can guide public health initiatives and policies to improve global preparedness and response to future health emergencies.

II. Methodology

A. Data Collection and Study Period

The secondary data for this study was collected from various reputable international databases such as the World Health Organization (WHO), the World Bank and the United Nations Development Program (UNDP). The dataset contains information on COVID-19 metrics (cases, deaths and tests per million population) collected by Worldometers over the period 2020-2023 [10]. Data on vaccination rates (complete primary vaccination and at least one dose) were collected by the WHO up to 2023 [11]. The database of health system indicators (health expenditure, hospital beds and availability of soap and water) was collected by the World Bank from 2015 to 2019 [12]. In addition, socio-economic variables such as GDP per capita, unemployment rate, Gini index and other relevant indices from the same source were included. The Human Development Index data was collected by UNDP between 2015 and 2019 [13]. The situation before the pandemic of five years mean value was assessed as the ability to cope with the pandemic.

B. Estimated Variable Selection

The key variables selected for analysis are divided into three groups. Pandemic outcomes are cases per million population, deaths per million population, and tests per million population. And for prevention, we collected the primary dose and at least one vaccine dose. As health system indicators, we calculated health expenditure as a percentage of GDP, the number of hospital beds per thousand inhabitants, the availability of soap and water, and the number of doctors and nurses per thousand inhabitants. The current gross domestic product (GDP), the per capita GDP, the HDI, the level of education, the literacy rate (+25 years, both genders) and the poverty rate of employees were calculated as socioeconomic status indicators.

C. Data Preprocessing

Data preprocessing involved cleaning and normalizing the collected data to ensure consistency and accuracy. Steps included removing incomplete or missing data entries, normalizing the data to account for differences in reporting standards across countries, and, if necessary, transforming variables to meet the assumptions of the statistical analyses.

D. Statistical Analysis

We calculated the last five years of data on the COVID-19 pandemic as countries' pandemic management capacity and situation. A multivariate analytical approach was used to examine the relationships between the selected variables where <0.05 was considered statistically significant. To quantify the influence of independent variables (socioeconomic and health indicators) on dependent variables (pandemic outcomes), multiple regression analysis was performed. MRAH and SSES collected separately, and any disputes were discussed with the third author (MAK). If no decision was made, a third co-author (MAK) was consulted to reach consensus. Microsoft Excel for Microsoft 365 MSO (version 2112 build 16.0.14729.20254) was used to collect, process and store data. Statistical analyzes were performed
using JMP16.0.0 software (SAS Institute Inc., Cary, NC, USA).

Table 1: COVID-19 metrics with healthcare system association

Variables	Health expenditure	Hospital Beds	Soap and water usage	Phsyician (Per 1000)	Nurse and Midwives (Per 1000)
Cases/ Million Pop	0.5745†	0.5656†	0.7413†	0.6914†	0.6903†
Deaths/Million Pop	0.4192†	0.4927†	0.5782†	0.5973†	0.4261†
Tests/Million Pop	0.3833†	0.2283‡	0.4647†	0.4892†	0.4014†
Primary Complete	0.5013†	0.173	0.5666†	0.5142†	0.5169†
At least One Dose	0.4629†	0.1031	0.5135†	0.4609†	0.4607†

E. Ethical consideration

This study examined openly accessible data, and the datasets utilized underwent prior de-identification and complete anonymization. The analysis of publicly available data without any patient-identifying information did not necessitate ethical approval. The study was conducted in adherence to the principles outlined in the Declaration of Helsinki.

III. Results

A. Distribution of COVID-19 cases and dataset

The dataset included 69,33,69,947 cases and 6987895 deaths reported from 209 countries and territories. The average number of cases was 3317559.56 (range: 2942-1118200082), the average number of deaths was 33434.9 (range: 1-1219487) and a total of 423152207 COVID-19 tests performed per million, as reported by 136 countries and territories. Regarding vaccination, 84.83% (range: 03%-92%) of the population from 158 countries reported having a complete primary vaccination course, with 93.93% (range: 04-100%) of the population having at least one had received a vaccination dose.

B. COVID-19 Pandemic data with healthcare system

The correlation matrix shows significant relationships between COVID-19 metrics and various health indicators. Cases (0.5745, <0.01) and deaths per million population (0.4192, <0.01) show moderate to strong positive correlations with healthcare spending, suggesting that regions with higher healthcare spending tended to have increased COVID-19 - Record case and mortality rates. In addition, both cases and deaths have moderately positive correlations with the availability of doctors (0.6914, <0.01; 0.5973, <0.01) and nurses/midwives (0.6902, <0.01; 0 .4261, <0.01) per 1000 population, highlighting the importance of health workers in managing outbreaks and providing medical care. In addition, there are moderate positive correlations between cases and deaths and the number of hospital beds per population, suggesting that regions with more hospital resources may

experience higher incidence and mortality from COVID-19. Furthermore, cases and deaths show moderate to strong positive correlations with soap and water consumption (0.7413, <0.01; 0.5782, <0.01), highlighting the crucial role of hygiene practices in controlling the spread of the virus underlined. Initial vaccination was associated with healthcare expenditure (0.5013, <0.01), soap and water consumption (0.5666, <0.01), doctor (0.5143, <0.01) and nurses and midwives (0.5168, <0.01) (Table:1).

C. *COVID-19 Pandemic data with socioeconomic factors*

We found a strong positive correlation between HDI and all COVID-19 metrics, suggesting that regions with higher human development tend to have higher COVID-19 incidence (0.7339, <0.01), mortality (0.6047, <0.01) and testing rates (0.4862, <0.01) and primary vaccine protection dose (0.6004, <0.01). GDP showed no significant relationship with COVID-19 metrics. However, GDP per capita showed a moderate positive correlation with COVID-19 metrics, suggesting that regions

Table 2: COVID-19 metrics and Socioeconomic factors association

	HDI	GDP	GDP per capita	Educational attainment	Literacy rate	Poverty headcount ratio
Cases/Million Pop	0.7339†	0.0781	0.607†	0.664†	0.4803†	0.5417
Deaths/ Million Pop	0.6047†	0.1128	0.2285†	0.573†	0.4587†	-0.5355
Tests/ Million Pop	0.4862†	0.0301	0.4316†	0.437†	0.2978†	-0.2893
Primary Completed	0.6004†	0.1719	0.4605†	0.546†	0.4716†	-0.5191
At Least one Dose	0.5579†	0.1866	0.4189†	0.4488†	0.4764†	-0.4603

with higher economic prosperity tend to have higher COVID-19 metrics. High GDP per capita is strongly associated with COVID-19 cases (0.607, <0.01). There are moderate positive correlations between education level and COVID-19 metrics, suggesting that regions with higher education levels may have higher COVID-19 incidence (0.664, <0.01), mortality (0.573, <0, 01) and testing rates (0.437, <0.01) and primary dose of vaccination (0.546, <0.01). Interestingly, there are negative correlations between poverty rates and COVID-19 metrics. This suggests that regions with higher poverty rates may have lower COVID-19 incidence, mortality, testing rates and vaccination rates (Table 2).

IV. *Discussion*

Our study highlighted the important role of socioeconomic conditions and health system infrastructure in the management and outcomes of the COVID-19 pandemic. Our analysis showed that regions with higher healthcare spending tend to experience higher COVID-19 cases and mortality rates. This could be due to better reporting and detection capabilities in wealthier regions, as well as the ability to manage and document more cases. Furthermore, the availability of health workers (doctors and nurses/midwives) and resources (hospital beds, soap and water) were positively correlated with both cases and deaths, highlighting the importance of health infrastructure in managing the pandemic.

The strong positive correlation between hygiene practices (soap and water consumption) and COVID-19 metrics highlighted the critical role of basic public health measures in controlling the spread of the virus. Vaccination rates also showed a significant relationship with health system indicators, underscoring the importance of robust health systems for successful vaccination campaigns [14].

Socioeconomic factors, particularly the Human Development Index (HDI) and GDP per capita, showed strong positive correlations with COVID-19 metrics, suggesting that higher human development and economic prosperity provide better opportunities to respond to pandemics, including testing, treatment and vaccination efforts. The positive correlation between educational attainment and COVID-19 metrics suggests that more educated populations may have better access to information and health services, thereby improving pandemic management [15].

Conversely, the negative correlation between the poverty headcount ratio and COVID-19 metrics suggested that regions with higher poverty rates may experience lower reported COVID-19 incidence and mortality, potentially due to underreporting, limited testing, and inadequate access to healthcare services.

V. *Limitations*

Despite the findings provided by this study, some limitations should be acknowledged. Firstly, the quality and completeness of COVID-19 data varied across countries, potentially leading to inconsistencies in reported cases, deaths and testing rates. The data spans multiple years, and fluctuations in pandemic waves and government responses over time could influence the observed correlations. Secondly, the interactions between socioeconomic factors and health system indicators are complex and may not be fully captured by correlation analysis. Thirdly, variables such as government policies, cultural factors, and public adherence to health measures could also significantly impact COVID-19 outcomes and were not considered in this analysis. Lastly, in regions with inadequate healthcare infrastructure and limited testing, COVID-19 cases and deaths may be underreported, compromising the accuracy of data.

VI. Conclusion

This study highlights the critical connection between socioeconomic status, health system infrastructure and pandemic management. Regions with higher health spending, better equipped health systems, and higher socioeconomic development have more effective pandemic responses, as reflected in higher testing rates, higher vaccination rates, and reported cases and deaths. The findings highlight the need to invest in health systems and address socioeconomic disparities to improve global preparedness for future health emergencies. Future research should focus on the impact of specific government policies, the effectiveness of public health interventions in different contexts, and improving data quality and consistency. These efforts will provide actionable insights

to strengthen global health system resilience and socioeconomic equity in pandemic preparedness and response.

Abbreviations:
HIV: Human Immunodeficiency Virus, H1N1: A subtype of the influenza virus also known as swine flu, AIDS: Acquired Immunodeficiency Syndrome, GDP: Gross Domestic Product, HDI: Human Development Index, WHO: World Health Organization, COVID-19: Corona virus disease-2019, UNDP: United Nations Development Program

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An Age-Period-Cohort Analysis of Suicide Mortality Rates by Gender in Japan, 1995–2019

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***Abstract*— In 2019, Japan had the second highest suicide rate among the G7 developed nations. Suicide remains a critical public health problem in Japan. Understanding the interplay of age, time, and birth cohort effects on suicide mortality rates is crucial for formulating effective public health strategies. The aim of this study is to examine the age, period, and birth cohort effects of suicide mortality by gender across different prefectures in Japan from 1995 to 2019. Age-period-cohort (APC) modeling was employed to estimate these effects, utilizing suicide and population data obtained from the Global Burden of Disease (GBD) and the Statistics Bureau of Japan. The analysis identified high-risk groups based on age, period, and birth cohort reference values, and examined regional differences by grouping the 47 prefectures into eight regions. The results showed that Japan recorded 22,303 suicides in 2021, with age-standardized mortality rates of 18.86 and 7.56 per 100,000 for men and women, respectively. Suicide rates increased with age, peaking at 55-59 years for men and 50-54 years for women, and period effects indicated peak suicide rates around 2002.5 for both genders. Significant regional differences were observed, with some prefectures exhibiting persistently higher rates than others. These findings underscore the need for targeted, region-specific intervention strategies to effectively address the suicide epidemic in Japan.**

***Index Terms*— Suicide mortality, age-period-cohort analysis, regional disparities, Japan, prefecture-specific strategies.**

I. Introduction

Suicide remains a significant public health concern in Japan, with the country consistently reporting Despite efforts to mitigate suicide, Japan's persistently high suicide rates indicate the need for more targeted and effective strategies. This study analyzes suicide mortality patterns by age, period, and birth cohort to identify high-risk groups and temporal trends. [1-4]

This study aims to provide a comprehensive analysis of suicide mortality rates in Japan from 1995 to 2019, examining age, period, and birth cohort effects across different prefectures.

The study will identify specific population groups at higher risk of suicide and uncover temporal trends influenced by socio-economic, cultural, or policy changes. Furthermore, regional disparities in suicide rates will be explored, highlighting unique characteristics and challenges that influence suicide mortality in different prefectures. The findings will inform public health policies and strategies aimed at reducing suicide rates in Japan. By identifying high-risk groups and periods, as well as understanding the impact of socio-economic and cultural factors on suicide trends, stakeholders can develop more focused and effective prevention programs. Ultimately, this research aims to contribute to reducing suicide mortality in Japan and improving the overall mental health and well-being of its population.

II. Data collection and Methods

A. Data Collection

Suicide data for Japan, covering all 47 prefectures, from 1995 to 2019, disaggregated by gender and five-year age intervals, were obtained from the Global Burden of Disease (GBD) website. Population data by gender and corresponding age groups for the same period were collected from the Statistics Bureau of Japan website.

B. Statistical Analysis

Age-period-cohort (APC) modeling was employed to estimate the effects of age, period, and birth cohort on suicide mortality rates for each prefecture by sex. This method allows for the decomposition of suicide mortality rates into components attributable to age, period, and cohort effects, providing a comprehensive understanding of the temporal and demographic patterns in suicide rates.

C. Identification of High and Low-Risk Groups

High and low-risk groups were identified using reference values for age (42.5 years), period (2007.5), and birth cohort (1965). These reference values were selected based on the study period's midpoint and the population's age distribution.

D. Regional Grouping

To examine regional differences in suicide rates, the 47 prefectures were grouped into eight regions based on traditional geographic divisions. This regional grouping enabled the analysis of geographical variations and the identification of localized risk factors.

E. Analysis of Regional Differences

Suicide rates were analyzed within the eight geographic regions to identify patterns and trends. This regional analysis aimed to uncover differences in suicide rates across Japan, facilitating the development of targeted intervention strategies tailored to the specific needs of each region. By combining APC modeling with regional analysis, this study

aimed to provide a detailed and nuanced understanding of suicide mortality trends in Japan, identifying key demographic and temporal factors contributing to suicide risk.

III. Results

In 2021, Japan recorded 22,303 suicides, with age standardized mortality rates of 18.86 and 7.56 per 100,000 in men and women, respectively. Over the period 1990-2021, the age-standardized mortality rate showed a decreasing trend, with an average APC of 0.12%. Suicide mortality rates increased with age, peaking at 55-59 years for men and 50-54 years for women, compared to the reference age of 42.5. Period effects indicated peak suicide rates around 2002.5 for both genders. (Figure 1, 2)

Figure 1: Age-Period-Cohort Curves for Male

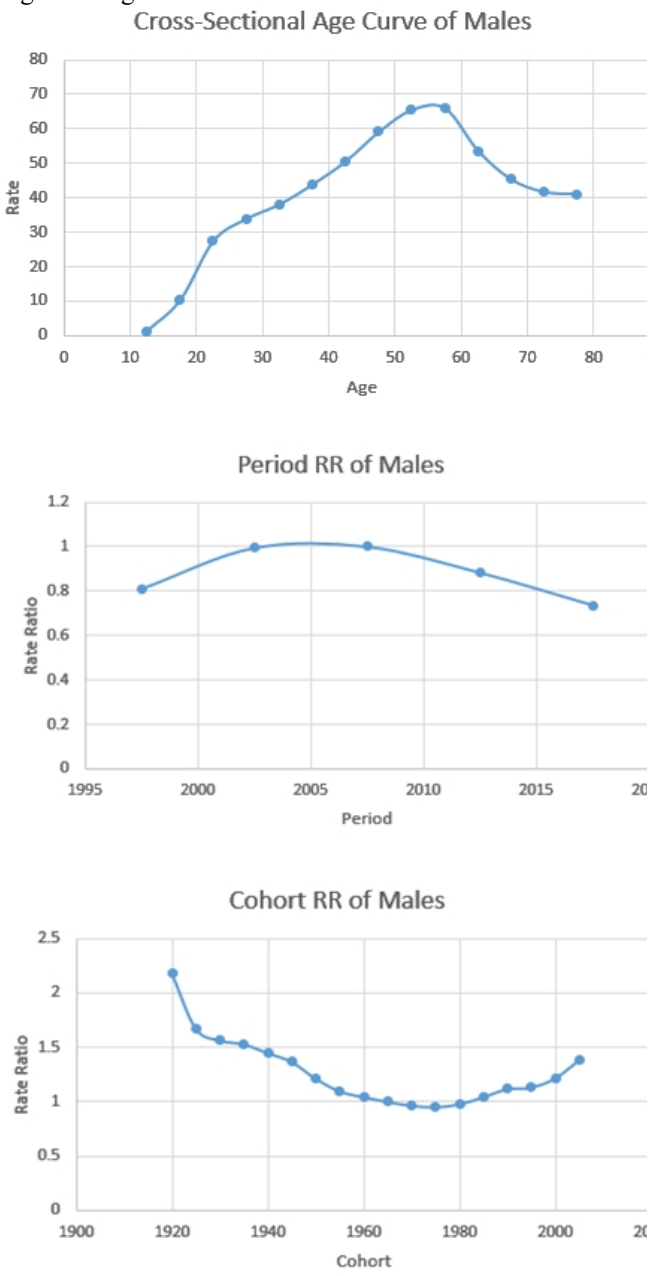
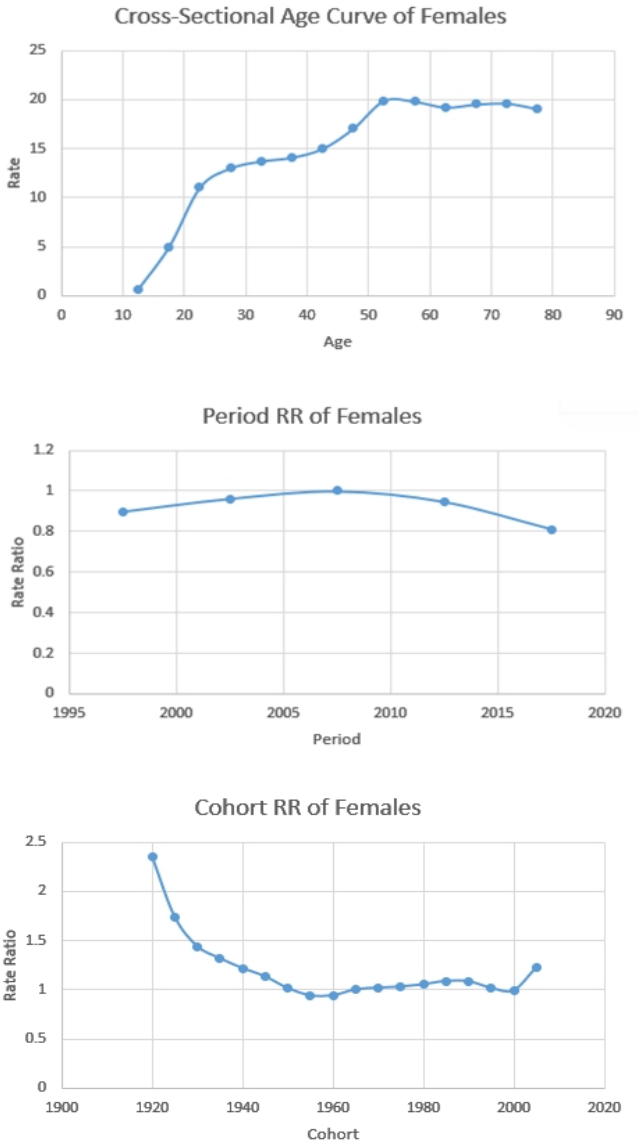


Figure 2: Age-Period-Cohort Curves for Female



Birth cohort effects showed higher suicide rates among cohorts born in the 1920s compared to those born in 1965, with relative risks of 2.18 for males and 2.35 for females. (Figure 1, 2)

Significant regional differences in suicide rates were observed, with some prefectures exhibiting persistently higher rates than others. In the descriptive analysis, in 2021, the prefectures with the highest male and female suicide rates in Japan were Tokyo, Osaka, Kanagawa, Saitama, and Aichi, respectively. Among these, Tokyo had the highest suicide rate for both genders, followed by Osaka, Kanagawa, Saitama, and Aichi.

Conversely, the prefectures with the lowest male suicide rates in 2021 were Tottori, Fukui, Tokushima, Kōchi, and Shimane, respectively. Among these, Tottori had the lowest male suicide rate, followed by Fukui, Tokushima, Kōchi, and Shimane. (Table 1)

For female suicide rates in 2021, the lowest prefectures were Tottori, Fukui, Saga, Yamanashi, and Shimane, respectively. Tottori had the lowest female suicide rate, followed by Fukui, Saga, Yamanashi, and Shimane. (Table 2)

In 2021, the total number of male suicides in Japan was

15,678, which was more than double the total number of female suicides, which was 6,625.

Table 1: Global Burdern of Suicide in 2021 And Their Annualized Changes from 1990 to 2021 of male

Male					
	Death Rank		Death	Age-standarized Death Rate	
Location	1990	2021	#	per 100,000 (95% UI)	% change 1990-2021(95% UI)
Japan	6	9	15678.0	18.9 (18.4 to 19.3)	-0.041 (-0.062 to -0.019)
Tōkyō	6	9	1503.0	16.1 (15.3 to 16.95)	-0.086 (-0.143 to -0.024)
Ōsaka	6	9	1077.8	18.7 (17.7 to 19.8)	-0.129 (-0.181 to -0.071)
Kanagawa	6	9	1042.9	16.8 (15.8 to 17.8)	0.008 (-0.061 to 0.0799)
Saitama	6	9	856.1	16.99 (16.0 to 17.9)	0.006 (-0.063 to 0.075)
Aichi	6	9	825.9	16.4 (15.4 to 17.4)	-0.005 (-0.084 to 0.065)
Chiba	7	9	774.3	18.4 (17.3 to 19.4)	0.134 (0.048 to 0.223)
Hokkaidō	7	9	724.0	22.7 (21.3 to 24.1)	0.072 (-0.005 to 0.1495)
Hyōgo	7	9	675.7	20.1 (18.9 to 21.2)	0.022 (-0.049 to 0.088)
Fukuoka	6	9	634.2	19.4 (18.2 to 20.7)	-0.156 (-0.2195 to -0.087)
Shizuoka	8	9	464.4	19.6 (18.4 to 20.9)	0.173 (0.086 to 0.277)
Ibaraki	9	9	399.9	22.1 (20.9 to 23.5)	0.239 (0.148 to 0.332)
Hiroshima	8	9	340.8	19.0 (17.7 to 20.3)	-0.0897 (-0.161 to -0.015)
Niigata	5	9	327.5	22.3 (20.6 to 24.1)	-0.089 (-0.166 to -0.006)
Miyagi	6	9	299.2	20.5 (19.1 to 21.9)	0.024 (-0.065 to 0.120)
Gunma	7	9	272.9	21.3 (19.8 to 22.8)	0.063 (-0.017 to 0.162)
Kyōto	8	9	270.5	16.8 (15.5 to 18.1)	-0.090 (-0.173 to 0.005)
Fukushima	8	9	267.4	22.2 (20.7 to 23.9)	0.136 (0.049 to 0.237)
Nagano	8	9	256.6	18.8 (17.5 to 20.3)	0.011 (-0.081 to 0.109)
Tochigi	7	9	254.1	19.3 (18.1 to 20.7)	-0.0429 (-0.121 to 0.036)
Gifu	8	9	246.6	18.6 (17.2 to 20.1)	0.027 (-0.066 to 0.126)
Kagoshima	8	9	232.2	22.7 (21.1 to 24.5)	-0.108 (-0.189 to -0.030)
Kumamoto	8	9	219.7	19.7 (18.3 to 21.1)	-0.070 (-0.146 to 0.014)
Okayama	10	9	217.8	18.7 (17.1 to 20.3)	0.018 (-0.093 to 0.127)
Mie	9	9	216.4	17.3 (15.97 to 18.8)	-0.011 (-0.105 to 0.093)
Okinawa	5	8	213.7	21.8 (20.1 to 23.3)	-0.217 (-0.295 to -0.146)
Aomori	6	9	193.2	24.6 (22.6 to 26.6)	-0.077 (-0.171 to 0.008)
Nagasaki	7	9	193.0	22.9 (21.0 to 25.0)	0.028 (-0.071 to 0.132)
Yamaguchi	8	9	186.8	20.98 (19.5 to 22.7)	-0.048 (-0.127 to 0.043)
Iwate	6	9	183.5	21.3 (19.5 to 22.99)	-0.220 (-0.291 to -0.142)
Ehime	8	9	177.7	20.4 (18.7 to 22.2)	-0.097 (-0.190 to -0.012)
Akita	4	9	166.9	26.2 (24.1 to 28.6)	-0.105 (-0.1896 to -0.011)
Miyazaki	6	9	166.9	23.7 (21.5 to 26.2)	-0.126 (-0.213 to -0.014)
Yamagata	7	9	155.0	22.97 (20.99 to 24.98)	0.059 (-0.048 to 0.172)
Shiga	9	9	154.5	17.5 (15.9 to 19.0)	-0.028 (-0.142 to 0.0799)
Nara	8	9	148.8	17.3 (16.0 to 18.8)	-0.007 (-0.099 to 0.107)
Toyama	7	9	139.7	20.0 (18.4 to 21.9)	-0.054 (-0.144 to 0.064)
Ōita	8	9	138.7	19.8 (18.3 to 21.4)	-0.061 (-0.144 to 0.041)
Wakayama	7	9	129.0	21.1 (19.4 to 22.9)	-0.117 (-0.205 to -0.021)
Ishikawa	8	9	127.4	16.7 (15.3 to 18.1)	-0.112 (-0.198 to -0.019)
Yamanashi	8	9	115.5	21.7 (19.95 to 23.4)	0.034 (-0.062 to 0.145)
Kagawa	9	9	114.7	18.2 (16.46 to 20.2)	-0.067 (-0.169 to 0.046)
Saga	9	9	113.0	23.4 (21.2 to 25.8)	0.121 (0.003 to 0.254)
Shimane	7	9	109.7	23.1 (21.1 to 25.2)	-0.154 (-0.234 to -0.061)
Kōchi	8	9	95.7	21.1 (19.1 to 23.2)	-0.170 (-0.255 to -0.068)
Tokushima	10	9	93.2	20.2 (18.5 to 21.99)	0.049 (-0.058 to 0.164)
Fukui	10	10	88.1	16.4 (14.9 to 18.2)	-0.127 (-0.217 to -0.012)
Tottori	8	9	73.6	20.9 (19.1 to 22.9)	-0.107 (-0.209 to -0.009)

IV. Discussion

A. Overall Trends

The recorded 22,303 suicides in Japan in 2021 underscore the ongoing public health challenge of suicide in the country. The age-standardized mortality rates of 18.86 and 7.56 per 100,000 in men and women, respectively, highlight the higher burden of suicide in men. However, it is encouraging to note the decreasing trend in age-standardized mortality rates from 1990 to 2021, suggesting potential improvements in suicide prevention and mental health efforts over the years.

B. Age and Gender Differences

The age-specific patterns of suicide mortality rates, peaking at 55-59 years for men and 50-54 years for women, indicate the importance of considering age-specific interventions. The higher rates among older age groups could be attributed to various factors, including social isolation, financial stressors, and declining physical health.

Table 2: Global Burdern of Suicide in 2021 And Their Annualized Changes from 1990 to 2021 of female

Female					
	Death Rank		Death	Age-standarized Death Rate	
Location	1990	2021	#	per 100,000 (95% UI)	% change 1990-2021(95% UI)
Japan	8	10	6625.9	7.6 (7.3 to 7.8)	-0.277 (-0.295 to -0.2595)
Tōkyō	8	10	744.4	8.3 (7.9 to 8.7)	-0.142 (-0.194 to -0.085)
Ōsaka	8	10	533.0	8.7 (8.1 to 9.2)	-0.176 (-0.231 to -0.117)
Kanagawa	8	10	470.6	7.4 (6.98 to 7.9)	-0.219 (-0.272 to -0.169)
Saitama	7	10	382.7	7.97 (7.5 to 8.4)	-0.251 (-0.308 to -0.187)
Aichi	8	10	338.8	6.6 (6.2 to 7.0)	-0.357 (-0.400 to -0.310)
Hokkaidō	8	10	316.7	8.6 (8.1 to 9.3)	-0.126 (-0.195 to -0.055)
Chiba	8	10	313.5	7.5 (7.1 to 8.0)	-0.212 (-0.265 to -0.148)
Hyōgo	8	10	294.7	7.6 (6.9 to 8.1)	-0.290 (-0.35 to -0.233)
Fukuoka	8	10	257.8	7.1 (6.6 to 7.6)	-0.268 (-0.329 to -0.209)
Shizuoka	8	10	160.5	6.2 (5.6 to 6.7)	-0.305 (-0.368 to -0.239)
Ibaraki	8	10	142.0	7.4 (6.8 to 8.0)	-0.298 (-0.358 to -0.231)
Niigata	6	10	140.9	8.5 (7.7 to 9.4)	-0.422 (-0.4795 to -0.357)
Miyagi	7	10	125.0	7.96 (7.3 to 8.7)	-0.243 (-0.318 to -0.160)
Kyōto	8	10	124.9	6.6 (5.96 to 7.1)	-0.397 (-0.4497 to -0.337)
Hiroshima	8	10	124.8	5.8 (5.3 to 6.3)	-0.456 -0.503 to -0.406)
Gunma	8	10	111.5	7.8 (7.1 to 8.4)	-0.3695 (-0.427 to -0.305)
Tochigi	8	10	110.5	8.8 (8.1 to 9.6)	-0.302 (-0.365 to -0.231)
Nagano	8	10	106.6	7.8 (7.3 to 8.5)	-0.317 (-0.376 to -0.254)
Fukushima	8	10	104.3	8.7 (7.95 to 9.5)	-0.232 (-0.305 to -0.146)
Gifu	8	10	100.6	6.96 (6.4 to 7.6)	-0.417 (-0.465 to -0.362)
Mie	8	10	93.5	7.5 (6.8 to 8.3)	-0.231 (-0.315 to -0.142)
Iwate	7	10	83.2	9.1 (8.2 to 9.95)	-0.395 (-0.465 to -0.327)
Kumamoto	8	10	80.7	6.2 (5.6 to 6.7)	-0.326 (-0.393 to -0.256)
Kagoshima	8	10	78.9	6.6 (6.1 to 7.3)	-0.386 (-0.447 to -0.314)
Aomori	7	10	77.7	8.4 (7.6 to 9.3)	-0.288 (-0.366 to -0.203)
Akita	7	11	76.1	9.4 (8.5 to 10.3)	-0.3598 (-0.428 to -0.291)
Okayama	8	10	73.8	5.3 (4.8 to 5.9)	-0.414 (-0.473 to -0.349)
Nara	8	10	72.3	7.9 (7.2 to 8.5)	-0.199 (-0.276 to -0.112)
Ehime	8	10	70.0	8.0 (7.3 to 8.8)	-0.241 (-0.316 to -0.1599)
Yamaguchi	8	10	68.7	7.0 (6.3 to 7.7)	-0.316 (-0.388 to -0.2396)
Nagasaki	8	11	67.1	6.8 (6.1 to 7.5)	-0.272 (-0.348 to -0.187)
Yamagata	8	10	66.0	8.5 (7.7 to 9.3)	-0.268 (-0.362 to -0.186)
Okinawa	8	10	65.5	6.7 (6.1 to 7.2)	-0.266 (-0.345 to -0.184)
Miyazaki	8	10	63.5	7.7 (6.9 to 8.5)	-0.341 (-0.4095 to -0.262)
Shiga	8	10	60.4	5.9 (5.3 to 6.5)	-0.419 (-0.479 to -0.358)
Wakayama	8	10	57.7	7.4 (6.6 to 8.1)	-0.392 (-0.459 to -0.319)
Toyama	7	11	56.0	7.4 (6.6 to 8.2)	-0.399 (-0.467 to -0.326)
Ōita	8	10	52.4	6.9 (6.2 to 7.5)	-0.303 (-0.377 to -0.225)
Kagawa	8	10	50.5	7.1 (6.4 to 7.7)	-0.2798 (-0.355 to -0.199)
Ishikawa	8	11	49.6	5.6 (5.1 to 6.2)	-0.388 (-0.444 to -0.317)
Tokushima	8	11	40.3	6.4 (5.7 to 7.2)	-0.387 (-0.463 to -0.305)
Kōchi	8	10	39.7	7.8 (7.0 to 8.6)	-0.241 (-0.330 to -0.141)
Shimane	8	11	39.2	7.6 (6.9 to 8.4)	-0.370 (-0.4399 to -0.293)
Yamanashi	8	10	39.2	6.7 (6.1 to 7.4)	-0.365 (-0.432 to -0.292)
Saga	8	10	38.2	6.5 (5.8 to 7.2)	-0.2896 (-0.375 to -0.199)
Fukui	8	11	35.3	6.1 (5.4 to 6.7)	-0.392 (-0.467 to -0.315)
Tottori	8	10	26.9	6.4 (5.7 to 7.1)	-0.384 (-0.458 to -0.306)

A. Period and Birth Cohort Effects

The peak in suicide rates around 2002.5, as indicated by period effects, suggests the impact of societal factors or events around that time. Understanding these factors could provide insights into effective suicide prevention strategies. The higher suicide rates among cohorts born in the 1920s compared to those born in 1965 highlight the role of historical

factors and life experiences in shaping suicide risk across generations.

B. Regional Differences

The significant regional differences in suicide rates, with some prefectures consistently exhibiting higher rates than others, emphasize the need for targeted interventions and support in these areas. Conversely, the lower rates in certain prefectures suggest the presence of protective factors or effective suicide prevention efforts that could be studied and replicated in other regions.

C. Gender Disparity

The absolute gender disparity in suicide rates, with significantly higher rates among men compared to women, underscores the importance of gender-specific approaches to suicide prevention. Tailoring interventions to address the specific risk factors and mental health needs of each gender is crucial in reducing this disparity.

IV. Conclusion

This study highlights the importance of considering age, period, and birth cohort effects in understanding suicide trends in Japan. The findings underscore the need for prefecture-specific suicide prevention strategies, taking into account regional socio-economic and cultural factors to effectively address the suicide epidemic.

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Assessment of Insecticide Resistance and Voltage-Gated Sodium Channel Gene Mutations in *Aedes aegypti* Mosquitoes in Bangladesh

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***Abstract*—Arboviral diseases such as dengue, chikungunya, and yellow fever pose significant public health challenges globally. In Bangladesh, dengue control primarily relies on targeting the main vector, *Ae. aegypti*, through insecticides. This study was conducted to evaluate the level of insecticide resistance in *Ae. aegypti* particularly focusing on pyrethroids, organophosphates, and carbamate groups that have been used in Bangladesh for mosquito control and also to analyze the voltage gated sodium channel gene mutations V1016G and F1534C that are associated with pyrethroid resistance. This study was conducted in Dhaka and Chattogram cities, encompassing both field-reared (F_0) and laboratory-reared (F_1) adult *Ae. aegypti* following the stringent methodology of WHO susceptibility tube bioassay protocols and molecular assays were conducted to detect target site resistance. Recommended doses of all pyrethroids (deltamethrin, etofenprox, alphacypermethrin, and permethrin) showed resistance against *Ae. aegypti* in both cities. Among the 3 tested concentrations of deltamethrin (0.05%, 0.25%, and 0.5%), only a 10-fold higher concentration (0.5%) shows 99±0.25% knockdown effects against Dhaka city (F_1) *Ae. aegypti* where the population of Chattogram city was less than 98%. The carbamate group insecticide, bendiocarb (0.1% & 0.5%) also showed resistance in both cities. Conversely, malathion 5% (organophosphates) was found to be the only susceptible insecticide (mortality >98%) against dengue vector mosquitoes both in Dhaka (F_0, F_1) and Chattogram (F_0, F_1). The gene sequencing data analysis showed that resistant samples had mutations F1534C and V1016G, along with a number of other point**

mutations. This is what made them less sensitive to pyrethroids. However, in certain *Ae. aegypti* populations, resistance wasn't fully explained by kdr mutations, indicating other mechanisms may be involved. The findings of this study emphasize the use of malathion or other susceptible insecticides for controlling *Ae. aegypti* to reduce dengue in Bangladesh. Furthermore, this study highlights the importance of integrated pest management (IPM) to combat the dengue burden in Bangladesh.

Keywords: Insecticide Resistant, Susceptibility, Knockdown, Mortality, *Ae. aegypti*, Dengue

I. Introduction

This Dengue fever is the most rapidly spreading vector-borne disease and a major public health problem in Bangladesh and occurs in an endemo-epidemic pattern [1]. Over 2.5 billion people live in areas where these diseases can spread, with between 50 and 100 million people infected annually [2].

Ae. aegypti is highly abundant throughout Bangladesh, especially in Dhaka [1]. In the absence of a specific dengue treatment or vaccine, controlling *Ae. aegypti* relies on a limited range of approved chemical insecticides, notably pyrethroids, organochlorines, organophosphates, and carbamates [3]. However, resistance to many insecticides has developed in *Ae. aegypti* globally, posing a serious threat to control programs [4].

Resistance in *Ae. aegypti* and other vector and pest species can arise through two major mechanisms. The first mechanism is metabolic or enzymatic resistance, which occurs through the up-regulation or constant overproduction of detoxifying enzymes [6]. The second mechanism is knockdown resistance (kdr), which arises from insecticide selection and is not overcome by metabolic inhibitors. This resistance often involves single point mutations in the genes coding for proteins targeted by insecticides [7]. Pyrethroid insecticides bind to voltage-gated sodium channels (VGSC) in neurons, preferentially attaching to open channels [8].

Despite rising Aedes-borne diseases in Bangladesh, insecticides against *Ae. aegypti* are infrequently used. The increasing cases suggest current pesticides are ineffective, likely due to local *Aedes* populations developing resistance. In Bangladesh, the insecticide resistance status of *Ae. aegypti* has not been extensively assessed. This study aimed to evaluate insecticide resistance status and detect mutations in the VGSC gene to correlate with observed susceptibility, informing future insecticide selections for vector control.

II. Materials and Method

A. Study Area

The dengue endemic areas, mainly Dhaka and Chittagong City were selected for the study. Larvae and pupae were collected from artificial containers in domestic and per i-domestic areas in selected urban locations.

B. Adult Bioassays

Standard testing procedures for adult *Ae. aegypti* was followed through WHO guideline [9].

C. AS-PCR genotyping

For this detection of V1016G mutation, an AS-PCR assay was performed using a standard PCR thermal cycler, with results visualized via gel electrophoresis. Each 10 µl reaction included 1.5 mM MgCl2, 1x PCR buffer, 0.25 µM forward primer (5′-ACCGACAAATTGTTTCCC-3′), 0.125 µM reverse primer (5’-AGCAAGGCTAAGAAAAGGTTAA-3’), 200 µM dNTP mixture, 0.2 units Taq polymerase, and 25 ng of genomic DNA and for F1534Cmutation, each reaction was performed in a 10 µl volume with 1.5 mM MgCl2, 1x PCR buffer, 0.5 µM Phe forward primer (5′-GCGGGCTCTACTTTGTGTTCTTCATCATATT-3′), 0.5 µM common reverse primer (5′-TCTGCTCGTTGAAGTTGTCGAT-3′), 200 µM dNTP mix, 0.2 units Platinum Taq DNA polymerase, and 25 ng template DNA. The thermal cycling was done following the S.A. Stenhouse (2013) [10]

III. Results

This study was assumed with the aim of examining the susceptibility status of *Ae. aegypti* in Dhaka and Chittagong city mosquitoes’ populations. The results showed high levels of resistance against pyrethroid and carbamate except organophosphate. All populations collected sample in this study demonstrated resistance to the pyrethroids (permethrin, deltamethrin, alphacypermethrin and etofenprox) as well as the carbamate (bendiocarb). However, the tested populations appeared responsive to the organophosphate (malathion). The impact of these insecticides at concentrations 5x and 10x higher than the standard dosage was evaluated on collected samples, and the outcomes were juxtaposed with those observed at the standard 1x concentration.

I. *Effect of Pyrethroids*

Table 1 show the impact (after 1 hour and 24 hours) of each tested insecticide on the levels of mortality by adult *Ae. aegypti* from Dhaka city (D) and *Ae. aegypti* from Chattogram city (C) mosquitos’ population both Field collected (F_0) and laboratory reared (F_1) under the study. As can be seen at one hour exposure was ineffective in eliciting any significant mortality in all populations, with the highest rate being observed at 13 ± 3% in the *Ae. aegypti* F_1 (D) mosquito by alphacypermethrin. When observed at 24 hours post exposure, for all pyrethroids mortality was below a maximum of 40%.

The percent knockdown after 1-hour post-exposure and mortality 24-hour post exposure deltamethrin (0.05%) resulted in mortality less than 26 ± 2.58% in both *Ae. aegypti* population collected from Dhaka and Chittagong city. When the dose increases 10 times 0.5% (compare with recommended dose) show the highest mortality among the pyrethroid group resulting 100% mortality at *Ae. aegypti* F_1 (D) generation and lowest at 94 ± 1.15% at *Ae. aegypti* F_0 (C). There were significant differences (Table.2) among the tested concentration of deltamethrin (0.05%, 0.25% and 0.5%) ($p<0.05$) and no significance difference mortality rates among the populations. Alphacypermethrin has more knockdown effect compare to the mortality. All population *Ae. aegypti* have the more ability to recover the insecticides effect. Alphacypermethrin show the highest (35± 1%) mortality in *Ae. aegypti* F_1 (D) with recommended dose 0.05% compare to the other pyrethroids in both *Ae. aegypti* population collected from Dhaka and Chattogram mosquitoes. No significance difference between Dhaka and Chattogram city mosquito population and also have no significance between field collected and lab reared population ($p>0.05$). The knockdown effect of permethrin can be ignored. Permethrin shows the lowest knockdown result at recommended dose (0.75%) at 1 hour post exposure period. Permethrin was the least effective among the pyrethroids group showing the highest 10± 0.28% mortality at 0.75% concentration against all the population after 24 hours exposure time. At 7.5% concentration 10 times to recommended dose show the highest

knockdown effect only 18± 1.15% against and highest mortality between the concentration 0.75% and 7.5% for both population in F_0 and F_1 generation ($p<0.05$).

The results at 24 hours post-exposure to 0.5% etofenprox were not effective either, with mortality ranging from 7 ± 1.91%–15 ± 1.91%. When the dose increased 5 times 2.5% also ineffective against both *Ae. aegypti* Dhaka and Chattogram cities population having highest mortality 33± 0.95% in *Ae. aegypti* F_1 (D).

II. *Effect of carbamates*

Bendiocarb at 0.1% resulted in mortality of 47 ± 0.95 - 71 ± 0.85 at 1-hour exposure time and 41 ± 1.91 – 65 ± 0.95% after 24 hours exposure time with no significant differences 25± 1% in *Ae. aegypti* F_1 (D). There is significance difference ($p<0.05$) in mortality between the treated populations (Table 2). The mosquito population both *Ae. aegypti* population have the ability to overcome the toxic effect of the insecticides showing more knockdown effect than the mortality after 24 hours.

III. *Effect of organophosphate*

Malathion (5%) was only the insecticides that was susceptible for all *Ae. aegypti* population. The mortality of 5% malathion after 24 hours post-exposure ranged between 98± 1.15–99 ± 1%, ($p < 0.05$) in Dhaka city population and in Chattogram city the range 98 ± 0.57% - 99 ± 0.5%).

Table 1: Percentage of knockdown and mortality at 1 hour and 24 hours post exposure

Insecticides	Dhaka City *Aedes aegypti*				Chattogram *Aedes aegypti*			
	Field Collection F_0		Laboratory Reared F_1		Field Collection F_0		Laboratory Reared F_1	
	1 hour	24 hours	1 hour	24 hours	1 hour	24 hours	1 hour	24 hours
Deltamethrin 0.05%	4±1.63%	17±1.91%	5±1%	26±2.58%	11±2.06%	16±2.16%	14±1.2%	19±2.06%
Deltamethrin 0.25%	85±1.91%	81±2.51%	93±1.91%	90±2.58%	75±1.25%	79±1.73%	81±0.5%	85±0.8%
Deltamethrin 0.5%	96±1.63%	97±1.91%	99±1%	100±0%	88±3.77%	94±2.21%	87±2.6%	95±1.5%
Alphacypermethrin 0.05%	9±1.91%	32±1.63%	13±3%	35±1%	5±0.5%	17±1.29%	9±0.9%	19±0.9%
Alphacypermethrin 0.25%	61±3%	35±1.91%	64±1.63%	26±3.46%	49±1.5%	57±1.29%	52±1.8%	63±0.9%
Alphacypermethrin0.5%	67±2.51%	43±1%	77±1.91%	60±3.65%	55±1.70%	66±1.41%	57±1.2%	58±0.8%
Permethrin 0.75 %	2±0.5%	10±1.15%	1±1%	10±1.15%	5±0.5%	7±0.5%	5±1.2%	10±0.5%
Permethrin 7.5%	16±1.63%	21±1%	18±1.15%	25±1%	12±1.29%	16±2.16%	8±0.8%	19±0.7%
Etofenprox 0.5%	4±1.63%	7±1.91%	5±1%	10±1.15%	5±0.25%	10±1.29%	7±1.7%	15±0.9%
Etofenprox 2.5%	14±2.58%	25±1.91%	18±2%	33±1.91%	13±1.94%	24±1.15%	27±0.9%	32±0.8%
Bendiocarb 0.1%	66±1.15%	56±2.82%	71±1.91%	65±1.91%	57±0.95%	65±0.95%	65±0.9%	68±0.8%
Bendiocarb 0.5%	82±2.58%	71±1.91%	89±1.91%	87±2.51%	78±0.81%	71±0.95%	70±1.5%	80±1.4%
Malathion 5%	93±1.91%	98±1.15%	95±2.51%	99±1%	89±0.5%	98±0.57%	92±0.8%	99±0.5%

Fig 1: Point mutation in gene for F1534C

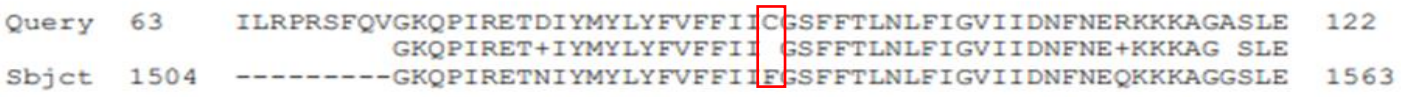

Fig 2: Amino acid mutation for F1534C resistance sample

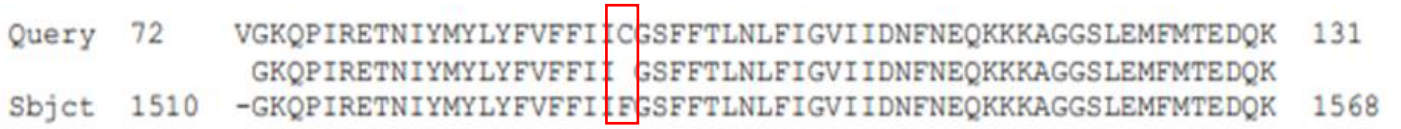

Fig 3: Amino acid mutation for F1534C susceptible sample

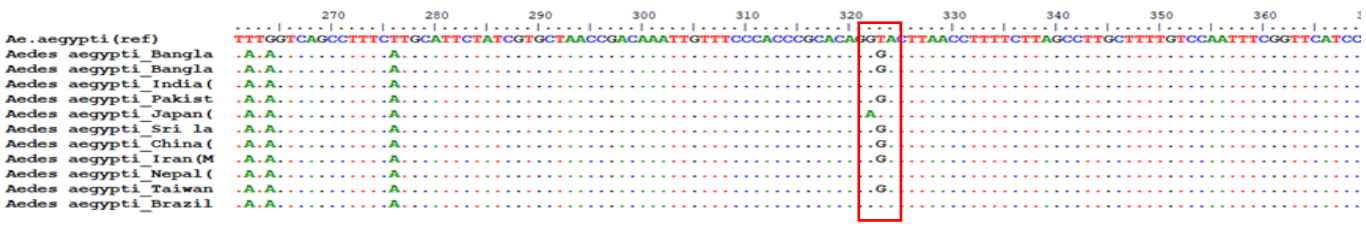

Fig 4: Point mutation in gene for V1016G

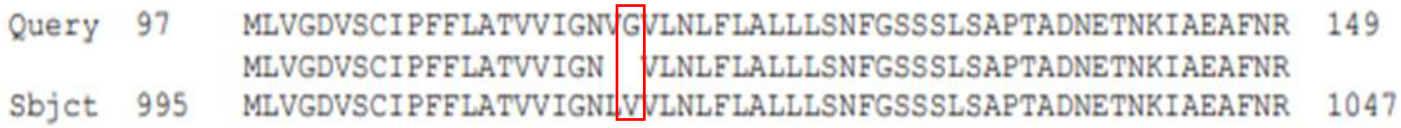

Fig 5: Amino acid mutation for V1016G

Table 2: Comparative efficacy of different insecticides against two population and two generation (p value) of mosquitoes

Insecticides	Significant difference between two species and two generation (*p* value)			
	Ae. aegypti F_0 (D) vs F_1 (D)	*Ae. aegypti* F_0 (C) vs F_1 (C)	*Ae. aegypti* F_0 (D) vs *Ae. aegypti* F_0 (C)	*Ae. aegypti* F_1 (D) vs *Ae. aegypti* F_1 (C)
Deltamethrin (1x)	0.03	0.04	0.02	0.03
Alphacypermethrin (1x)	0.16	0.17	0.0003	0.0001
Etofenprox (1x)	0.22	0.17	0.38	0.06
Permethrin (1x)	0.98	0.09	0.09	0.99
Bendiocarb (1x)	0.03	0.01	0.004	0.004
Malathion (1x)	0.50	0.51	1.00	1.00

IV. Discussion

In Bangladesh, particularly in Dhaka, *Ae. aegypti* mosquitoes are abundant [11]. From the study, all the mosquitoes' populations tested demonstrated resistance to pyrethroids. The poor knockdown effect and the overall low toxicity caused by the pyrethroids tested on all the *Ae. aegypti* mosquitoes are evidence of strong resistance to these insecticides. Almost all over the world it has evidence that deltamethrin is being resistance against *Aedes aegypti* mosquitoes [12, 13]. In contrast Al amin et al. claimed that in Dhaka city several place still now mosquito susceptible to deltamethrin [14]. Overuse of deltamethrin in agriculture and mosquito control programs in Dhaka has led to mosquito resistance [14]. Alphacypermethrin, a pyrethroid used for over fifty years in Bangladesh Tasin et al., (2020), showed the highest mortality rate (35±0.5) at 1x concentration among the pyrethroids studied. Additionally, alphacypermethrin has been used in LLINs for malaria, and in IRS programs for malaria and Kala-azar, leading to global mosquito resistance [19, 20]. Permethrin, widely used in Bangladesh for mosquito control in aerosols [14, 22] showed the lowest knockdown effect and mortality in our study. Long-term use of permethrin in household insect management and aerosols [19] has contributed to mosquito resistance. Etofenprox is highly resistance insecticides with poor knockdown effect and mortality. However, there are many reports to resistance to etofenprox against Ae. aegypti s mosquitoes [20]. The impact of carbamates on mosquitoes was minimal in our study, contradicting some previous reports Al-Amin et al., (2020) and Deming et al., (2016), suggesting possible resistance development against bendiocarb [12, 14]. The study revealed that bendiocarb, a carbamate, induced more knockdown effects than mortality in both mosquito populations, consistent with findings from several studies, including Darvesh et al., (2008) [22]. Malathion under organophosphate, on the other hand, appeared to be an effective toxin against mosquitoes. Malathion is still effective for vector control and it is supported with many report [12,14,22]. Multiple mutations in the VGSC gene of Aedes aegypti have been reported, but only a limited number of them have been confirmed to be associated with pyrethroid resistance [25]. We also observed a high rate of point mutations at F1534C and V1016G, similar to the observations from other nearest country [26,27]. In our study, we have found that both resistance and susceptible sample have the F1534C mutation while V1016G mutation in resistance sample against deltamethrin. Despite the presence of the F1534C kdr mutation, which is typically associated with pyrethroid resistance, Aedes aegypti in Bangladesh remain susceptible to deltamethrin. This indicates that the F1534C mutation alone does not confer complete resistance. The V1016G mutation is reported to be associated with resistance to both type I (permethrin) and type II (deltamethrin) pyrethroids, while F1534C is linked only to resistance against type I pyrethroids [10].

V. Conclusion

The inaccessibility of advanced vector management technologies hampers efforts to control *Ae. aegypti* and prevent disease spread. This study reveals significant resistance to carbamates and pyrethroids in Bangladesh, with the exception of malathion. High resistance levels threaten current control methods and complicate alternatives. Continuous insecticide resistance monitoring is essential to track trends and inform

effective strategies. Sustainable methods, like biocontrol, should be considered in cities facing insecticide resistance challenges. Our findings highlight the need for ongoing, standardized insecticide-susceptibility testing in *Ae. aegypti*.

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Nurses' knowledge regarding Evidence-Based Practice to prevent ventilator-associated pneumonia (VAP)- a meta-analysis

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***Abstract*— Purpose:** This paper explores how Evidence-Based Practice (EBP) and nurses' EBP training on ventilator-associated pneumonia (VAP) significantly reduce ICU mortality and morbidity. This meta-analysis evaluates the nurses' knowledge regarding EBP practices and identifies the gap in preventing VAP for better patient outcomes.

Method: This meta-analysis was conducted by searching PubMed and Google Scholar databases with the keywords VAP bundle, and nurses EBP knowledge. This study analyses the implementation of the VAP bundle and nurses' knowledge regarding EBP to prevent VAP.

Findings: This meta-analysis included 10 studies from various countries but set on study design. The study indicates that nurses' EBP training improves their knowledge and competency and significantly prevents VAP conditions. By comparing nurses' pre- and post-assessment data we found the positive impact of EBP training, with a standardized mean difference (SMD) of -1.25 and 95% confidence interval of [-1.50, -1.00], and a p-value <0.001.

Implications: These findings indicate that the knowledge of VAP prevention among nurses is essential for VAP prevention and regular professional development is necessary. Implementing regular EBP training for nurses helps close the knowledge gap and improve standard care in the ICU. Healthcare organizations should develop infrastructure and resources to provide continuous EBP training for their nursing staff, especially in developing countries.

Keywords: Nurse, Evidence-Based Practice (EBP), Ventilator-Associated Pneumonia (VAP), VAP bundle, Intensive Care Unit (ICU).

I. Introduction

Ventilator-associated pneumonia (VAP) is a condition that significantly affects healthcare-associated infection, especially in the Intensive Care Unit (ICU). Despite the strong use of Evidence-Based Practice (EBP) in VAP prevention among ICU patients, there is still space for improvement in effectively applying these strategies in healthcare settings [1].

EBP in the ICU is crucial for preventing VAP and ICU nurses must practice EBP strategies to reduce VAP. Continue education and training management for nurses building the knowledge gap and ultimately reducing the incidence of VAP. However, most of the current publications find that knowledge and practice regarding educational guidelines prevent VAP [2, 3, 4].

Understanding and adherence to EBP practice among nurses are widely used globally, with better access to resources and utilizing high-middle-income countries. In Asian countries, the prevalence of VAP and EBP practice among nurses significantly differs based on the country's economic condition and healthcare setting. For instance, Japan and South Korea reported advanced their healthcare system and nurses' EBP practice [5].

Many developing countries face inadequate staffing, inadequate materials, and a lack of knowledge about EBP practice. The importance of EBP to prevent VAP is the gap in knowledge and EBP practice of nurses due to systemic issues, lack of resources, and institutional support. The study aims to nurses' knowledge regarding VAP prevention and the guidelines followed for VAP prevention. The research study clarifies the following research question:

1. What is the current state of nurses' knowledge regarding EBP to prevent VAP?
2. How effective is the implementation of the VAP bundle?
3. What is the impact of EBP training on nurses' knowledge competency?

II. LITERATURE REVIEW

Evidence-based practice (EBP) in nursing is a systematic approach to clinical decisions on available evidence. Ventilator-associated pneumonia (VAP) is a hospital-acquired infection and a major concern in healthcare settings. Nurses are the main responsible person for preventing VAP by using their knowledge regarding EBP practice.

Melnyk and Fineout-Overholt (2011) identified EBP as a critical strategy in VAP. EBP integrates clinical expertise with the best available evidence and patient preferences. Enhancing nurses' competency through educational guidelines improves adherence to prevent VAP prevention, where significant improvement of pre and post-test results reduces VAP incidence [3].

Educational training based on EBP guidelines has been shown to significantly improve nurses' knowledge and competency in preventing VAP. Training programs that focus on the implementation of VAP prevention bundles and adherence to EBP guidelines have demonstrated positive outcomes in reducing VAP rates in ICUs [13]. For instance, pre-and post-training assessments have revealed significant improvements in nurses' knowledge and practices regarding VAP prevention, leading to a decrease in VAP incidence [12]. Concerning the studies nurses practice regarding VAP prevention. Providing educational training according to guidelines changes nurses' knowledge and prevents VAP [5].

The implementation of EBP practices for VAP prevention varies globally, influenced by factors such as economic conditions and healthcare settings. In high- and middle-income countries, better access to resources and more robust EBP implementation have been reported compared to low-income countries [1].

More studies showed, that educating nurses and improving their knowledge based on EBP practice reduces VAP in ICUs. Providing educational training according to guidelines changes nurses' knowledge and prevents VAP. [2,4,7,10,11].

III. METHODS

This meta-analysis was conducted by searching PubMed and Google Scholar databases with the keywords 'VAP bundle', 'ventilator-associated pneumonia prevention', and 'nurses' EBP knowledge'. Irrelevant article removed and article includes quasi-experimental study and systemic review.

This study focuses on-

1. Nurses' knowledge regarding EBP to prevent VAP.
2. Analyses the implementation of the VAP bundle and
3. Pre- and post-assessment data to evaluate the impact of nurses' EBP training and competency.

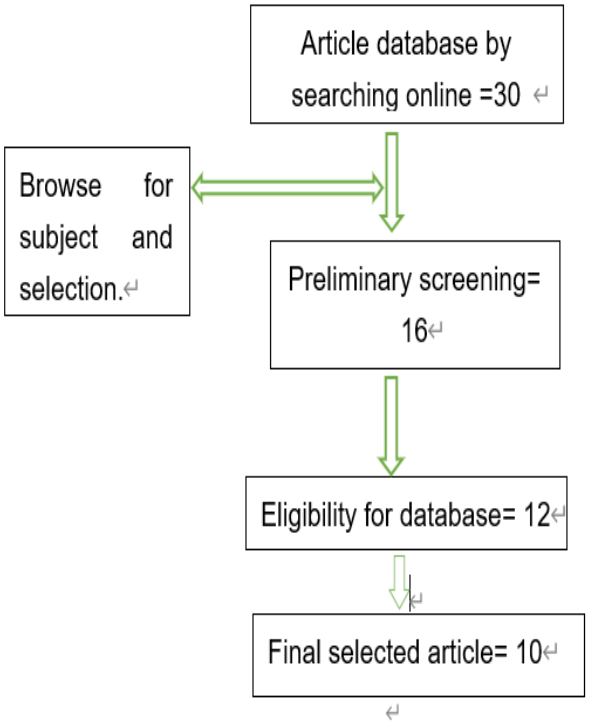

Fig: studies screening process

Data extraction and analysis:

The reviewers extracted data using standard format including the: study design, sample size, intervention details, VAP rate, and outcome. Using the JBI (Joanna Briggs Institute) critical appraisal checklist for a Quasi-experimental study to assess the quality of this study. The checklist evaluates the aspects of the aim, the appropriate selection of this study design, and the methods used for statistical analysis.

A random effect model was used to analysis of this study's heterogeneity. The incidence rate between pre- and post-training results is variation. Effect size was calculated by SMD (standardized mean differences) with 95% CI (confidence intervals). The 50% of substantial heterogeneity and sensitivity analyses the robustness of the findings.

Characteristics of this study:

The sample size range of 50-400 and interventions are varied like workshops, seminars, and hands-on training for EBP practice for VAP prevention. The duration of the EBP training 1 week to 6 months.

IV. RESULTS

All studies have shown the significant impact of EBP training and VAP prevention. The pooled analysis of the 10 studies showed a significant reduction in VAP incidence following EBP training for nurses. The overall effect size was calculated as: SMD=-1.25, 95% CI -1.50, -1.00, p-value <0.001, and heterogeneity among studies 45%.

The significant p-value <0.001 indicates that the observed reduction in VAP incidence is unlikely to have occurred by chance. The 95% CI suggests a high level of precision in the estimate of the effect size, with the true effect likely to fall within this range. The moderate level of heterogeneity (I^2 = 45%) suggests some variability among the included studies, which is expected in a meta-analysis of educational intervention.

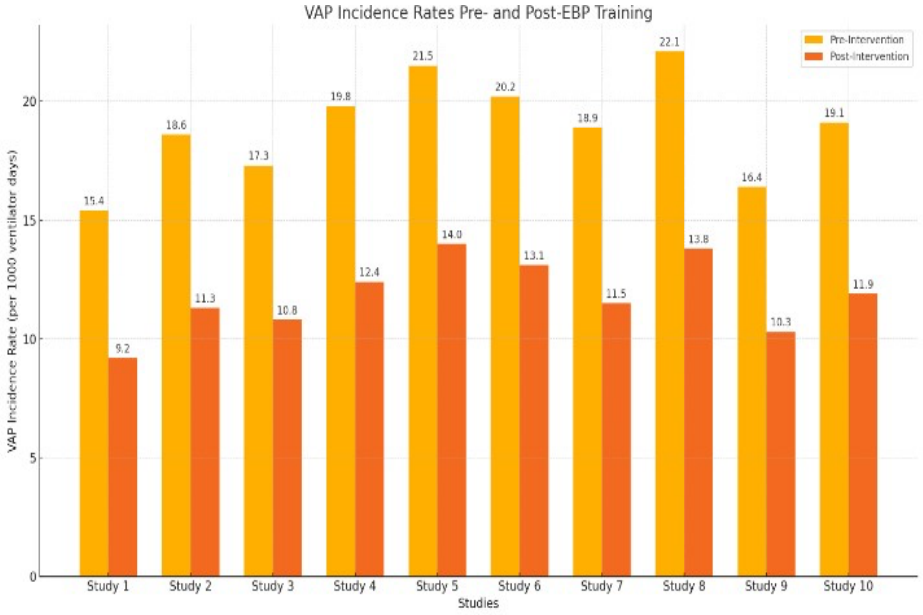

Fig 2: VAP incidence rate based on EBP training.

This graph showed the VAP incidence rate per 1000 ventilator days and before and after the implication of EBP training across the 10 studies. Each study 2 representative bars where the left bar shows the pre-intervention result, and the right bar shows the post-intervention rate of VAP incidence. The following EBP training decreases the rate of VAP incidence.

V. DISCUSSION

The result of the meta-analysis shows that nurses' EBP training increases the knowledge and competency level which effect on reduces the rate of VAP incidence in ICU settings. The calculated SMD of -1.25 with a 95% confidence interval of CI -1.50, -1.00, and p-value <0.001 strongly supported the effectiveness of EBP training. This indicates a substantial improvement in nurse competency and a corresponding decrease in VAP rates, highlighting the critical role of EBP in enhancing patients' outcomes.

EBP is a fundamental component of contemporary nursing practice because it combines clinical knowledge, the best available data, and patient preferences. Nurses can provide excellent care that enhances patient outcomes and lowers healthcare costs by following EBP principles. For example, it has been demonstrated that adherence to the VAP bundle, a collection of evidence-based strategies intended to prevent VAP, lowers the incidence of this disorder, thereby improving patient outcomes and lowering medical costs [9]. Our findings align with previous studies that have demonstrated the positive impact of EBP training on nurse competency and patient outcomes. For example, a study by Rello et al. (2002) showed that implementing EBP guidelines significantly reduced VAP rates in ICUs. Similarly, Melsen et al. (2013) found that hospitals that provided regular EBP training for their staff had lower rates of hospital-acquired infections, including VAP.

The effectiveness of EBP training is influenced by various institutional and educational variables, including the availability of resources, the level of institutional support, and the quality of the training programs [12].

Healthcare organizations should promote evidence-based practice (EBP) by providing resources like research, training materials, and clinical guidelines, and incorporating EBP training into nursing curricula to prepare future nurses for better patient outcomes and reduced healthcare costs.

Regular EBP training for nurses helps close the knowledge gap and improve standard care in the ICU. Continuous professional development ensures that nurses remain up to date with the latest evidence and best practices, enabling them to provide optimal care to their patients. This is particularly important in preventing VAP, as it requires adherence to specific guidelines and protocols.

Healthcare organizations should invest in infrastructure and resources to provide continuous EBP training for their nursing staff. This is especially crucial in developing countries, where the lack of resources and institutional support can hinder the effective implementation of EBP practices. By prioritizing ongoing education and training, healthcare facilities can enhance the competency of their nursing staff, reduce the incidence of VAP, and improve overall patient outcomes.

Limitation of this study:

There are several limitations of this study. The first heterogenicity of this study could affect the generalizability of this study. The second variety of the study such as the small number of papers, and duration of intervention may affect the outcome. Additionally, there is limited geographical diversity in these studies.

VI. FUTURE RESEARCH

The focus is on future research to evaluate the long-term effect on EBP training on VAP prevention. Its focus will be on tertiary-level hospitals where nurses receive EBP training by VAP guidelines. By concentrating on a particular context and according to established protocols, the research provides useful insight into patient outcomes.

Furthermore, figure out the specific EBP training that works best and customize it for the greatest positive impact. To ensure the long-lasting improvement of VAP, I want to assess the application of EBP training in clinical settings.

Healthcare facilities must implement advanced equipment and technology to support the EBP implementation and VAP prevention guidelines. My future study explores advanced technology, checks the impact of advanced technology, and reduces the VAP incidence.

Organizational culture and institutional support its essential for adherence use of EBP. My future implication is how different organizations affect the nurse's ability.

VII. CONCLUSION

The meta-analysis provides strong evidence that EBP training improves the nurse's knowledge considerably and lowers the rate of VAP in intensive care units. Healthcare quality and patient safety require ongoing professional growth and education in EBP. Healthcare organizations should prioritize continuous education programs in clinical settings to better patient outcomes and reduce the costs. Regular EBP training is essential for maintaining high standards of care, fostering professional growth, and ensuring the overall quality and safety of healthcare services. The findings highlight the need for healthcare systems to invest in and support ongoing professional development, particularly in resource-limited settings, to achieve sustained improvements in patient care.

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Accepted Poster Presentations

Implementation of AI-based Vision Filter using Spectrum Correction for Color Weakened Environment

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1. Background of the Research: Color weakness is caused by abnormalities and losses of abstract cells in the retina. According to the type of abnormality, it is divided into P type (Protanopia), D type (Deuteranomaly), and T type (Tritanopia). In the case of P and D types, red and green colors are weakly recognized [1]. Color correction is necessary to provide a more improved color experience to people with color weakness (Fig. 1).

2. Research Objectives: It is very important to solve this trouble and enhanced color vision can contribute to eliminate the hassle of color weakness. In order to contribute to easy color recognition, this study proposes enhanced vision using spectrum correction and image learning skills.

3. Research Problem/ Research Questions: People with color weakness are less able to distinguish colors in a certain color domain with weak cognition. In order to solve this problem, color correction algorithm maps the weak cognitive domain to a strong cognitive domain. The correction is performed in the HSV (H:color, S:saturation, V:brightness) color space, and Fig.2 shows the color conversion process of the color enhancement algorithm[1]. In the case of color weakness people, color, brightness, and saturation are perceived in the same way as the general people at 60°, 180°, and 240°, and the perception is weakened in proportion to the distance from the spectrum.

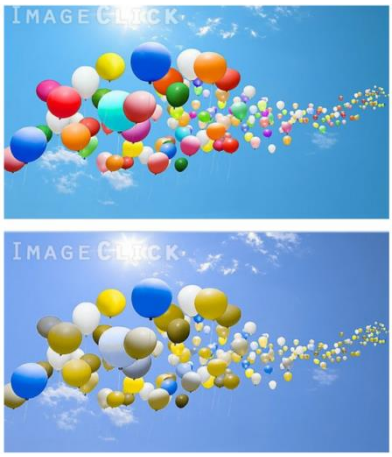

Fig.1 Color image seen by people with color weakness

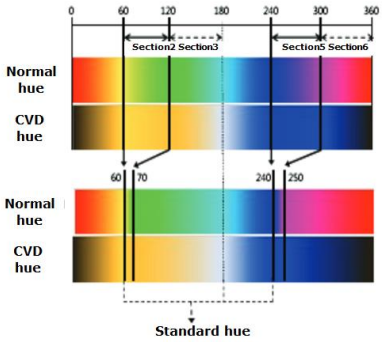

Fig.2 Color Conversion of Color Enhancement

4. Approach: We reduced the color range of 6 0°~120° to 60°~70°, and the color range of 240°~300° to 240°~250°. Our color distinguishing enhancement algorithm facilitates color identification because it corrects all colors in the image to a color range that can be perceived by the color impaired, which is suitable for image correction for the purpose of providing information. The deep learning model YOLO [2] was used to classify the images. YOLO is a flexible model that can be expanded or reduced according to the user's hardware limitations or performance requirements, which is suitable for people with color loss who need to be calibrated in various environments such as smartphones, PCs, and tablets. Using a deep learning model, training data were created and trained directly to distinguish the purpose of the image into aesthetic appreciation and information transmission. We tried to

distinguish the purpose of the image by labelling artworks and natural landscapes as images for aesthetic appreciation, and by labelling diagrams, blueprints, and maps as images for information understanding. However, there were no clear features to distinguish between aesthetic appreciation and information understanding, so the accuracy was low. Therefore, as a second measure, text detection was used to determine whether text was included in the image, and images containing text were classified as images for the purpose of information understanding.

5. Experiment/Methodology: Google Colab [3] was used for the development environment, Python was used for coding, and Google form [4] was used for the survey to verify the results using 200 pieces of training data. At first, to determine the degree of color weakness, FM100 (Farnsworth Munsell 100) Hue test [5] is used.

6. Results: The results of the test are good, but the pass rate of the color weakness test is low (62%). Then, the correction intensity is increased from 0 to 100 and then the most preferred image is selected. In order to prove the performance of our color enhancement algorithm for information understanding, the pass rate of the color weakness was compared after correction of the original image. The order of each test paper was randomly placed, and the average pass rate of the original is 58%. Our color enhancement algorithm increases the pass rate to 92 % (Table 1), so it is effective for the purpose of information understanding.

Table 1: Comparison of Pass rates

Number	Original	Enhanced
12	100%	100%
8	50%	50%
74	50%	100%
15	50%	100%
6	50%	100%
16	50%	100%
Average	**58%**	**92%**

7. Conclusion and Future Work: Color weakness means insufficient ability to perceive color or variations in color and color blindness cannot distinguish colors. This study implemented color spectrum correction and image learning that can contribute to easy color recognition. This study evaluates the performance of the proposed technique using Google Colab. The experiments show that the pass rate is improved from 58% to 92%, indicating that it could provide better color vision. Other complex factors such as image saturation, histogram distribution, and display environment will be considered in future work. Future studies will also extend the proposed scheme to complex IoT environments and exploit deep learning, which compensates for weak but important IoT signals into meaningful diagnostic information.

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Understanding Mismedication of Non-Communicable Diseases in Telecare Systems for Developing Countries

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1. Background of the Research: Telecare systems have revolutionized healthcare delivery, particularly in underserved regions, but they also present challenges such as the risk of mismedication. This research addresses the issue of mismedication, where patients either receive insufficient or excessive medication. By utilizing prescribed drug data, chief complaints, and health check-up records, the research proposes a detection logic enhanced by Natural Language Processing (NLP)-based machine learning algorithms.

2. Research Objectives: Research objective is to identify and mitigate mismedication for non-communicable diseases, specifically hypertension and diabetes, in telecare systems, improving patient outcomes and optimizing healthcare delivery through informed decision-making.

3. Research Problem/ Research Questions: The research problem focuses on two primary medication errors in telecare systems: insufficient medication, referred to as False Negative medication, and overmedication, referred to as False Positive mismedication. High rates of False Negative medication can significantly worsen patients' health due to inadequate treatment. Conversely, a high incidence of False Positive medication increases financial costs and exposes patients to unnecessary side effects that may harm their health.

4. Approach: The dataset used is curated from the Portable Health Clinic (PHC), including data from over 45,000 users and more than 9,000 e-prescriptions, accompanied by health checkup data[1]. The proposed research introduces a classification model for the prescription datasets, focusing on tele-care for hypertension (HTN) and diabetes mellitus (DM). The model divides prescriptions into eight groups using three Yes/No binary answer questions.

Patient vital information and doctor prescriptions serve as inputs to the model. Using natural language processing (NLP), relevant attributes are extracted from the prescriptions and validated with the MedEasy Database. Patient vitals are compared with the B-Logic as per the PHC System[2][3]. These attributes are converted into numeric representations to classify prescriptions into eight classes (0-7). Class 0 and 7 indicate proper medication, class 1 indicates doubtful prescriptions requiring rechecking of patient vitals, and classes 2-6 indicate mismedications.

5. Experiment/Methodology: As mentioned in the approach, the classification model uses the following three binary answerable questions:

1. Did the patient receive any disease-relevant drugs?
   - Obtain an indication from the drug open database by searching for the prescribed drug name.
   - Check whether the drugs affect diseases (HTN/DM).
2. Did the doctor mention the disease name in the Chief Complaint (CC)?
   - Check if the CC sentence written by the doctor contains the name of the diseases.
3. Is the patient unhealthy (as per the PHC indicator)?
   - Check specific data from the patient's health check-up strongly related to the diseases (blood pressure or glucose).
   - Compare the numbers with general health indicators or guidelines to judge the patient's healthiness.

The binary answer for Q1 is verified with the MedEasy database to confirm that the drug provided in the prescription matches the recommended guidelines and to identify its consequences for patients with HTN/DM.

For Q2, the CC written by the doctor for the patient includes the name of the disease (HTN/DM/Generalized Weakness).

For Q3, the PHC B-Logic indicator is confirmed with the patient's vitals to verify the potential of the patient having the disease.

Case Number	Q1	Q2	Q3	Description
#0	0	0	0	**Not** Prescribed, Disease **Not** Mentioned, **Not** Unhealthy
#1	0	0	1	**Not** Prescribed, Disease **Not** Mentioned, Unhealthy
#2	0	1	0	**Not** Prescribed, Disease Mentioned, **Not** Unhealthy
#3	0	1	1	**Not** Prescribed, Disease Mentioned, Unhealthy
#4	1	0	0	Prescribed, Disease **Not** Mentioned, **Not** Unhealthy
#5	1	0	1	Prescribed, Disease **Not** Mentioned, Unhealthy
#6	1	1	0	Prescribed, Disease Mentioned, **Not** Unhealthy
#7	1	1	1	Prescribed, Disease Mentioned, Unhealthy

Table 1. Mismedication Logic Table

Cases 0 and 7 are considered as Ture Positives and True Negatives, Cases 2-6 belong to the category of False Positives or False Negatives. However, there are scenarios where the doctor might have provided non-pharmacological advice instead of medication, used different terminology to describe the disease, or suggested an advanced level of screening to understand the patient's problem at a deeper level. To handle potential mismedication cases (2-6), a BERT-based fine-tuned model was created to enhance the performance of classification [4][5]. Case 1 is considered as a doubtful classification because it represents a higher probability of containing incorrect patient data.

6. Results: Below are the results of the research: 45 cases of HTN and 8 cases of DM out of 3,158 records were detected as mismedications.

	Before applying medical considerations	After applying medical considerations
Proper Medication	HTN: 65.1% (2068) DM: 83.8% (2645)	HTN: 83.8% (2656) DM: 93.8% (3029)
Mismedication	HTN: NA DM: NA	HTN: 1.4% (45) DM: 0.3% (8)
Doubtful Medication	HTN: 34.9.8% (1100) DM: 16.2% (513)	HTN: 14.4% (457) DM: 3.5% (121)

Table 1. Result of Applying the Logic

7. Conclusion and Future Work: Our research on mismedication in telecare systems for developing countries identified 1.4% mismedications in HTN and 0.3% in DM from real-world datasets. We proposed strategies to mitigate these risks, aiming to prevent future mismedications in telecare. Future work involves enhancing the detection model to address wrong dosages, and frequencies of drugs, as well as developing a prescription prediction and advice assistant model.

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An AI-Driven Solution for Transforming Paper-Based Medical Records into Digital Formats

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1. Background of the Research: In today's digital age, it's hard to believe that 80% of medical data remains unstructured, particularly in developing countries [1]. This means that a patient's past medical history is often stored on paper, making it difficult to access and interpret. As a result, patients are burdened with the responsibility of keeping track of their medical histories, either on paper or from memory. Additionally, human memory can be unreliable, and papers can easily be lost or damaged. This lack of accessible and usable medical data is a significant barrier to effective healthcare. Doctors, meanwhile, require this information to make informed clinical decisions. In this poster, we present the architecture for digitizing and structuring medical data, leveraging vision and large language models capability.

2. Research Objectives: The use of low-resource languages in developing countries and limited interoperability of data between healthcare providers make it challenging to digitize medical histories. In the US, healthcare providers need to maintain data "liquidity" [2] or risk being labeled as information blockers [3] under the 21st Century Cures Act [4]. This poster aims to propose an architecture that addresses the challenge of unstructured medical history by digitizing, structuring, and standardizing past medical records.

3. Research Questions: Given the limitations of varying layout structures of medical documents, noisy images sometimes, low-resource language issues, and the lack of systems that can effectively exchange data, this research focuses on the following sub-questions: i) How can we classify medical documents? ii) How can the classified medical data be structured to improve usability and accessibility? iii) How can the structured data be standardized to ensure interoperability between different healthcare providers and systems?

4. Approach: Past medical history can be collected through three different sources: from patient memory (queried by a health professional), using digital documents, and paper-based documents. This poster focuses on data collection from paper-based documents. For this type of data, many challenges arise, such as the quality of the scanned image, multi-language issues, and the layout of the document. Figure 1 illustrates the high-level architecture of the approach, which comprises four main components:

1) **AI Model (Vision Model) for Classification:** A pre-trained vision model [5], fine-tuned for the classification tasks, will classify the uploaded images into specific categories (e.g., hematology report, kidney report, etc.) or determine if they are not relevant. If the document is deemed irrelevant, it will be discarded.
2) **Template Matching and Filling:** Relevant images are added to their specific predefined templates (e.g., a JSON file). These templates are designed based on international standards to ensure consistent information extraction for each type of document.
3) **Multimodal Model for Template Filling:** The images and their corresponding templates are fed to a multimodal model [6] capable of handling both textual and visual inputs. The model will fill the templates with the appropriate information extracted from the images.
4) **Mapping and Storage:** The filled templates are mapped to a set of rules and specifications designed for exchanging electronic healthcare data, specifically adhering to the FHIR (Fast Healthcare Interoperability Resources) and OpenEHR standards. This ensures the data is flexible, adaptable, and interoperable across different healthcare information systems.

5. Methodology: To validate the concept of digitizing and structuring medical records, we propose the following methodology:

1) **Data Collection and Preparation:** A diverse dataset of medical documents, including different medical reports hematology reports, kidney reports, and other medical records from various healthcare providers will be collected and annotated to create a labeled dataset for training and evaluation purposes.
2) **AI models:** A pre-trained vision model, such as Vision Transformer, will be fine-tuned using the annotated dataset to classify medical documents into predefined categories, while a multimodal

model will be fine-tuned to process both text and images, enabling it to fill predefined templates with extracted information from the documents.

3) **Template Creation and Standardization:** Templates for each type of medical document will be designed based on international standards. These templates will define the structure and required fields for each document type. The filled templates will be mapped to FHIR resources to ensure interoperability and then stored in an OpenEHR format.
4) **Validation and Testing:** A separate validation dataset will be used to test the performance of the models. This dataset will include documents in different languages and varying qualities to ensure robustness. The models will be evaluated using standard metrics such as accuracy, precision, recall, and F1-score for each document category.

6. Expected results: Given the complexity of medical data, such as the quality of scanned images, multi-language issues, and varying document layouts, this approach is expected to address these challenges. The capabilities and promising performance of both vision models and large language models, as demonstrated in various studies, suggest that the methodology will be robust and effective in handling these issues.

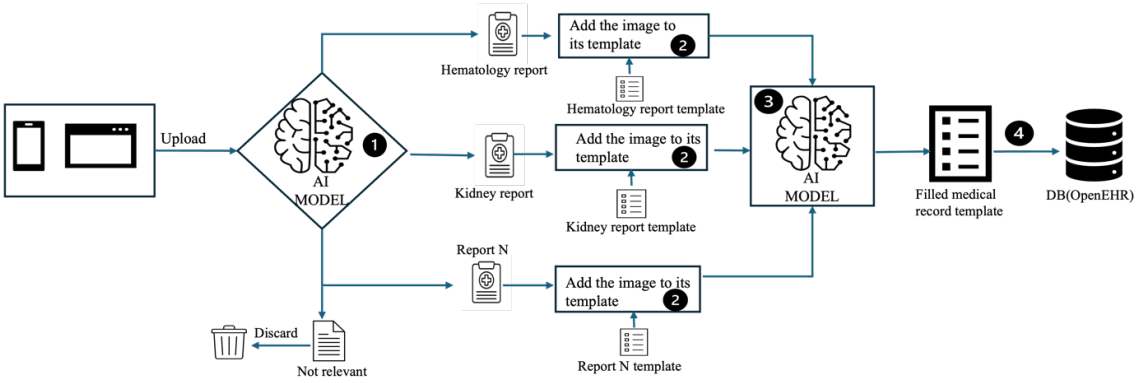

Figure 1: High-level architecture

7. Conclusion and Future Work: This poster presents a method for digitizing and structuring paper-based medical records using vision and multimodal models, addressing challenges like image quality and document layout variations. Future work will focus on collecting and labeling the dataset, fine-tuning models with larger datasets, and integrating with healthcare systems.

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Role-Based Speaker Diarization in Healthcare: Optimizing Patient-Doctor Interactions

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1. Background of the Research: In developing South Asian countries, the interaction between doctor and patient predominantly takes the form of verbal conversation rather than written text for maintaining Personal Health Records (PHRs). If we perform a knowledge discovery by analyzing these doctor-patient interactions, we can gain valuable insights that have the potential to significantly enhance healthcare delivery and improve patient outcomes. One key aspect of this analysis is diarization, also known as speaker classification. Diarization is a classification problem focused on identifying multiple speakers in a conversation, essentially determining "who spoke when"[1]. By applying diarization techniques to these interactions, we can accurately identify speakers in a conversation, which in turn can enhance the accuracy and completeness of PHRs.

2. Research Objectives:

- Evaluate the effectiveness of diarization systems in medical environments.
- Identify who is speaking and when, along with determining the role of each speaker in a medical setting (e.g., doctor, patient, health worker, interpreter, etc.).

3. Research Problem: Majority of the current diarization systems are trained and evaluated of conversational data extracted from telephonic calls and meetings where the training and testing environment is strict more with less interference from outside entities. Whereas in a medical conversation there can be patient, doctors and health workers speaking simultaneously or in quick succession, often in environments with significant background noise and interruptions. These factors introduce complexities that are not typically present in telephonic calls or structured meetings. Moreover, the nature of medical conversations can vary greatly, with discussions ranging from diagnostic information and treatment plans to casual talk aimed at putting patients at ease.

Given these unique challenges, there is a critical need to adapt and enhance current diarization systems to perform accurately in medical environments. This involves:

1. Handling Multiple Speakers: Ensuring the system can differentiate between various participants such as doctors, patients, health workers, and interpreters, even when their speech overlaps.

2. Role Identification: Not only recognizing "who spoke when" but also identifying the specific roles of the speakers, which is crucial for accurate documentation and analysis of medical interactions.

4. Approach:

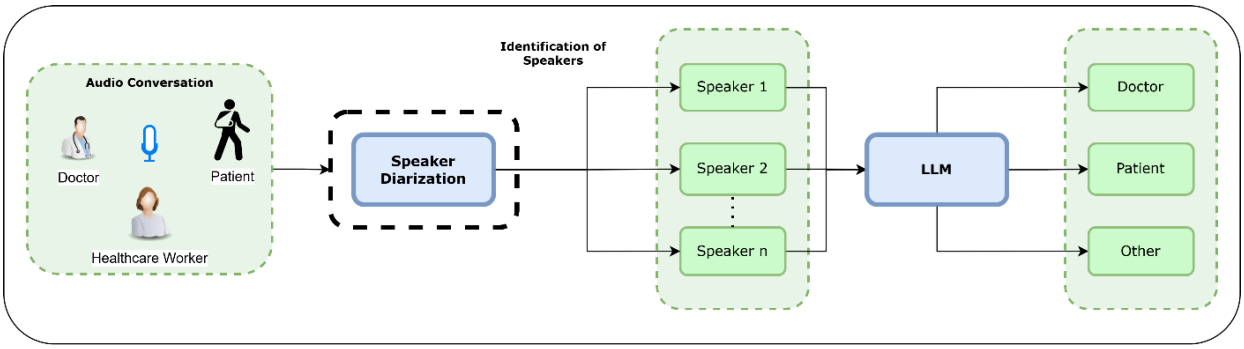

Fig 1. Proposed Architecture for identifying role of Speaker(s)

The proposed architecture, illustrated in Figure 1, outlines an approachfor extracting speaker segments from audio and utilizing Large Language Models (LLMs) to assign roles based on the context in which the speakers are speaking.

$$Diarization\ Error\ Rate\ (DER) = \frac{False\ \ Alarm\ + Missed\ \ Detection\ + Speaker\ \ Confusion}{Total\ Speech}$$

DER is a widely used metric for evaluating the quality of speaker diarization systems [2]. Unit for DER is in seconds and is primarily concerned with four parameters: False Alarm, Missed Detection, Speaker Confusion, and Total Speech.

False Alarm: This occurs when the system incorrectly identifies speech when no speaker is speaking.

Missed Detection: This happens when the system fails to detect speech when a speaker is actually speaking.

Speaker Confusion: This parameter indicates instances where speech is correctly detected, but the system incorrectly assigns the speech to the wrong speaker.

Total Speech: This is the cumulative duration of all speech segments in the conversation.

These parameters collectively influence the overall diarization performance, with the goal being to minimize DER to improve the accuracy of speaker identification and segmentation. As shown in the proposed architecture, leveraging LLM-based role identification can help the system to relabel segments that are assigned to incorrect speakers, as the context between patient and doctor is different in nature. This will, in turn, suppress speaker confusion, which is an important aspect of calculating DER.

5. Experimental Environment: The Portable Health Clinic (PHC) is designed for delivering healthcare through telehealthcare, involving patients, doctors, interpreters, and healthcare workers [3]. It incorporates digitized prescription generation, maintaining traditional methods of collecting PHRs. An ideal experimental environment to test the proposed system should involve PHC and a substantial number of participants to evaluate diverse healthcare scenarios effectively. The experiment should include at least 10 doctors representing different specialties, around 50 patients belonging to different demographical region and have diverse medical conditions, ensuring a broad range of health concerns are addressed. Additionally, include 5 interpreters to manage language barriers and 5 healthcare workers, to support consultations as needed. The interaction scenarios should consist of routine check-ups, chronic disease management, and acute illnesses.

6. Expected Outcome: This research focuses to enhance the extraction of information from medical conversations, focusing on accurately identifying doctors, patients, health workers, and interpreters [4]. By utilizing diarization techniques on medical conversation, and identifying the roles of speakers, the aim is to decrease the DER along with adding more information to the existing PHRs. This structured approach not only improves transcriptions of medical conversations, but also facilitates informed decision-making by enabling doctors to track the sequence of events in consultations. Furthermore, this organized data will serve as a valuable resource for researchers, offering insights for developing new technologies and deeper understanding of medical interactions.

7. Conclusion and Future Work: In conclusion, integrating speaker diarization and leveraging LLMs for medical conversations significantly enhance the quality and accessibility of information for both healthcare providers and patients. This approach supports enhancing the medical records that aid in better decision-making and patient self-care, especially in areas where the medical interactions are more conversationally focused. Future work will focus on implementing these advancements in real-world healthcare settings, addressing challenges specific to medical environments, and continuing to refine techniques to further improve the usability and reliability of diarization in enhancing healthcare outcomes.

Acknowledgement: This work was supported by JST BOOST, Japan Grant Number JPMJBS2406.

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Prospects of Robotic Surgery in Bangladesh to improve gynecological surgery outcomes in Bangladesh: A Scoping Review

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1. Background of the Research: Robotic surgery represents a significant advancement in medical technology, offering precision, reduced recovery times, and minimized surgical complications. In Bangladesh, gynecological surgeries often face challenges such as limited access to advanced technology, high rates of surgical complications, and prolonged recovery periods. This study explores the potential impact of introducing robotic surgery on gynecological surgical outcomes in Bangladesh, aiming to provide insights into its feasibility, benefits, and implementation strategies..

2. Research Objectives: This research aims to assess the potential impact of robotic surgery on gynecological outcomes in Bangladesh by evaluating current surgical results, identifying benefits such as reduced complications and recovery times, and exploring healthcare professionals' perspectives.

3. Research Problem/ Research Questions: How can the adoption of robotic surgery improve gynecological surgical outcomes in Bangladesh, and what are the associated benefits, and barriers to its successful implementation in the healthcare system?

4. Experiment/Methodology: A literature review was conducted to examine the impact of robotic surgery on gynecological procedures in resource-limited settings, with a focus on Bangladesh. PubMed, Google Scholar, and relevant databases were searched using keywords such as "robotic surgery," "gynecology," "Bangladesh," and "surgical outcomes." Studies published between 2010 and 2023 were included for the review. Initially total 127 articles were found among them (51 – out of the timeline, 46 – full text not available) 25 articles were excluded. Finally total 20 articles included in the review. In Bangladesh usually clinicians are involved in clinical care. There is scope of more research on gynecological surgeries and robotic surgeries in Bangladesh.

5. Results: The retrospective analysis revealed high rates of surgical complications (7.2%) and prolonged recovery times (average of 14-18 days) in conventional gynecological surgeries. Patient satisfaction scores is not satisfactory. Interviews with healthcare professionals in regular hospital team discussion highlighted a positive attitude towards robotic surgery, citing potential benefits such as increased precision, reduced intraoperative blood loss, and shorter hospital stays. However, concerns were raised about the high initial costs and the need for specialized training. The cost-benefit analysis indicated that while the initial investment for robotic surgical systems is substantial, long-term savings from reduced hospital stays and complications could offset these costs within five to seven years.
Pros and cons of robotic surgery at a glance:

Pros of robotic surgery	Cons of robotic surgery
Better operative site visibility	Installation & maintenance charge is high
Flexible dexterity	No tactile feedback
Improved surgical precision	Separation of surgeon from the operative field
Better ergonomics for surgeon	No tactile feedback
Faster recovery period	Unable to use qualitative information

Source: doi:10.4081/ejtm.2019.8727

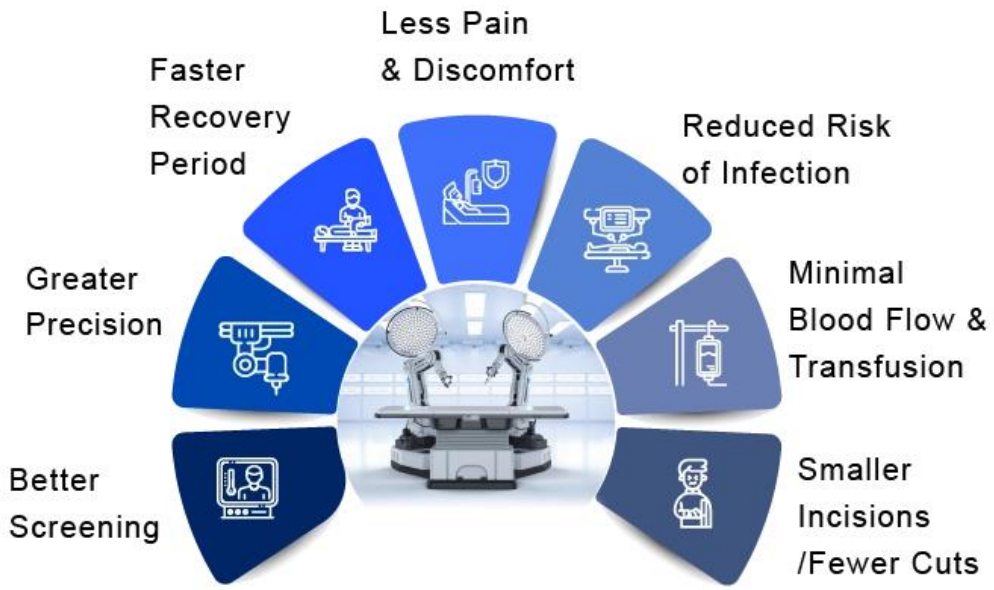

Fig: Advantages of robotic surgery (Delveinsight)

7. Conclusion and Future Work: Robotic surgery has the potential to revolutionize gynecological surgical outcomes in Bangladesh by overcoming existing barriers such as limited surgical expertise and infrastructure. The adoption of robotic technology can lead to safer, more effective surgeries, benefiting patients through reduced morbidity, shorter recovery periods, and improved quality of life. However, challenges such as cost and training need to be addressed to facilitate widespread implementation. Investing in training programs for healthcare providers and expanding access to robotic surgical platforms could significantly enhance gynecological care across Bangladesh, aligning with global efforts to improve surgical outcomes and women's health worldwide. Further research and collaboration are essential to fully realize the potential of robotic surgery in advancing gynecological healthcare in resource-constrained settings like Bangladesh. .

Acknowledgement: Munzur-E-Murshid, PhD Candidate, Graduate School of Biomedical and Health Sciences for his co-operation and gudance.

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Enumerating miR-424-503 cluster expression in patients with diverse molecular subtypes of breast cancer from Bangladesh

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1. Background of the Research: Breast cancer is a heterogeneous disease considered a leading cause of cancer-associated death worldwide in women, characterized by diverse pathological and molecular features with varied clinical outcomes and differential responses to therapeutics [1]. MicroRNAs (miRNAs) are non-coding RNA that regulate gene expression by degrading target mRNA or inhibiting the translation [2]. Although antagonists against cell surface receptors and several intracellular mediators have accomplished a significant outcome in breast cancer treatment strategies, limited data is available about how microRNAs participate in the regulation of breast cancer pathogenesis. Recent studies reported that miR-424 and miR-503 act as tumor suppressors in breast cancer cell lines [3]. Rodriguez-Barrueco R. *et al.* reported that loss of miR-424-503 is associated with higher protein levels of IGF1-R (Insulin like growth factor 1 receptor) and BCL-2 (B-cell lymphoma-2) which are reported to induce chemotherapy resistance in mice models [4]. However, these findings were primarily based on *in-vitro* data, with a small number of clinical specimens, mostly Caucasians. No data is available on the patients of the South Asian subcontinent. Moreover, understanding the expression pattern of miRNA and miRNA-mediated details mechanism of breast cancer progression will uncover an unexplored chapter to tune existing treatment procedures and discover new treatment strategies.

2. Research Objectives: Our research objective was to determine the expression pattern of miR-424 and miR-503 in patients with progressive breast cancer of Bangladeshi origin and to find the potential targets for these two miRNAs.

3. Research Problem/ Research Questions: *In-vitro* studies reported the tumor-suppressive nature of miR-424 and miR-503 as they are involved in the antitumor cytotoxicity, promoting the apoptosis of tumor cells, repressing breast cancer cell proliferation, and increasing chemo-sensitivity. Therefore, we addressed the following questions in the study: i) What are the expression patterns of miR-424 and miR-503 in breast cancer patients of Bangladeshi origin? ii) Is there any alteration in expression patterns of miR-424 and miR-503 in breast cancer subtypes? iii) What are the potential targets of miR-424 and miR-503 in breast cancer?

4. Approach: We assumed that the expression pattern of miR-424 and miR-503 in breast cancer patients is similar to the expression in breast cancer cell lines that supports the suppressive nature of these two miRNAs. Also, a similar pattern of expression is anticipated in breast cancer subtypes. We predicted that these two miRNAs may associate with potential targets related to cell proliferation, metastasis, and apoptosis.

5. Experiment/Methodology: A total of thirty (30) newly diagnosed breast cancer patients were recruited in our study. After surgery, tumor and adjacent tissue samples were collected from the selected study subjects. Histopathological techniques were used to evaluate normal tissue samples and tumor samples through microscopic identification. Breast cancer subtypes were confirmed by measuring the expression of receptors such as ER (estrogen receptor), PR (progesterone receptor), HER2 (human epidermal growth factor receptor 2) using immunohistochemistry. In immunohistochemistry, primary antibodies such as EP1, PgR636, and CB11 were used to detect ER, PR, and HER-2/neu, respectively. The detection system was HRP (horseradish peroxidase) polymer based. Expression of miR-424 and miR-503 was determined from tumor tissue and adjacent healthy tissue by miRNA-specific qRT-PCR (quantitative real time polymerase chain reaction). In brief, total RNA was isolated from the tissue samples using the TRIzol-chloroform-isopropanol method. GoScript Reverse Transcription System was utilized to generate cDNA from RNA (Promega). SYBR green-based GoTaq qPCR master mix (Promega) was used to carryout qRT-PCR (Quantitative real-time PCR) for determining the expression of the target genes. Overall survival was analyzed using a computational tool such as KM (Kaplan Meier) plotter. The data were presented as mean ± SD.

Two-tailed paired student ‘t’ tests were adopted to evaluate the differences between the normal tissue samples and breast cancer samples.

6. Results: miR-424 and miR-503 expression was significantly downregulated in tumor tissue compared to adjacent healthy tissue of breast cancer patients, and the downregulation was consistent in all breast cancer subtypes (Figure-1 and 2). We further noticed an inverse correlation between the expression of miRNAs of this cluster (miR-424 and miR-503) and histological tumor grade in breast cancer patients (Figure-3). Analyzing the public datasets of breast cancer, patients with a high level of miR-424 and miR-503 expression have better overall survival (OS). Further, we identified target genes of miR-424 and miR-503, most of which are associated with tumor initiation, cell growth, proliferation, metastasis, regulation of cell cycle, and apoptosis.

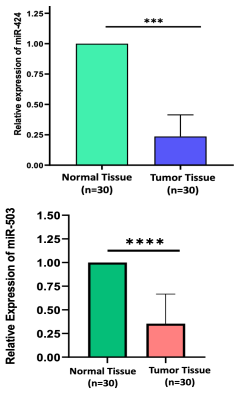

Figure-1: Expression of miR-424 and miR-503 in normal tissue and tumor tissue of the BC patients. The data is presented here as mean ± SD. Here, ***p< 0.001, ****p< 0.0001.

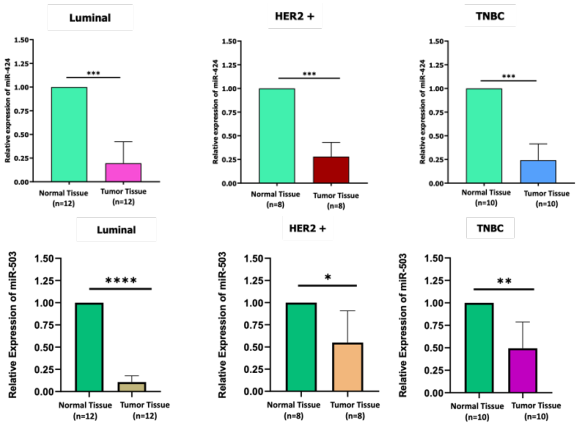

Figure-2: Expression of miR-424 and miR-503 in normal tissue and tumor tissue of the BC subtypes. The data is presented here as mean ± SD. Here, *p<0.05, **p<0.01, ***p< 0.001, ****p< 0.0001.

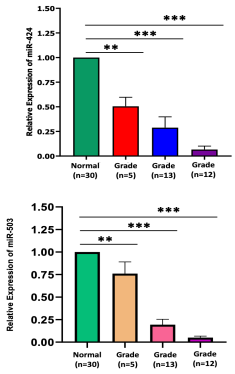

Figure-3: Expression of miR-424 and miR-503 in tumor tissue of the BC patients based on grade. The data is presented here as mean ± SD. Here, **p<0.01, ***p< 0.001, ****p< 0.0001.

7. Conclusion and Future Work: The findings suggest that miR-424 and miR-503 have the potential to be employed as prognostic and predictive biomarkers, potentially opening a novel therapeutic option for breast cancer patients in the future. The next plan is to investigate the role and mechanism of miR-424-503 cluster-mediated chemoresistance using the models of breast cancer cell lines. The key objectives of our future research are: i) Characterization of the functions of miR-424-503 cluster in the progression, invasion, and metastasis of breast cancer cell lines. ii) Investigation whether loss of miR-424-503 cluster develops chemotherapeutic (Doxorubicin, Cyclophosphamide, 5-Fluro Uracil) resistance in breast cancer cell lines or not and alternatively whether the introduction of miR-424-503 can rescue chemotherapeutic potential or not.

8. Acknowledgement: The authors greatly acknowledge The World Academy of Sciences (TWAS) (Ref: 19-148 RG/BIO/AS_I – FR3240310169) for financial support to complete the work.

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Assessment of health literacy regarding smoking behavior among the company employees: A cross-sectional study

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1. Background of the Research: Globally, the prevalence of low health literacy has become a foremost public health issue, especially in Asian countries [1]. This health issue is strongly associated with underprivileged health outcomes, low self-management, and increased mortality. Health literacy has a greater impact on people's health, either to ensure a healthier quality of life or to spend more money to improve their health [2]. Furthermore, poor health literacy has a robust connection with deprived health behavior in various age groups of the population such as smoking behavioral practice [3]–[5]. Particularly, health literacy based on smoking behavior among the company employees needs to assist in promoting smoking cessation.

2. Research Objectives: Health literacy is an essential factor for company employees' health and well-being. This study aims to evaluate health literacy in relation to smoking behavior among employees.

3. Research Problem/ Research Questions: What is the level of health literacy based on smoking behavior among company employees?

4. Approach: Improvement of health literacy is significant regardless of sociodemographic and smoking status for optimistic health outcomes (Figure 1).

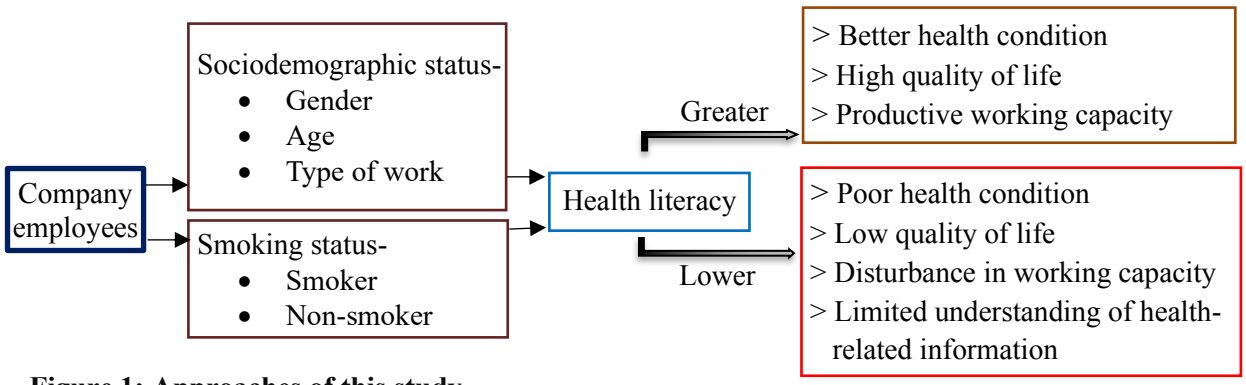


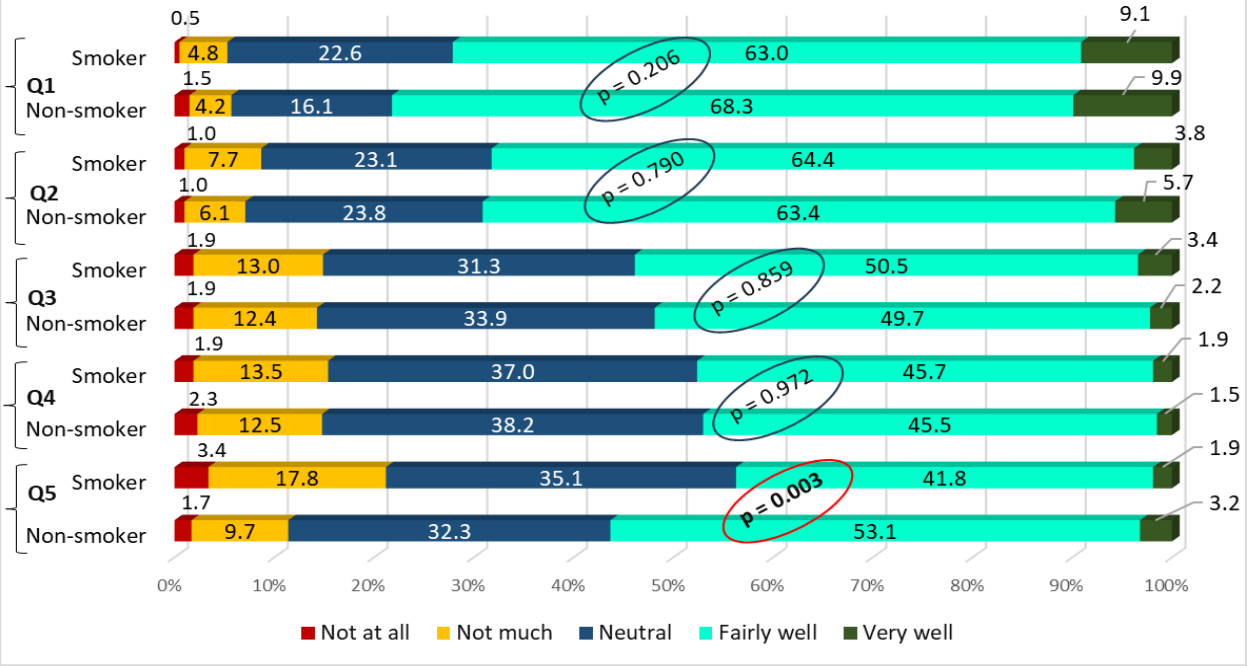
Figure 1: Approaches of this study

5. Experiment/Methodology: A cross-sectional study was conducted with manufacturing industrial workers in Hiroshima city. A survey was administered from 10th October to 10th November 2023 using both internet- and paper-based methods. The survey included a total of 1,519 employees and consisted of socio-demographic information and a health literacy scale which was 5-point Likert scale (5 items). On this scale, the highest score indicated high health literacy among the participants. The inclusion criteria for the participants were a willingness to participate and providing consent. Among them, those with missing answers were excluded from the study. The descriptive analysis and chi-square test were used to analyze the data.

6. Results: A total of 896 participants responded to the survey and were included in the analysis. Of these, 680 were male and 216 were female. The lowest number of participants (0.6%) were teenagers, and over 40% were 50s years old. Most participants worked in administrative positions (37.9%) and in outdoor fields (27.5%). We found that 688

(76.8%) participants were non-smokers, while 208 (23.2%) participants were smokers. The smoking behavior of the respondents showed a significant association between gender (<0.001) and the type of their work (0.004), respectively. In evaluating health literacy among employees, the ability to make plans and take actions for health improvement based on information showed significantly lower values in smokers (p = 0.003) (Figure 2).

Figure 2: Association between health literacy with smoking behavior (n=896)



Q1 = Gather information from various sources such as newspaper, book, television and internet
Q2 = Select the information you seek from the abundance of available information
Q3 = Understand information and communicate it to others
Q4 = Determine the reliability of information
Q5 = Make plans and take actions for health improvement based on information (Chi-square test)

7. Conclusion and Future Work: Health literacy, particularly support for planning and action to improve health, is important for smoking cessation among males and workers in outdoor fields. Therefore, it is in high demand to take action for the improvement of health literacy and implement it in regular life to reduce smoking cessation.

Acknowledgment: We are cordially thankful to the Institutional Review Board and all the participants for their active participation in this research.

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How Diagnostic Medical Ultrasonography Contributing In Positive Pregnancy Outcomes in Bangladesh: A Scoping Review

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1. Background of the Research: This scoping review examines the role of diagnostic medical ultrasonography in enhancing positive pregnancy outcomes in Bangladesh. Through a comprehensive analysis of available literature, we explore the various ways ultrasound technology contributes to maternal and fetal health, highlighting its significance in prenatal care and its impact on improving birth outcomes in the country.

2. Research Objectives: The research objective is to identify the positive impacts of diagnostic medical ultrasonography on pregnancy outcomes in Bangladesh through a scoping review.

3. Research Problem/ Research Questions: What are the impacts of diagnostic medical ultrasonography on improving pregnancy outcomes in Bangladesh?

4. Methodology: The methodology for investigating the contribution of diagnostic medical ultrasonography to positive pregnancy outcomes in Bangladesh involves a comprehensive scoping review of articles up to December 2022. This review encompasses systematic searches of relevant databases, including PubMed, Google Scholar, and Bangladeshi medical journals. The search strategy incorporates keywords related to ultrasonography, pregnancy outcomes, and Bangladesh. Screening of articles, data extraction, and synthesis will be conducted to map the existing literature and identify key findings and gaps in knowledge. Total of 37 articles were included in this review.

5. Results: Diagnostic medical ultrasonography, commonly referred to as ultrasound, plays a crucial role in ensuring positive pregnancy outcomes in Bangladesh, as it does globally. Here are several ways in which diagnostic medical ultrasonography contributes to positive pregnancy outcomes in Bangladesh: Ultrasound allows healthcare providers to confirm pregnancy and estimate gestational age accurately. This early detection enables timely prenatal care initiation. Ultrasound examinations help detect fetal abnormalities and developmental issues early in pregnancy. It helps in appropriate medical intervention or treatment plan [1]. Regular ultrasound scans enable healthcare providers to monitor fetal growth and development throughout pregnancy. Ultrasound is instrumental in detecting multiple pregnancies, such as twins or triplets. Identifying multiple gestations early in pregnancy is essential for monitoring maternal and fetal health closely and managing potential complications that may arise. Ultrasound examinations can assess the health and position of the placenta, which is crucial for ensuring adequate fetal nutrition and oxygenation[2,3].In cases of invasive procedures (amniocentesis, chorionic villus sampling), ultrasound provides real-time guidance to healthcare providers, minimizing the risk of complications and ensuring accurate sample collection. For pregnancies deemed high-risk due to maternal age, pre-existing medical conditions, or previous pregnancy complications, ultrasound is used to monitor maternal and fetal health closely [4].

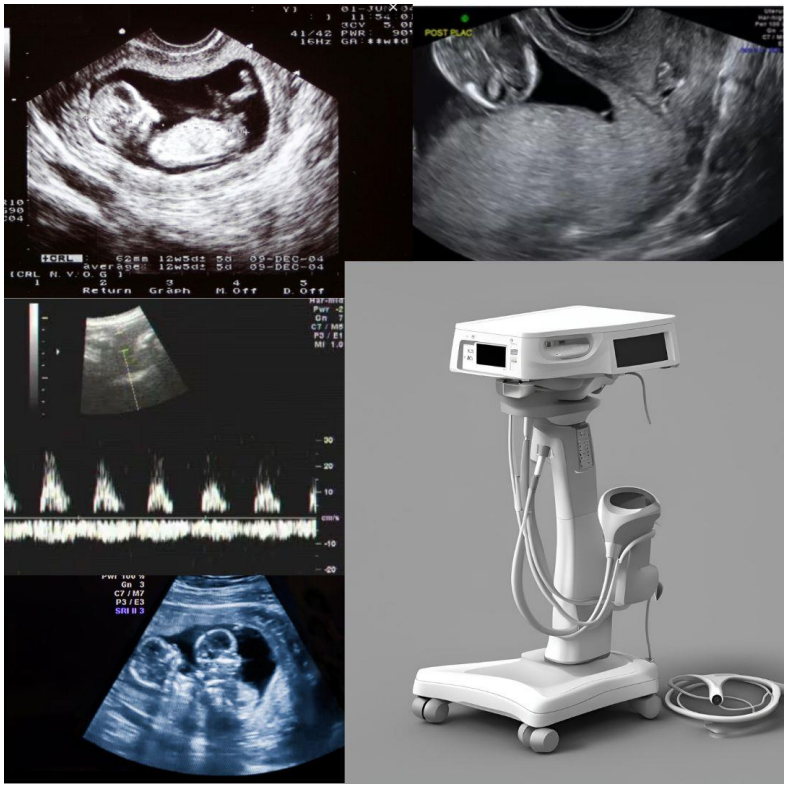

Fig: Uses of ultrasonography to detect pregnancy, placenta, IUGR, twin pregnancy
Photo source: Raising Children Network Australia, Medscape, Ultrasound Care

6. Conclusion: In Bangladesh, where access to healthcare services may be limited in certain areas, efforts to expand the availability of ultrasound services and training for healthcare providers can significantly contribute to positive pregnancy outcomes by ensuring early detection of complications, timely interventions, and improved prenatal care delivery. Additionally, raising awareness among expectant parents about the importance of prenatal ultrasound examinations can encourage them to seek timely medical care during pregnancy, further enhancing maternal and fetal health outcomes.

7. Future recommendations: Though diagnostic medical ultrasonography has been contributing to positive pregnancy outcomes in Bangladesh, Still, there is scope for improvement to improve awareness among expected mothers and their husbands. In some cases, women know the positive impacts, but they face financial barriers to accessing medical ultrasonography. On the provider end, there is scope for doctor skill improvement. There is scope for further research on improving awareness, increasing access, and ensuring quality diagnosis..

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Identification of Shh signaling pathway-related gene expression profiles in Bangladeshi breast cancer patients

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1. Background of the Research: Breast cancer (BC) is a highly aggressive and diverse illness that frequently affects women worldwide [1-3]. Despite the amazing advancements in multimodality therapy, BC remains a severe health concern for women, with an estimated global incidence of 2,261,419 new cases and 685,000 deaths annually [4]. In Bangladesh, BC is the second most common cancer among women after cervical cancer and accounting for 38% of all cancers [5]. Research on different ethnic groups that have breast cancer suggests that unchecked cell proliferation and the development of cancer are caused by activation of the Sonic Hedgehog (Shh) signaling pathway. The Shh pathway's associated molecules, namely smoothened (SMO), Glioma-associated oncogene homolog (GLI), Sonic Hedgehog (Shh), and Patched 1 (PTCH1), have unclear expression patterns in breast cancer patients from Bangladesh, which could aid in the development of a treatment plan specifically for this ethnic group.

2. Research Objectives: There is no published data on the expression pattern of the molecules associated with the Shh pathway in our ethnic region. Therefore, the primary objective of the study was to determine the expression and association of genes associated with the Shh pathway in breast cancer from blood samples.

3. Research Problem/ Research Questions: Given the background and goals mentioned above, our research question was: What are the Shh's and its associated genes expression pattern in Bangladeshi BC patients? Is there a noteworthy alteration or correlation with regards to the tumor grade?

4. Approach: In total, 44 (forty-four) diagnosed breast cancer patients and 24 (twenty-four) healthy volunteers were included in this prospective case-control study. BC Patients who did not receive chemotherapy were enrolled in our study at random. The histological and immunohistochemistry analyses were completed by a licensed histo-pathologist. No other concurrent clinical conditions and no chemotherapy before being included in this research work were taken into consideration as inclusion criteria. Informed consent was obtained verbally and in writing, and the study's purpose was explained in detail to each participant. Five (5) ml of peripheral blood samples were collected from both patients and healthy volunteers by a certified phlebotomist, in cooperation with the Department of Surgery, Chittagong Medical College and Hospital (CMCH). The samples were then promptly transferred to an EDTA anticoagulant tube and sent to the lab for molecular analysis, all the while maintaining proper storage conditions (blood sample tubes were placed inside an insulated container with cooling packs to maintain a temperature range of 2°C to 8°C). Blood samples from BC patients and healthy volunteers were used to measure target gene expression.

5. Experiment/Methodology: Blood samples from the BC patient and healthy volunteer were used to determine the expressions of GLI1, SMO, Shh, and PTCH. qRT-PCR, or quantitative real-time PCR, was used to measure the expression of the target genes. The SYBR green-based GoTaq qPCR master mix (Promega) was used for qRT-PCR. The data was analyzed using the comparative CT value approach, also known as the ΔΔCT method.

6. Results: In BC patients, PTCH1 expression was downregulated while SMO, Shh, and GLI1 expression were elevated in comparison to healthy controls. Shh, SMO, and GLI1 expression were considerably higher in triple negative breast cancer (TNBC), luminal breast cancers, and human epidermal growth factor receptor 2 positive

(HER2+) breast cancers compared to controls (Figure-1). Conversely, PTCH1 had the most negligible expression in Grade III BC patients, while Shh, SMO, and GLI-1 had the maximum expression level in Grade III BC patients (Figure-2).

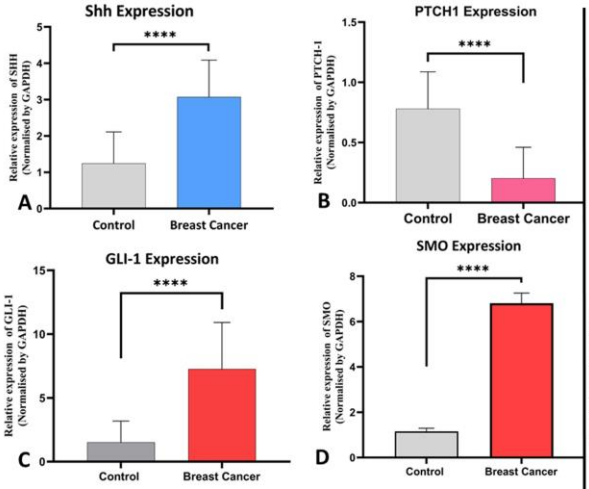

Figure 1: Shh signaling pathway-related gene expression against control

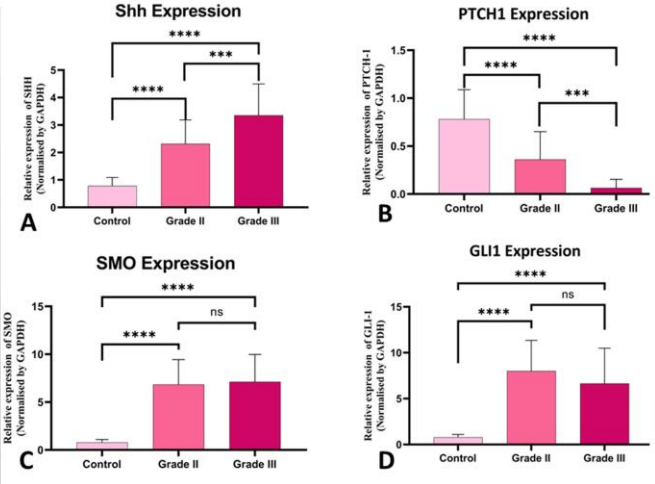

Figure 2: Shh signaling pathway-related gene expression according to grade

7. Conclusion and Future Work: Breast cancer subtype-specific differential expression of genes connected to the Shh signaling pathway may provide insight into potential targeted treatment in the future. Further investigation is required to correlate the results with a sizable sample. In future, in-silico based computational model will be utilized to find out novel antibody based targeted therapies against Shh signaling pathway.

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Effectiveness of virtual reality education on food safety: an example of meat hygiene inspection training in veterinary education

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1. Background of the Research: Meat hygiene inspection (MI) aims to detect public health hazards such as foodborne pathogens in meat. Due to the necessity of knowledge and skills on animal diseases, MI is included as an essential duty for veterinarians. MI is important topics in veterinary education and the on-site learning of MI has been considered to be essential. However, there are several constraints on the experiential learning of MI. Only a few learners are accepted to visit the MI facility to ensure the safety of workers. In addition, during and after the COVID-19 pandemic, enhanced hygiene measures prompted the suspension and reduction of student admissions to MI. To address these issues, an immersive virtual reality (VR) education system for MI was established by Rakuno Gakuen University and NEC Solution Innovators. Ltd in 2022. To evaluate the replaceability of the immersive VR to the traditional on-site learning (TEL) in MI, the educational effects of both learning schemes were compared.

2. Research Objectives: The aim of this study is to understand the replaceability of the immersive VR education system to the traditional on-site education of MI. The specific objective is to clarify the effectiveness of the traditional experiential learning (TEL) and the immersive VR learning (VRL) regarding skills and knowledge of MI.

3. Research Problem/ Research Questions: Our research question is “whether the immersive VR effectively educates the students compared with the on-site hands-on experience in the MI”. Veterinary students learn the knowledge and skills regarding i) the classification of cattle organs inspected, ii) the criteria of condemnation, iii) the flow of MI, and iv) appropriate attire for MI. We focused on the differences in the educational effectiveness between the TEL and the VRL of these topics.

4. Approach: The educational effects of TEL and VRL were evaluated through a crossover trial. Two groups were created in the trial; a group that was educated by VRL first and subsequently by TEL (VR-first group) and one by TEL first and subsequently by VRL (MI-first group). We measured the effect of each learning through the scores of correct answers in examinations about MI.

Our VRL offers learners a 3D-simulation environment of a meat hygiene inspection center. By wearing a head-mounted display, learners can experience the meat inspection tasks from a first-person perspective. The system primarily focuses on post-slaughter inspection of cattle. Learners examine several kinds of internal organs on a belt conveyor in a simulated MI facility. Learners learn by touching the organ models and observing abnormal pathological images that appear as pop-up panels. Additionally, the learners can manipulate a virtual knife to cut some organs and observe their cross-sections, providing a simulated hands-on experience of a real-world TEL.

Educational effects were evaluated three times: before the learning events (i.e., baseline), after the first learning event (i.e. VRL in the VR-first group and TEL in the MI-first group), and after the second learning event (i.e., TEL in the VR-first group and VRL in the MI-first group). The change in scores of correct answers in each group was analyzed. Then, the difference between the groups at each examination was analyzed.

5. Experiment/Methodology: The study enrolled 40 fifth-year veterinary students at Rakuno Gakuen University in 2023. The students were assigned to the VR-first and the MI-first groups by a block randomization based on gender and grade point average. The questions to evaluate the learning effectiveness were designed to detect changes in learning outcomes in two categories—intellectual skills and verbal information. The intellectual skills outcomes were

assessed by students' ability to respond correctly to procedural knowledge tasks such as classifying. The verbal information outcomes were evaluated based on the student's ability to recall and describe specified subjects. Regarding the evaluation of intellectual skills, the following questions were asked: i) the classification of organs in the "red-organs inspection" and "white-organs inspection", which are traditionally conducted at Japanese MI facilities (15 questions), ii) the criteria for carcass condemnation (8 questions), iii) the flow of inspection procedures (1 question), and iv) the tasks performed by a meat hygiene inspector (10 questions). Regarding the evaluation of verbal information, v) description of the appropriate attire for MIs, and vi) description of the handling of liver abscesses were asked.

Statistical tests were conducted to detect the difference in scores or percentages of correct answers. In addition, the difference between VRL and TEL was analyzed by general estimation equations (GEE). We took into account the carryover effect after VRL as well as the time effect in GEE.

6. Results: Nine-teen and six-teen students completed the education in the VR-first and the MI-first groups, respectively. No significant differences in scores between the VR-first and the MI-first groups were found in Q1 (the classification of organs in the "red-organs inspection" and "white-organs inspection), Q2 (the criteria for carcass condemnation), and Q3 (the flow of inspection procedures). On the other hand, for Q4 (the tasks performed by a meat hygiene inspector), the VR-first group scored significantly lower on the first test (Wilcoxon's rank sum test, $p = 0.03$). According to the GEE analysis for Q4, the educational effect of VRL was estimated to be 0.78 times lower compared to TEL in MI. Additionally, a significant negative carryover effect from VRL was estimated to reduce the effect of TEL to 0.73 times.

As for the learning outcomes of verbal information, the VR-first group scored significantly lower on the first test for Q5 (description about the appropriate attire for MI) (Wilcoxon's rank sum test, $p = 0.04$). The GEE analysis for Q5 estimated the educational effect of VRL to be 0.56 times lower compared to TEL. In contrast, there was no significant difference between the groups' scores for Q6 (description about the handling of liver abscesses). GEE analysis also did not show any significant effect of VRL for this topic.

7. Conclusion and Future Work: the immersive VR provides equivalent educational effectiveness with on-site learning at MI facilities, except for understanding of the overall flow of meat inspections and appropriate attire. Although this study did not evaluate it, VR has been reported to enhance students' learning motivation through the enjoyment it provides [2]. Improving the reproducibility of the overall flow and appropriate attire of MIs in this VR application will be the key to increasing the educational effectiveness of this system. Results of this study show the potential of immersive VR, which will offer resilience in veterinary education and food safety by serving as a substitute for TEL, during the next outbreak of emerging infectious diseases.

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Towards distributed cooperative analytics for health education in developing communities

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1. Background of the Research: The rapid advancement of smart technologies is arguably widening the digital divide, making the lives of people without easy access to the Internet increasingly challenging. Such digital divide can exacerbate the gap in health education, between communities with and without reliable digital infrastructures [1]. There is a need of educational technologies that work without reliable Internet access, and integrate into networks of individuals, organizations, and resources that interact and cooperate to facilitate and enhance health education.

2. Research Objectives: To create a digitally-enhanced support environment for health education in developing communities, we aim to develop effective methodology and mechanisms for enabling management of digital learning contents, learning analytics, and interaction with educational AI agents without reliable digital infrastructures.

3. Research Problem/ Research Questions: Despite the recent developments in intermittent networking and distributed machine learning techniques, most of the current educational technologies rely on centralized servers demanding users to have reliable high-speed access to the Internet. Proper methodology and techniques for extending and integrating such techniques for health education are yet to be explored and developed by considering relevant educational ecosystems. In this research, we aim to uncover effective techniques for addressing the limitations of learning-content distribution, learning analytics, and educational AI chatbots through iterative development.

4. Approach: The approach we introduce enables management of digital learning contents, learning analytics, and interaction with AI agents based on slowly transmitted and shared learning data, thereby providing mechanisms for supporting teachers and learners in distributed environments by extending and integrating Delay-Tolerant Networking, Semi-supervised Federated Learning, and Progressive Visual Analytics techniques.

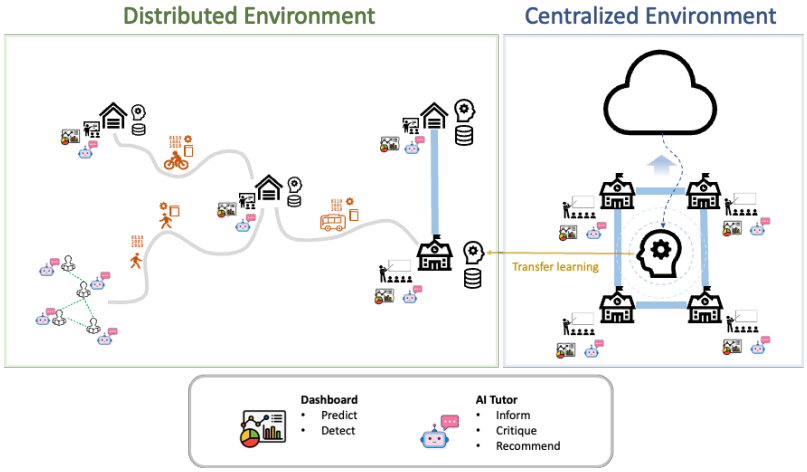
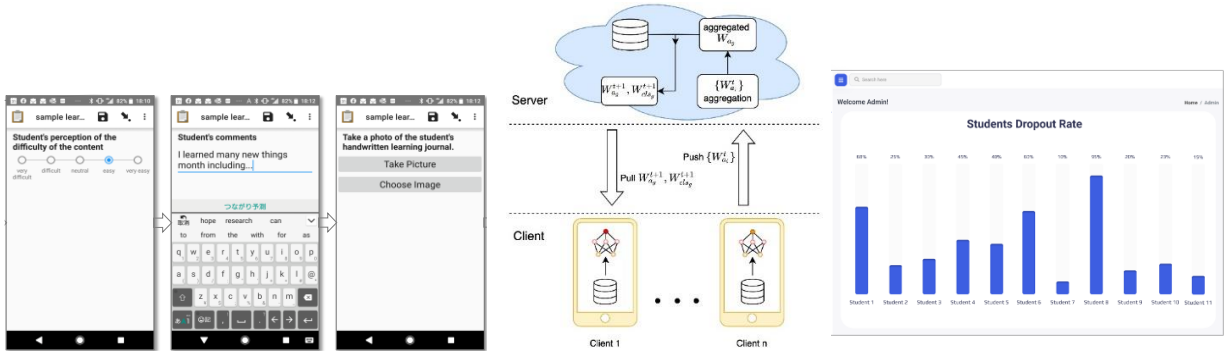


Figure 1. Overview of the distributed cooperative learning environments for development (DCL4D). First published in [2].

The distributed cooperative learning environments (see Figure 1) is based on the key insights we learned by looking at specific cases in Tanzania and by analyzing datasets from areas in East Africa [3]. The large rectangle on the right shows a centralized environment involving four schools. The large rectangle on the left shows a distributed environment, in which learning activity data at each site is accumulated locally, and slowly transferred to other sites based on a Delay-Tolerant Networking (DTN) environment that exploits pedestrians, bikes, cars, buses, and other vehicles as "data mules". Local machine intelligence at each site processes the local data and the data received from other sites to provide progressive visualizations and AI-based feedback to local teachers and students. To boost local machine intelligence, models learned in the centralized environment can be transferred to the sites in the distributed environment.

5. Experiment/Methodology: To validate our approach, we employed an iterative development process involving prototype and mockup developments as well as visits to different educational organizations in Dar es Salaam, Tanzania for acquiring feedback about the evolving design. Through this process, we have designed and refined mobile-based data collection tools [4], an intermittent data sharing environment using USB sticks, Raspberry Pi and Moodle [3], and a federated learning mechanism and its progressive visualization UI [2].

6. Results: Besides the understandings we gained regarding specific technical and UI components, we developed mockups, models and preliminary prototypes (see Figure 2). We also identified the need to refine our data collection, sharing, and analytics mechanisms to ensure they fit the unique needs and capacities of each educational setting.



(a) Mobile data collection tool based on Open Data Kit (b) Federated learning analytics architecture (c) Progressive visualization of students' states

Figure 2. Sample screenshots from our iterative development process.

7. Conclusion and Future Work: We discussed our approach to create a digitally-enhanced support environment for health education in developing communities without reliable internet access. We also briefly reported on the results of our iterative development process. Our future wok includes further technological developments and feasibility tests "in the wild".

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Prevention of recurrence of stroke by providing health education to stroke patients and their caregivers to control modifiable risk factors: Protocol for a Randomized Control Trial

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1. Background of the research: Stroke is the most common debilitating diseases causes death and disability [1]. Lack of knowledge and compliance with treatment to control modifiable risk factors and lifestyle changes increases the risk of recurrence of stroke [2]. Health education can be an effective way to increase knowledge regarding behavioral changes to prevent recurrence of those who had a stroke [3].

2. Research Objective: This study aimed to evaluate a health education program among stroke patients and their family caregivers who were admitted to a tertiary specialized hospital in Bangladesh by controlling modifiable risk factors.

3. Research Problem/ Research Questions: We hypothesized that a health education program could be effective for the prevention of the recurrence of stroke. In Bangladesh, patients' health education at the inpatient and outpatient department of the hospital is limited. We tried to establish a well-organized patient-disease management education system to increase knowledge regarding stroke, gain a healthy lifestyle, healthy dietary habits, control blood pressure (BP), improve quality of life (QoL) to prevent recurrence of stroke. Patients also do not take medicine and attend follow-up visits regularly. Therefore, we provided health education to stroke patients and their family caregivers to increase awareness for recurrence stroke related risk factors modification.

4. Approach: We collected socio-demographic and clinical characteristics data of stroke patients and tried to explore the modifiable risk factors for the recurrence of stroke. We educate stroke patients and their family caregivers about their risk factors and try to control those risk factors.

5. Experiment/Methodology: This is a parallel, open-label, prospective randomized controlled trial conducted at the National Institute of Neurosciences & Hospital in Dhaka, Bangladesh. With 20% recurrence rate, 50% reduction, 80% power and 10% dropout, we calculated the final sample size was 432. We collected data sociodemographic and clinical data by using a questionnaire. We enrolled ≥18-year-old patients of both sexes who had a history of different types of strokes (transient ischemic attack, hemorrhagic, lacunar, atherothrombotic, or cardioembolic). This study was approved by the institutional review board and the ethics review committee of the National Institute of Neurosciences & Hospital (IRB/NINSH/2022/151) on August 30, 2022. **In the Intervention Group (IG):** we provided health education twice a month for the 1st to 3rd month, then monthly from 4th to 12th month by a phone call to get information about the health condition of the patients and documented in the questionnaires. Patients received a reminder phone call at 5th month to

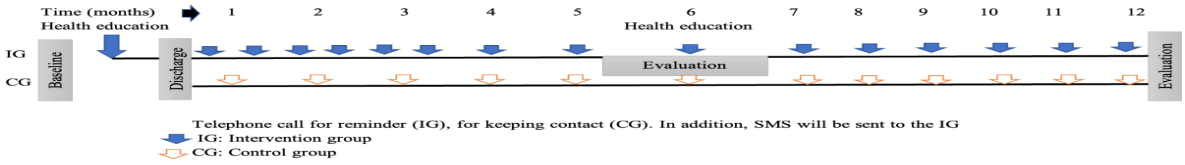

Figure 1: Study activities among the intervention and control groups

visit in the hospital for 6th month follow up visits. At 6 months follow up visit (midline), if the patient and family caregiver were not able to come for any reason, we collected data and provided refresher health education over phone call (Figure 1). **In the Control Group (CG):** participants received a monthly telephone call solely

to gather information about the patients' health condition and documented the information in the questionnaires. At the 5th month, patients were reminded to visit the hospital for their 6th month follow up visits (Figure 1).

Study Activities are summarized below:

Schedules	Intervention Group	Control Group
At Baseline	• Data collection by RA nurses through structured questionnaires. • RA nurses provided knowledge-related health education before discharge/after the hospital visit: Health education (face-to-face, 45 mins) by RA nurse & exercise session by the physiotherapist. • RA nurses performed physical examination-BP value (systolic and diastolic). • Blood test- HbA1c, total cholesterol, and HDL-cholesterol (calculate non-HDL cholesterol).	• Data collection by RA nurses through structured questionnaires. •Provide usual practice. • RA nurses performed physical examination-BP value (systolic and diastolic). • Blood test- HbA1c, total cholesterol, and HDL-cholesterol (calculate non-HDL cholesterol).
Midline (6 months)	• Data collection by RA nurses through structured questionnaires. • RA nurses provided refresher health education same as baseline. • RA nurses performed physical examination-BP value (systolic and diastolic). • Blood test – HbA1c, total cholesterol, and HDL-cholesterol (calculate non-HDL cholesterol).	• Data collection by RA nurses through structured questionnaires. • Provide usual practice. • RA nurses performed physical examination-BP value (systolic and diastolic). • Blood test – HbA1c, total cholesterol, and HDL-cholesterol (calculate non-HDL cholesterol).
Endline (12 months)	• Data collected by RA nurses through structured questionnaires. • RA nurses performed physical examination-BP value (systolic and diastolic). • Laboratory test-HbA1c, total cholesterol, and HDL-cholesterol (calculate non-HDL cholesterol).	• Data collected by RA nurses through structured questionnaires. • RA nurses provided health education at the end of the study and a health education booklet will be given to them. • RA nurse performed physical examination-BP value (systolic and diastolic). • Laboratory test- HbA1c, total cholesterol, and HDL-cholesterol (calculate non-HDL cholesterol).

Abbreviations: HbA1c, glycated hemoglobin; HDL, high-density lipoprotein; RA, research assistant.

6. Result: Patients' enrollment started in October 2022, follow-up completed in March 2024 and now analyzing the data. A total of 432 patients were included in both the intervention (n=216) and control groups (n=216). As an intention-to-treat analysis, we will analyze the data of all 432 patients.

7. Conclusion and Future Work: Our health education program is expected to reduce the recurrence of stroke and improve the quality of life of patients who had stroke. The results of this study will provide insights into the importance of health education for (self)-management and prevention of stroke.

Acknowledgment: We would like to thank our study participants and their caregivers for their generous support. We extend our thanks to the National Institute of Neurosciences & Hospital and the research staff for their unwavering assistance.

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Socio-demographic and clinical factors of hypertension among the pregnant women in urban and rural hospitals in Bangladesh

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1. Background of the Research: Hypertension (HTN) in pregnancy with or without pre-eclampsia/eclampsia is a significant risk factor for morbidity and mortality to both mother and fetus [1]. Antenatal care (ANC) is a crucial preventive measure for developing pregnancy related complications among pregnant women and their offspring [2]. By taking ANC visits, women can understand healthy behavior and recognize the danger signs those are the fatal outcome for themselves and their fetuses during childbirth. During the ANC visits, they have the opportunity to know what pregnancy-related treatment for HTN to prevent eclampsia. They undergo a physical examination, laboratory test and receive treatment for complications [3].

2. Research Objectives: The aim of this study was to identify the sociodemographic and clinical factors of HTN among the pregnant women in urban and rural hospitals in Bangladesh.

3. Research Problem/ Research Questions:

Pregnancy related HTN causes adverse outcomes such as eclampsia which increase the morbidity and mortality of the pregnant women and their childbirths. We want to identify the sociodemographic and clinical factors that cause pregnancy related HTN.

4. Approach: If we can identify the factors of pregnancy related HTN, we can prevent pregnancy related complications such as eclampsia. When pregnant women came for ANC visit, we collected the data of sociodemographic and clinical factors to identify the pregnancy related complications.

5. Experiment/Methodology: This is a cross-sectional study using baseline data of a cluster randomized control trial (RCT) (Clinicaltrials.gov, Trial registration number NCT05135026) to find out the factors of pregnancy related hypertension during the ANC visits. The baseline data was collected between November and December 2021**.** Two urban hospitals [Dhaka Medical College and Hospital (DMCH) and Sir Salimullah Medical College and Hospital (SSMC), and two rural hospitals [Bogra 250 Bed Mohammad Ali District Hospital (BDH) and Munshigonj General Hospital (MGH)], Bangladesh were included to enroll the study participants. We included all the pregnant women irrespective of age visited the designated hospitals, had/had no complications to see the delivery outcome with the indication of normal delivery and caesarean section (C/S) and willing to participate in the study. We excluded early pregnancy with the indication for C/S (co-morbidities, history of previous C/S). The participants were consented for study enrollment and data collection.

6. Results: We enrolled a total of 288 pregnant women from four different hospitals (72 from each hospitals). Housewives (98.61 % vs. 88.89 %, p=0.001) were significantly more among the rural hospitals compared to urban hospitals, respectively. Among the pregnant women, a total of 9 (3.13%) had history of HTN, 4 (1.4%) had history of eclampsia and 118 (40.97%) had abnormal blood pressure (BP) (>120 and >80 mmHg). We found stage 1 HTN (28.47% vs. 9.03%, p=<0.001) and stage 2 non-severe HTN (4.86% vs. 3.47%, p=<0.001) were significantly higher among the urban hospitals compared to rural hospitals. In contrast, women of rural hospitals had significant higher in respect of normal BP 69.44% vs. 48.61%; p=<0.001) (Table 1).

Table 1: Comparison of demographic and clinical characteristics of the Urban and Rural hospitals'

Demographic Characteristics	**Total (n =288) n (%)**	**Urban Hospitals (n = 144) (%)**	**Rural Hospitals (n = 144) (%)**	**P value**
Age (years), mean± (SD)	24.31 (5.07)	24.44 (5.02)	24.17 (5.13)	0.556
Mother occupation				
Housewife	270 (93.75 %)	128 (88.89 %)	142 (98.61 %)	0.001
Other (specify)	18 (6.25 %)	16 (11.11 %)	2 (1.39 %)	
Number of household member, mean±(SD)	4.25 (1.68)	4.06 (1.71)	4.44 (1.63)	0.033

Clinical Characteristics				
Pregnancy (weeks) of mother	9.83 (2.45)	8.90 (2.34)	10.75 (2.21)	<0.001
Blood pressure (mmHg)				
Normal	170 (59.03 %)	70 (48.61 %)	100 (69.44 %)	<0.001
Elevated BP	52 (18.06 %)	26 (18.06 %)	26 (18.06 %)	-
Stage 1 HTN	54 (18.75 %)	41 (28.47 %)	13 (9.03 %)	-
Stage 2 non-severe HTN	12 (4.17 %)	7 (4.86 %)	5 (3.47 %)	-

*n-number, %-percentage, SD- standard deviation

We found women's abnormal BP was negatively associated with their age [Cl: 0.790 (0.628-0.994); p=0.044] and positively associated with their husbands age [Cl: 1.200 (1.004-1.435); p=0.045]. When women with HTN whose husbands engaged as industrial worker, office non-executive and petty business (income less than Bangladesh (BDT) 10,000/month) employment [Cl: 0.155 (0.024-0.996); p=0.049], their pregnant wives suffered significantly less from abnormal BP compared to those who had no job and was doing day labor jobs (Table 2).

Table 2: Multivariable logistic regression showed the association between demographic factors and abnormal blood pressure of study participants

Variables	**AOR (95% Cl)**	**P value**
Age of women (years)	0.790 (0.628-0.994)	0.044
Age of husband (years)	1.200 (1.004-1.435)	0.045
Occupation of husband		
Others (informal day workers)	Ref.	
Industry worker, office non-executive, petty business	0.155 (0.024-0.996)	0.049
Skilled, office-executive, big business, overseas employment	0.614 (0.122-3.088)	0.554
Location		
Urban	Ref.	
Rural	0.444 (0.101-1.964)	0.285

AOR: Adjusted Odds ratio, Cl: Confidence Interval, Ref: Reference

7. Conclusion and Future Work: We analyzed the data when pregnant women attended in their first ANC visit in the urban and rural tertiary and district hospitals. We found few mothers suffered from HTN, eclampsia in their previous pregnancies. In their current pregnancies, below half of them had abnormal BP that is the pregnancy related risk factors for maternal and neonatal morbidity and mortality. Urban women suffered with more abnormal BP compared to rural hospitals. Regular ANC visits, all the pregnant women of urban and rural areas, specially who had abnormal BP need to be addressed. More attention needs to be ensured for the pregnant women with HTN whose husbands had no job and was doing some informal day labor jobs.

Acknowledgement: We acknowledge all the pregnant women who participated in this study. We thank all the study staff for their valuable efforts. We especially give thanks to North South University, Bangladesh and Obstetric and Gynecological Society of Bangladesh (OGSB). We thank the donor the Hiroshima University of Japan.

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The Dilemma of AI in Healthcare: An Umbrella Review

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1. Background of the Research: Artificial intelligence in healthcare is a contemporary demand. The current umbrella review delves into the multifaceted intersection of artificial intelligence (AI) and healthcare. This comprehensive analysis scrutinizes the challenges and opportunities presented by AI adoption in medical settings. From enhancing diagnostic accuracy to streamlining administrative tasks, AI holds immense promise. However, concerns regarding privacy, bias, and regulatory hurdles cast a shadow on its integration. This review navigates through the complex landscape, shedding light on the balancing act between innovation and ethical considerations in leveraging AI to revolutionize healthcare.

2. Research Objectives: The primary objective is to explore the existing applications of artificial intelligence in healthcare. Secondary objectives are to identify ethical, social, and practical dilemmas arising from AI integration.

3. Research Problem/ Research Questions: What are the applications of artificial intelligence in healthcare, as evidenced by existing literature? What are the ethical, social, and practical aspects of AI in healthcare?

4. Experiment/Methodology: The methodology employed for the umbrella review on the dilemma of AI in healthcare involved a systematic and comprehensive literature search across major databases, encompassing studies published up to the knowledge cutoff date of January 2022. Inclusion criteria were defined to capture relevant reviews, meta-analyses, and systematic reviews addressing the ethical, clinical, and socio-economic implications of AI in healthcare. Screening and data extraction were conducted independently by two researchers, with disagreements resolved through consensus. The quality of included reviews was assessed, and findings were synthesized to provide a comprehensive overview. A total of 34 scientific papers were finally included in the study.

5. Results: Pros of AI integration in healthcare: AI is helping in improved diagnostics by analyzing vast amounts of medical data in a more accurate and timely manner. It ensures cost effectiveness by automating routine tasks. AI-driven tools, such as virtual assistants, can enhance patient engagement and support. It can accelerate drug discovery by analyzing genomic data and identifying potential action sites for the molecules [1].
Ethical Concerns about AI in Healthcare: The use of AI in healthcare requires a relatively large data matrix, raising concerns about patient privacy and the security of the collected data. There are chances of bias from AI algorithms. Biased algorithms may lead to disparities in treatment and outcomes. The inherent complexity of AI algorithms can make it challenging to understand decision-making processes. Lack of transparency and accountability may erode trust among healthcare professionals and patients. Establishing standardized protocols and certifications for AI applications in healthcare is a complex task. It requires collaboration between regulatory bodies, industry stakeholders, and healthcare professionals. It is also a challenge for overall healthcare systems to adapt to rapidly evolving AI technologies. It requires updated infrastructure, training, and education for healthcare professionals [2].

Clients Autonomy and Informed Consent: Ensuring that patients fully understand the implications of AI-driven interventions becomes crucial. Informed consent must evolve to encompass the unique challenges posed by AI applications. There are other dilemma on artificial intelligence integration in healthcare system. AI overreliance may diminish the human connection in healthcare. Striking a balance between technological advancements and preserving the empathetic aspects of patient care is essential [3,4].

Surgeons observing high-precision programmable automated robot arms [Newsweek, 28-02-2024]

7. Conclusion: The dilemma surrounding the use of AI in healthcare encapsulates the tension between unlocking the potential for innovation and addressing ethical concerns. It is imperative to prioritize transparency, fairness, and patient well-being. The responsible integration of AI in healthcare requires a collaborative effort involving policymakers, healthcare professionals, technologists, and the public to ensure that the benefits of AI are maximized while minimizing the ethical pitfalls.

8. Future recommendations: In near future AI will be integral part of healthcare system. In might be highly helpful for resource constraint country set up like Bangladesh. The country can enhance telemedicine services, develop AI-driven diagnostic tools to support rural healthcare providers, and create predictive analytics for disease management. AI can also improve patient data management and personalized treatment plans. Ensuring proper training for healthcare workers in AI technologies and establishing robust data privacy regulations are crucial for successful implementation. Collaboration with international AI research institutions can further advance healthcare innovation in Bangladesh, fostering a more efficient and accessible healthcare system for all.

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The impact of psychological distress on self-care ability among patients with cancer in Bangladesh

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Background: Cancer poses a significant health concern worldwide including Bangladesh, and patients often experience substantial psychological distress [1]. Distress can negatively impact on their self-care ability, which is essential to managing their health and treatment outcomes. It is important to know the psychological distress and its effect on the level of self-care ability, which is closely related to the survival rate and overall quality of life [2].

Objective: This study aims to assess the impact of psychological distress on self-care ability of cancer patients in Bangladesh.

Research Questions: How does psychological distress affect the self-care ability of cancer patients in Bangladesh?

Approach: The study adopted a quantitative approach to investigate the relationship between psychological distress and self-care ability among cancer patients.

Methodology: A hospital based cross-sectional study was conducted using convenient sampling among 415 adult participants with cancer at a tertiary care hospital in Bangladesh. Psychological distress was measured using the DASS-21 (Depression Anxiety Stress Scale -21), while self-care was measured using the EuroQol 5-Dimension 5-Level (EQ-5D-5L). Descriptive analysis was used to determine frequency and percentage and multivariate multinominal logistic regression analysis was used to determine the relationship between psychological distress and self-care ability.

Results: These studies have revealed that a notable proportion of cancer patients experienced psychological distress such as depression, anxiety, and stress at 61%, 55%, and 22%, respectively (Figure 1). Furthermore, the study indicated that 41% of patients had slight to moderate self-care ability, and 15% had severe to unable (Figure 2). We found a statistically significant association between depression and anxiety with those who have problems slight to moderate (p=<0.001), and severe to unable (p=<0.001) self-care ability. In addition, stress was significantly associated with severe to unable (p=<0.001) self-care ability. However, we cannot find any relationship between stress and slight to moderate self-care ability.

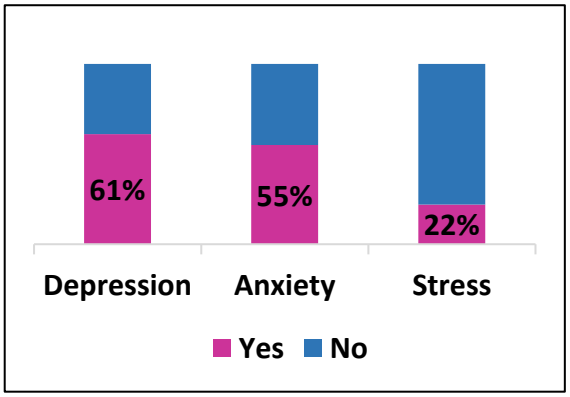

Figure 1: Depression, anxiety and stress level

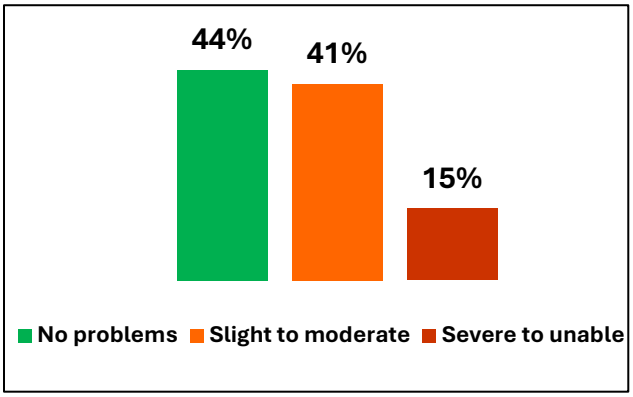

Figure 2: Self-care ability

Conclusion: Depression and anxiety are significantly associated with self-care ability in people who have problems ranging from slight to moderate and severe to unable. Ranging from severe to unable problems are also significantly associated with stress. Interventions aimed at reducing psychological distress can improve self-care practices, treatment outcomes, and overall quality of life. We need to take proactive measures through the government or policymakers to provide psychological support services, which are crucial for the well-being of individuals affected by cancer.

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Socioeconomic Determinants of Suicide Rates and Mental Health:A Multivariate Analysis Approach

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1. Background of the Research: Over the past few decades, suicide has emerged as a significant public health problem worldwide, with profound impacts on individuals, families, communities, and societies.[1] At the same time, mental disorders have attracted increasing attention due to their far-reaching impact on individuals' well-being and performance.[2] While both suicide rates and mental health outcomes are influenced by a variety of factors, socioeconomic status (SES) is a critical factor that determines susceptibility to suicide and mental health disorders. Socioeconomic status encompasses a range of indicators that reflect the economic and social position of individuals or households within society. [3, 4] These indicators include income, education, employment status, occupation, and access to resources such as health care and social support networks. The relationship between socioeconomic factors, suicide rates, and mental health outcomes is complex and multifaceted and is influenced by a variety of interacting variables.[3, 4] Individuals experiencing socioeconomic disadvantage often face a constellation of stressors, including financial strain, job insecurity, housing instability, and limited access to quality health care.[5] Understanding the interplay between socioeconomic factors, suicide rates, and mental health outcomes is critical to developing effective suicide prevention strategies and mental health interventions that address the root causes of stress and vulnerability.[1-4] By elucidating the mechanisms through which socioeconomic inequalities influence suicide rates and mental health outcomes, policymakers, health professionals, and community stakeholders can implement targeted interventions aimed at mitigating the negative effects of socioeconomic disadvantage and psychological well-being in different population groups.

2. Research Objectives: The study aims to assess socioeconomic factors associated with suicide rates and mental health outcomes and to examine the pathways through which socioeconomic disadvantage affects individuals' vulnerability to suicide and mental health disorders impact.

3. Research Problem/ Research Questions: What socioeconomic factors are associated with suicide rates and mental health, and what underlying mechanisms cause socioeconomic disadvantage to contribute to increased vulnerability to suicide and mental health disorders? Additionally, attention should be paid to which factors should be targeted and which intervention strategies aim to address socioeconomic inequalities to reduce suicide rates and improve mental health outcomes.

4. Approach: To address the complex interplay between socioeconomic factors, suicide rates, and mental health outcomes, our proposed solution involves a multi-pronged strategy that includes targeted interventions, policy reforms, and community engagement. Increasing access to mental health services and substance abuse treatment in underserved areas is critical. Policies to reduce income inequality through progressive taxation, higher minimum wages, and stronger social safety nets will ease financial burdens. Increasing public investment in education can improve economic mobility and reduce socioeconomic disadvantage. Public awareness campaigns educate communities aboutthe importance of mental health and available resources, while community support networks provide social connections and reduce isolation. This comprehensive approach aims to mitigate the impact of socioeconomic disadvantage on mental health and reduce suicide rates.

5. Methodology: We collected age-standardized data on suicide rates, mental disorders, and substance use disorders for both sexes across 204 countries and territories from 2017 to 2021, based on the Global Burden of Disease (GBD) database. Additionally, we gathered data from the World Bank database for 217 countries and territories covering the same period. The dataset was categorized into social, risk, and economic factors. Social factors included the refugee population, urban population (%), voice and accountability, and the Gini index. Risk factors included substance use disorders, mental health conditions, and population density. Economic factors included education expenditure (% of GDP), unemployment (%), health expenditure per capita, and the corruption rank. The average of the available data between 2017 and 2021 was used for the analysis. We performed multivariate linear regression analysis to assess the relation between dependent and explanatory variables, considering a p-value of less than 0.05 as statistically

significant. Statistical analysis was performed with JMP Pro (version 17).

6. Results: We only found records of all variables for 91 countries. In multivariate analysis, corruption rank (β=0.09, p= 0.0301) was associated with higher values of suicide rates. voice & accountability rank (β=-0.12, p= 0.0068), urban population (%) (β=-0.1, p= 0.0032) were associated with lower values of suicide rates. unemployment (%) (β=-0.04, p= 0.7608), health expenditure per capita (β=0.0, p= 0.9711), population density (β=0.0, p= 0.2155), refugee population (β=0.0, p= 0.4594), Gini index (β=0.01, p= 0.8786), education expenditure (% of GDP) (β=0.09, p= 0.8255) were not associated with the value of suicide rates. On the other hand, for mental disorders, health expenditure per capita (β=0.39, p= 0.005), unemployment (%) (β=142.36, p= 0.0004) were associated with higher values of mental disorders. corruption rank (β=-14.13, p= 0.2477), urban population (%) (β=-8.09, p= 0.3953), voice & accountability rank (β=-5.37, p= 0.6668), substance use (β=-0.23, p= 0.483), population density (β=-0.15, p= 0.8912), refugee population (β=0.0, p= 0.3974), Gini Index (β=27.7, p= 0.2853), education expenditure (% of GDP) (β=131.88, p= 0.2539) were not associated with the value of mental disorders. (Table 1)

Variables	Suicide Rate	Mental Health
Corruption Rank	β = 0.09, p = 0.0301*	β = -14.13, p = 0.2477
Health Expenditure per Capita	β = 0.0, p = 0.9711	β = 0.39, p = 0.005**
Refugee Population	β = 0.0, p = 0.4594	β = 0.0, p = 0.3974
Gini Index	β = 0.01, p = 0.8786	β = 27.7, p = 0.2853
Urban Population (%)	β = -0.1, p = 0.0032**	β = -8.09, p = 0.3953
Voice & Accountability Rank	β = -0.12, p = 0.0068**	β = -5.37, p = 0.6668
Education Expenditure (% of GDP)	β = 0.09, p = 0.8255	β = 131.88, p = 0.2539
Unemployment (%)	β = -0.04, p = 0.7608	β = 142.36, p = 0.0004***
Substance Use Disorders	β = 0.00436, p = 0.00023***	β = -0.23, p = 0.483
Mental Health Conditions	β = 0.00122, p = 0.0029**	—
Population Density	β = 0.0, p = 0.2155	β = -0.15, p = 0.8912

Table 1: Correlation among Suicide rate and mental health with social economic and risk factors
Significant level *p<0.05 **p<0.01 ***p<0.001 ****p<0.0001

7. Conclusion and Future Work: Our study identified the socioeconomic factors that influence suicide rates and mental health outcomes. Addressing socioeconomic inequalities was critical to effective suicide prevention and mental health promotion efforts. We can work towards creating fairer societies in which all people can thrive intellectually and emotionally. Identification of gaps in current research and recommendations for future studies such as longitudinal and intervention studies to further elucidate the complex relationship between socioeconomic factors, suicide rates, and mental health. Furthermore, it will be crucial to translate these findings into actionable policy recommendations.

Acknowledgement: Not applicable

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Recommendations for public health system resilience building after the 2023 Kahramanmaraş earthquakes: A Scorecard implementation study

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1. Background of the Research: Disasters can cause mass casualties by both direct and indirect reasons including a lack of access to basic needs. In addition, the loss of buildings, infrastructure, and other physical assets can cause a heavy burden on local and national economies. Minimizing the impact of disasters is possible through building resilience prior to disasters. Further, it is also possible to recover from damages from the disaster by rebuilding and organizing quickly if disaster resilience is built. The recent 2023 Kahramanmaraş earthquakes are a case to assess its resilience during the post disaster. The outcome of the systematical assessment of the disaster case can promote reduction measures to be planned and building resilient system in the future.

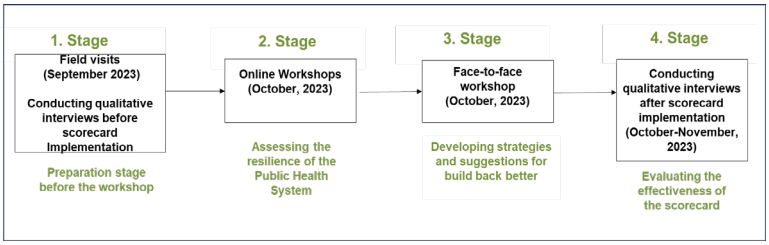
2. Research Objectives: The aim of this study was to evaluate the disaster resilience of the public health system after the Kahramanmaraş earthquakes using the United Nations Public Health System Resilience Scorecard and to develop strategies for promoting stronger reconstruction.

3. Research Problem/ Research Questions: The research problem is to address the urgent need to assess and develop strategies for strengthening the resilience of the public health system in the disaster area following the Kahramanmaraş earthquakes.

4. Approach: The United Nations Public Health System Resilience Scorecard (Scorecard) was developed to assess the resilience of the public health system to disasters and to identify areas for strengthening. The Scorecard consists of 23 indicators. Each indicator has a score ranging from 0 to 5. A high score indicates a high level of resilience for that indicator. The Scorecard allows public health system stakeholders to share their experiences, opinions and information about the resilience of the public health system and contribute to the identification of system weaknesses. As a result, the stakeholders can develop recommendations, strategies, and actions to address the identified weaknesses based on the results of the Scorecard implementation [2]. The Scorecard item that was rated "0" or "1" by the largest number of participants was accepted as the priority area to be addressed first for the development of recommendations. Then, strategies are developed to eliminate the weakness and build better resilience.

5. Experiment/Methodology: The study employed a convergent mixed method. Data was collected by organizing workshops to assess the disaster resilience of public health system in the earthquake zone, and to develop strategies for disaster resilient reconstruction. The workshops were held in Kahramanmaraş on October 24, 2023 and in Hatay on October 26, 2023. The workshops in both provinces were conducted in two phases: online, which included the evaluation of the Scorecard items, and face-to-face, which included the development of strategies and proposed solutions in accordance with the evaluation results. Prior to the workshops, participants were visited and informed about the study, and a Scorecard was distributed to participants for review. A purposive sampling method was used to

include participants from different disciplines that make up the public health system. Participants, for example, included Provincial Health Directorates, which are the basic components of the public health system in Türkiye, Provincial Disaster and Emergency Directorates (AFAD), which are responsible for disaster management, and unit heads within the municipality, who ensure the continuity of public health services through their work, were invited to participate in the study. The invitation was made through official correspondence and personal visits.



6. Results: The research was conducted in two phases in Kahramanmaraş and Hatay by holding online workshops (n=18, n=23 respectively), and face-to-face workshops (n=25, n=45 respectively). According to the scoring results of the Scorecard items in the online stage, the Scorecard items that the majority of participants rated as "0" or "1" were related to the extent to which public health infrastructure is resilient to disasters (n=16, 39.0%) (A8.1), whether key health facilities are capable and resilient enough to continue services after a disaster (n=15, 36.6%) (A4.1) and the extent to which public health data can be shared with other stakeholders (n=13, 31.7%) (A6.2). The second phase of the study, face-to-face workshops, brought together public health system stakeholders to exchange information and insights. During these workshops, existing weaknesses and vulnerabilities were addressed and recommendations for improving the system's resilience were formulated. The recommendations developed under the aforementioned items are as follows:

- Making transportation infrastructure, especially main roads, resilient to disasters (A8.1).
- Enhancing the resilience of communication infrastructure to disasters (A8.1).
- Establishing backup energy systems capable of providing services during disasters (A8.1).
- Structuring in accordance with horizontal architecture (A4.1).
- Constructing healthcare facilities in areas where transportation will not be hindered during disasters (A4.1).
- Installing seismic isolation devices in hospitals (A4.1).
- Conducting risk analysis regarding potential challenges in data distribution (A6.2).
- Establishing a region-specific satellite system to prevent interruptions in communication (A6.2).
- Developing resilient electronic systems to ensure continuity of data/information sharing in disasters (A6.2).

7. Conclusion and Future Work: The results of the study indicate that the most fundamental and highest-priority step in building a disaster-resilient public health system is the strengthening of buildings, infrastructure, and communication networks to be disaster resilient. In this regard, it is essential for both central and local governments to take the initiative and fulfill their duties and responsibilities at their level of governance.

Acknowledgement: The authors express their gratitude to the Scientific and Technological Research Council of Türkiye (TÜBİTAK 1002 - B: 123S888) and the Japan Science and Technology Agency (JST JPMJJR2303) for their generous support of the project.

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Lifestyle and Polycystic ovarian syndrome, digital implication, anxiety and depression state.

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1.Background of the Research:

Polycystic ovarian syndrome (PCOS) is a reproductive endocrine disorder of women that comes with both physical and mental sufferings. [1] PCOS is a complex syndrome that is often leading to hormonal imbalance, raise of male hormones in female, metabolic and psychological problems and hampers physical appearance such as hirsutism, obesity, male pattern balding etc. [2,3] The main treatment option of the disease is lifestyle modification. [5] With the advancement of technology, it is now possible to raise awareness and knowledge of this least discussed disease that many women are suffering from. [1] This study aims to find out the available studies on PCOS diet exercise digital implementation and the associated stress and anxiety.

2. Research Objectives:

1. To find out the digital implication of the disease.
2. To find out the association of depression and anxiety with PCOS.
3. To find out the available lifestyle, diet, exercise recommendation of polycystic ovarian syndrome.

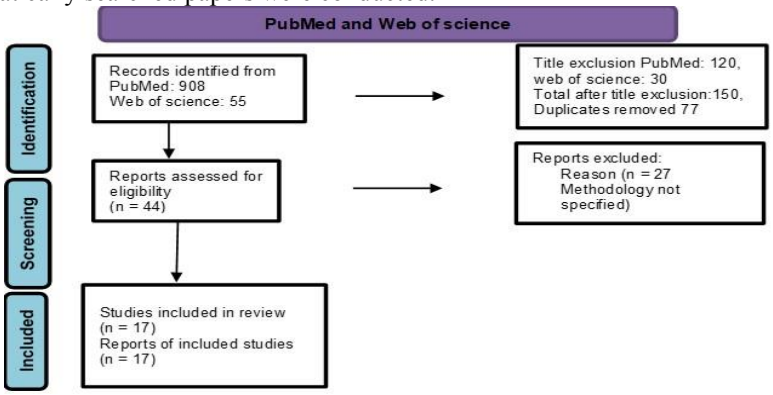
3. Research Problem:

Polycystic ovarian syndrome is a reproductive endocrine disorder that affects 5-20% women globally. [1] PCOS patients suffer from irregular menstruation, acne, excessive body and facial hair, infertility, metabolic disorder, diabetes, heart disease and emotional instability. So, the disease comes with intense stress, anxiety and depression. [2] The hormonal imbalances adversely impact patients metabolic and reproductive health. Presence of excessive male hormone or androgen excess hampers the quality of life of the patients. [2] Treatment of PCOS is limited to symptom specific treatment. The main treatment options are lifestyle modification, diet, weight management. [4]

Research Question:

1. What are the available digital implementations of the disease?
2. What is the association of depression and anxiety with PCOS?
3. What is the recommended lifestyle, diet and exercise available for polycystic ovarian disease?

4. Approach: Prisma flow diagram was used to extract the papers. PubMed and web of science database were searched with keywords Digital health awareness, polycystic ovarian syndrome, stress anxiety depression, cortisol and androgen level, Diet PCOS, exercise, lifestyle modification. MeSH terms were searched for PubMed. Total 908 articles were extracted initially from pybmed, 55 article from web of science initially. After title & abstract exclusion 44 articles remains which later on excluded after full paper exlusion which is 17. The papers included if they were published from 2020 to 2024. The papers were excluded based on relevance with keywords, methodology. A narrative analysis of the systematically searched papers were conducted.



5. Experiment/Methodology:

Study design: A systematic search was carried out using PubMed and web of science with the key words' polycystic ovarian syndrome, diet, exercise, digital health, depression, anxiety. Mesh terms were searched for PubMed.

Inclusion &Exclusion criteria:

1. Systematic review, full papers, randomized controlled trials, cohort or cross-sectional studies, review papers were included, Papers searched only if they were in English, Studies that are published in between 2019-2024 are included
2. Qualitative studies were excluded, Protocol papers excluded.

6. Results:

Initial screening of 150 articles led to the selection of 17 full-text articles. Ten studies discussed nutrition and lifestyle for PCOS, two studies focused on mobile health implications, and four studies examined the association of depression and PCOS.

Digital health Implication: Results suggest a transtheoretical mobile health application significantly reduced BMI, waist circumference, anxiety, and depression scores 6 months post intervention compared to routine care. [1]

Association of depression and anxiety: The reviewed studies, with cohort sizes ranging from 18 to 652 (median of 55), found that women with PCOS had worse cognitive function, and higher free testosterone levels were linked to poorer cognitive performance. [2] A prospective case-control study at the Medical University of Vienna with 31 PCOS patients and 31 healthy controls showed that higher BMI and older age were significantly associated with stress of the PCOS patients. [3] Whereas a cross-sectional study at the First Affiliated Hospital of Henan University of Chinese Medicine (January to June 2023) found that a high-fat diet, staying up late, mental stress, and acne were correlated with depression among PCOS patients. [4]

Impact of lifestyle intervention: A high-protein, low-carbohydrate diet with exercise effectively promoted weight loss in PCOS patients after four months intervention, studies suggest. [5] Regular yoga practice for 90 minutes daily over 6 weeks may reduce PCOS symptoms, while more than 150 minutes of aerobic exercise per week has also been shown to improve symptom reduction in PCOS.

7. Conclusion and Future Work:

The results show high protein low carbohydrate diet, along with regular exercise is effective management of PCOS and helps in improving PCOS related depression. A mobile health application can help improve the anxiety depression and lifestyle management of the patients. Future Goal is to develop a protocol with app-based research intervention which will allow health care professionals and doctors to modify the app according to the research outcome.

Acknowledgement: I am grateful to my respected Professor and Supervisors, Hiroshima University.

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Artificial Intelligence in Customized Healthcare: Application of AI Algorithms Addressing Challenges and Maximizing Opportunities for Personalized Medicine Transformation

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1. Background of the Research: This disruptive force in the field of healthcare, particularly in the field of customized medicine, artificial intelligence (AI) has emerged as a significant participant. This piece investigates the use of artificial intelligence algorithms in customized medicine, with a particular emphasis on the role that these algorithms play in illness detection, diagnosis, and therapy optimization. Artificial intelligence has the ability to personalize medical treatments for individual patients by evaluating a wide variety of datasets and utilizing powerful machine learning algorithms. This has the potential to substantially improve health outcomes and revolutionize medical procedures. Additionally, this article discusses the difficulties that are connected with using artificial intelligence in healthcare and offers suggestions for future research areas that might improve the incorporation of AI in customized medical procedures. **Keywords—**Personalized Medicine, Artificial Intelligence (AI), AI-Driven Therapy, AI Algorithms

2. Research Objectives: The primary goals of this study are to improve the accuracy and efficiency of disease detection and diagnosis by incorporating AI algorithms into personalized medicine, to address and overcome challenges related to data quality, privacy, and technological barriers, and to encourage interdisciplinary collaboration and continuous education among healthcare professionals. Furthermore, the study intends to create strong data governance frameworks and increase the interpretability of AI models, guaranteeing that AI-powered customized medicine is both clinically successful and ethical.

3. Research Problem: The integration of artificial intelligence (AI) with personalized medicine promises a dramatic possibility to better disease detection, diagnosis, and treatment outcomes. However, numerous hurdles limit its general adoption and efficacy. The quality and interoperability of data from multiple sources are typically inconsistent, affecting the reliability of AI models. Additionally, stringent privacy and security rules, including as GDPR and HIPAA, necessitate robust measures to secure sensitive patient information. Technological constraints, including the interpretability of AI algorithms and the necessity for constant training of healthcare workers, further complicate deployment. There is a pressing need for interdisciplinary collaboration to overcome these difficulties and produce ethical, transparent, and therapeutically beneficial AI systems that can transform personalized healthcare. This research intends to address the following questions: In customized medicine, how might AI algorithms enhance the precision and effectiveness of disease detection and diagnosis? What are the obstacles and opportunities connected with the deployment of AI in personalized medicine, and how may these be addressed to enhance treatment outcomes? By addressing these challenges, the project intends to propose solutions to overcome existing constraints and assure the ethical and transparent use of AI in customized healthcare.

4. Approach: Implementing AI algorithms in personalized medicine greatly improves the precision and speed of disease detection and diagnosis. AI accomplishes this by analyzing extensive and varied datasets that encompass genetic information, clinical records, and imaging data. With advanced machine learning techniques, AI has the ability to uncover complex patterns and correlations that might be overlooked by human analysis. With a data-driven approach, we can achieve more precise diagnostics, allowing for early detection of diseases and the creation of personalized treatment plans that cater to each patient's unique needs. In addition, AI plays a crucial role in enhancing

efficiency by automating repetitive tasks, prioritizing urgent cases, and providing valuable support to healthcare professionals in making timely and well-informed decisions. Implementing AI in personalized medicine presents both challenges and opportunities. Managing an IT project involves tackling a range of challenges. These include the crucial task of ensuring data quality and integration from multiple sources. Additionally, there is a need to address ethical and regulatory concerns related to patient privacy and data security. Overcoming technological barriers, such as acquiring AI expertise and establishing a robust infrastructure, is also a significant aspect of the role. On the flip side, there are numerous opportunities for advancements in diagnostics, personalized treatment plans, and overall efficiency gains in healthcare delivery. Addressing these challenges requires collaboration among healthcare providers, AI experts, policymakers, and regulatory bodies. To optimize treatment outcomes and fully realize the potential of AI in personalized medicine, it is crucial to implement robust data governance frameworks, invest in AI education and training programs for healthcare professionals, and adhere to ethical guidelines. Integrating algorithms that are powered by artificial intelligence (AI) into customized medicine results in a significant improvement in the accuracy of illness detection and diagnosis while simultaneously enhancing efficiency. AI is capable of processing enormous datasets that include genetic profiles, clinical histories, and imaging results, and it is able to recognize nuanced patterns that are beyond the capabilities of humans. Better health outcomes are achieved via the utilization of this data-driven strategy, which enables early illness detection and accurately tailors' treatment regimens to the specific requirements of individual patients. The adoption of artificial intelligence in customized medicine, on the other hand, involves a number of problems, including the need to ensure data quality, handle issues over privacy, and overcome technological restrictions. For the purpose of optimizing treatment outcomes and fully harnessing the potential of artificial intelligence to revolutionize personalized healthcare, collaborative efforts and effective data governance frameworks are vital prerequisites

5. Methodology: This study utilizes a qualitative approach to investigate the utilization of artificial intelligence (AI) in customized medicine, by analyzing current papers and research articles to get valuable insights. The study relies on a thorough examination of peer-reviewed publications, conference papers, and industry reports to find common themes, trends, and areas where information is lacking. This method enables a comprehensive comprehension of the use of AI techniques, such as artificial neural networks and deep learning models, in illness detection, diagnosis, and optimization of treatment. The process of thematic analysis will be used to combine the findings from multiple sources, ensuring a thorough investigation of the qualitative data to discover the difficulties and possibilities in adopting AI-driven tailored medicine. This technique enables a comprehensive examination of current knowledge, establishing a strong basis for future research paths in this revolutionary topic.

6. Results: The accuracy and efficiency of disease detection and diagnosis in personalized medicine are substantially improved by the application of AI algorithms, as demonstrated by this study. AI can identify intricate patterns that result in early disease detection and personalized treatment plans by analyzing a variety of datasets, including genetic profiles and clinical records. The primary obstacles that have been identified are the need to resolve privacy concerns, ensure data quality and interoperability, and surmount technological obstacles. The significance of interdisciplinary collaboration and comprehensive data governance frameworks in order to optimize the potential of AI in healthcare is underscored by the research. It is imperative to implement these measures in order to enhance patient outcomes and streamline healthcare delivery.

7. Conclusion and Future Work: In summary, the transformative potential of AI can only be realized through the surmounting of significant challenges in personalized medicine. In order to address the following: pure data, privacy laws, interdisciplinary cooperation, technology limitations, and continuing education for medical professionals, a multimodal approach is required. The following are the primary recommendations: nurturing interdisciplinary collaboration, emphasizing the interpretability of AI models, providing ongoing training for medical personnel, enhancing data quality and standardization, and ensuring that data security is in compliance with GDPR and HIPAA. It is imperative to implement these measures in order to enhance patient outcomes, streamline healthcare delivery, and integrate AI into personalized medicine.

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has been greatly influenced and improved by the expert guidance and mentoring provided by him, resulting in a deeper and more comprehensive knowledge.

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Socio-demographic and clinical factors and recovery of clinical features of severe pneumonia among under-five children with malnutrition in urban health care facilities of Bangladesh

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1. Background of the Research:

Globally, pneumonia is the leading infectious cause of death among under-five years children. Children with malnutrition are more susceptible to pneumonia [1]. Moreover, pneumonia and malnutrition are independently more liable to excess child deaths, and the combination of pneumonia and malnutrition has a detrimental effect on child morbidity and mortality [2]. The co-morbidity of childhood pneumonia and severe malnutrition had 15 times higher risk of deaths compared to those without having severe malnutrition [3]. Children less than five years, 45% of deaths occur due to malnutrition, mostly in the low- and middle-income countries [4]. In Bangladesh, 13% under five childhood death occurred due to pneumonia and 30.8% and 8.4% were stunted and wasting, respectively in 2018 [5].

2. Research Objectives:

This study aimed to find out the sociodemographic and clinical factors and recovery of clinical features (rapid breathing, lower chest wall in-drawing, hypoxemia, nasal discharge and fever) of severe pneumonia at day six after admission in urban health care settings among the malnourished under five children.

3. Research Problem/ Research Questions:

Under five children with severe pneumonia who had malnutrition were more vulnerable for hospitalization, prolongation of hospital stays, co-morbidities and death compared to well-nourished children. We attempted to assess the sociodemographic and clinical factors and recovery days of malnourished and well-nourished under five children at day six after admission in urban health care settings.

4. Approach:

We collected socio-demographic and clinical characteristics data of malnourished and well-nourished under five children by using a questionnaire and found out the clinical factors for early recovery from severe pneumonia. If we get the information, we can make the necessary modification in our treatment guideline for vulnerable malnourished children who had severe pneumonia. We analyzed data by chi-square, t-test/Mann-Whitney U and Wald test.

5. Experiment/Methodology:

This was a longitudinal study that compared malnourished and well-nourished children from the same cohort. The study was conducted at different day care facilities of primary health care centers (PHCCs), hospitals and clinics in Dhaka City, Bangladesh between January 2016, and January 2019. We enrolled children of both sexes aged 2 to 59 months, living in the study areas with severe pneumonia, parent/caregiver provided written informed consent administered by study nurses. We divided all children with malnutrition (defined as Z-score <-2 [weight-for-age; ZWA]) and without malnutrition (defined as Z-score≥-2 [(weight-for-age; ZWA]). We compared the baseline characteristics and resolution of clinical features of severe pneumonia between the malnourished and well-nourished children. We assumed 10% exposure rates of each of the clinical indicators of severe pneumonia. At a 5% level of significance with 80% power, our estimated sample size was 1,276 children - 638 each in the malnourished and well-nourished group (case and control ratio of 1:1 and desired odds ratio was 2.0).

6. Results: We found, well-nourished children were significantly more in number ($p<0.001$) compared to malnourished in <12 and ≥12 months of age group. Maternal and paternal illiteracy was significantly higher among the malnourished compared to well-nourished (18.3% vs. 8.7%; $p<0.001$ and 20.7% vs. 12.9%; $p<0.001$, respectively) children. Well-nourished children had significantly more housewife mothers than the malnourished (89.0% vs. 83.8%; $p=0.004$) children. Skilled workers, office non-executive and executive fathers had significantly more well-nourished children compared to malnourished (28.5% vs. 22.8%; $p=0.006$) children. On the other hand, fathers of day labor, garments and industry workers had significantly more malnourished children compared to well-nourished (23.2% vs. 17.9%; $p=0.006$) children. The median total household income of the malnourished children was USD 188 (IQR: 141, 270) and that for those without malnutrition USD 235 (IQR: 165, 253) ($p<0.001$). After recruitment, the proportion

of all children with fast breathing, lower chest wall in-drawing, hypoxemia, nasal discharge, and fever were 99.4%, 97.5%, 10.6%, 86.8%, and 84.8%, respectively; and they were not significantly different between the malnourished and the well-nourished children (Table 1).

Table 1. Basic clinical characteristics of the study children at admission.

Presence of clinical characteristics	Total (n=1693) n (%)	Malnourished children n (%)	Well-nourished children n (%)	P value
Rapid breathing; n (%)	1682 (99.4)	440 (99.3)	1240 (99.4)	0.935
Lower chest wall in-drawing; n (%)	1651 (97.5)	432 (97.5)	1217 (97.5)	0.999
Hypoxemia (SPO_2<90%); n (%)	179 (10.6)	39 (9.1)	140 (11.6)	0.168
Nasal discharge; n (%)	1470 (86.8)	377 (85.1)	1091 (87.4)	0.215
Fever; n (%)	1436 (84.8)	371 (83.8)	1064 (85.3)	0.446

Chi-square test, Student t-test, ¶Mann-Whitney U test, IQR=Interquartile range, SD=Standard Deviation, P-values indicate statistical significance at <0.05.

Wald test analyses suggested significant differences of resolution of rapid breathing (p=0.035), lower chest wall in-drawing (p=0.019), and fever (p=0.021) with well-nourished compared to malnourished children. On day six of the study, the proportion of children with the resolution of fast breathing (86.5% vs. 90.2%), lower chest wall in-drawing (90.5% vs. 93.9%), and fever (92.2% vs. 95.2%) were significantly higher in the well-nourished compared to malnourished children (Table 2).

Table 2. Compare the resolution of clinical features of severe pneumonia in malnourished children compared to well-nourished children at day six after admission.

Resolution at day six after admission in the health care facilities	Malnourished children n (%)	Well-nourished children n (%)	P value
No rapid breathing	365 (86.5), N=422	1077 (90.2), N=1194	**0.035**
No lower chest wall in-drawing	382 (90.5), N=422	1121 (93.9), N=1194	**0.019**
No hypoxemia	404 (99.5), N=406	1162 (99.5), N=1168	1.000
No nasal discharge	319 (75.6), N=422	874 (73.2), N=1194	0.335
No fever	389 (92.2), N=422	1137 (95.2), N=1194	**0.021**

Bolded P-values indicate statistical significance at $\alpha = 0.05$.

7. Conclusion and Future Work:

We found lesser disappearance of clinical features of severe pneumonia underscores the vulnerability among the malnourished children. Our study findings suggested for modification of clinical guideline for malnourished under five children suffering from severe pneumonia, the topmost cause of death, worldwide. This might ultimately help in preventing childhood morbidity and death in order to achieve the sustainable development goals (SDGs). Our study findings will provide future modification/separate clinical guidelines for the management of malnourished children.

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Designing an IoT Based Non-Invasive Glucometer and Platelet Counter

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1. Background of the Research: Dengue and diabetes are regarded as potentially fatal illnesses both locally and worldwide, and they require ongoing care to prevent complications [1-2]. It is crucial to regularly evaluate a patient with diabetes since the patient can decide which food and lifestyle are appropriate for controlling their condition and what level of insulin to take. In addition, it is crucial to monitor platelet counts in Dengue patients since a sharp decline in these cells might result in problems or even death. Traditional invasive techniques for measuring blood glucose and platelet levels are uncomfortable, expensive, and hazardous. Tissue injury might occasionally result from the patient's skin being punctured frequently. The non-invasive approach, which avoids skin punctures and is more effective and convenient, will benefit patients with severe diabetes and dengue who must regularly monitor their platelet and glucose levels.

2. Research Objectives: Our research project aims to design a blood glucose and platelet monitoring system integrated into an Internet of Things (IoT)-based device. This research is novel and innovative due to its non-invasive technique for measuring platelets and glucose.

3. Research Problem: Diabetes and dengue are serious illnesses requiring constant patient monitoring. Diabetes cases are increasing globally, especially in Asia [3]. Efficient management of blood glucose levels is crucial in reducing health risks associated with diabetes [4]. Nabil et al. [5] developed a non-invasive glucose monitoring system including Sp02 and BPM measurement. However, it doesn't have platelet monitoring system. Dengue fever threatens many global populations, with millions of cases reported annually. Real-time monitoring devices can help patients with diabetes and dengue receive timely and proper treatment, mainly benefiting those without health insurance in rural areas where primary level health care facilities are not available.

4. Approach: This study aims to provide timely and appropriate treatment for patients with dengue and diabetes through non-invasive technique real-time monitoring. Our gadget can assist anyone experiencing such health issues. Our test dataset mainly contains data on the blood glucose levels of non-diabetic individuals. The people who stand to gain the most from this affordable and user-friendly technology are those who reside in rural areas and do not have health insurance. Our study created a simple, affordable, and painless measuring system compared to the time-consuming, expensive, and painful methods. This device offers a non-invasive method of measuring blood sugar and platelets, which are crucial for understanding the health of dengue and diabetic patients. Moreover, the data is shown on the mobile app. Therefore, it will be easier for the patient to share the data with their doctor for further treatment. The invasive method of measuring a patient's platelet count and blood sugar level is widely used, but it can be hazardous for many patients. With further advancements, it will be preferable to shift the procedure towards a non-invasive method soon, as there is a lot of ongoing research in this area. This method will also be much more convenient for patients and doctors alike.

5. Experiment: The patient's one fingertip, which will be used to test the patient's platelet and glucose levels on the RPR220, serves as the input for the entire system, as seen in Figure 1.

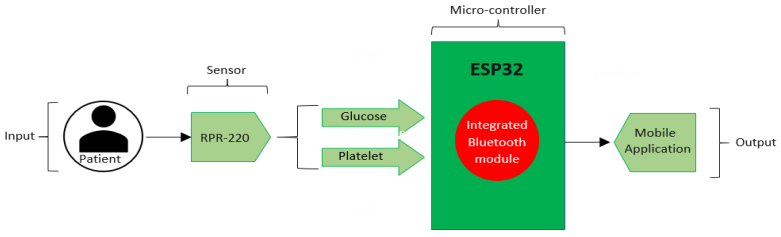

Figure 1: Block schematic of the complete system

The sensor's output signal is sent to the ESP32 microcontroller, which uses it to detect glucose and platelet counts. It then uses an embedded Bluetooth module to send the data to a mobile application developed by the MIT app inventor. Before putting the finger on the sensor, the mobile application must be linked to the Bluetooth module built within the ESP32 to show the data. Because all these components are inexpensive, lightweight, and small, the system is inexpensive and easy to operate. This technique requires no training and may be easily used by anyone with basic instructions, even those living in rural and distant places.

6. Results: Figure 2 and 3 show a graphical representation of the comparison between invasive and non-invasive glucometers and platelet counters, respectively. We contrasted the outcomes of our system's testing on five different human bodies with the traditional method. The average error rate for measuring the amount of glucose in our system is 2.336%. Furthermore, the average percentage error for the platelet counter compared to the commercially available platelet counter is 5.857%, meaning that the accuracy level of our system is 94.143%.

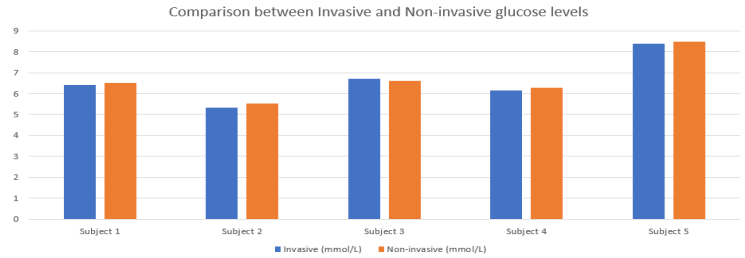

Figure 2: Graphical representation of comparison between invasive and non-invasive glucometer

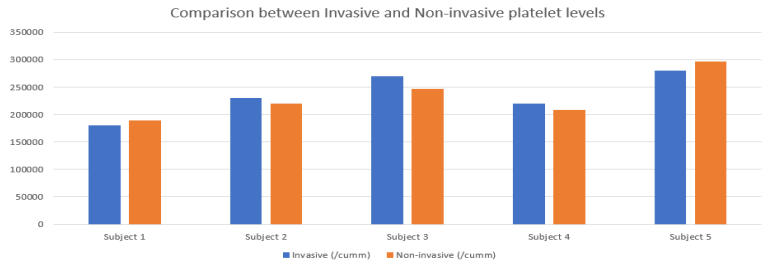

Figure 3: Graphical representation of comparison between invasive and non-invasive platelet counter

7. Conclusion and Future Work: A Near Infrared (NIR) sensor has been used in the study's design and implementation to test blood glucose and platelet levels. The results are shown on a mobile app. We will add several other blood parameter measurement features using non-invasive method. As a result, doctors will get all kinds of basic blood measurements to diagnose correctly without the help of healthcare workers.
Ethical issues: No ethical approval was taken for the experiment.

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Machine Learning for Disease Diagnosis

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1. Background of the Research: Machine learning (ML) is a branch of artificial intelligence that enables computer to learn and improve from experience without being explicitly programmed, reshaping traditional healthcare delivery paradigms by enhancing efficiency, accuracy, and personalization in disease diagnosis and assessment. (Fatima & Pasha, 2017) Diagnosis and assessment of complex heart diseases like chronic coronary syndrome, ST elevated myocardial infarction, hypertension prediction, and obstructive sleep apnea have already shown promising results in a combination of ML and traditional pathways. Therefore, this review compares various machine-learning algorithms for disease diagnosis. It focuses on the set of machine learning algorithms and tools used for disease analysis and decision-making.

2. Research Objectives: The primary goal of this review is to conduct a systematic analysis of experiments in which ML approaches are used in relation to various medical fields and diseases to determine their pattern. It examines trends and variations in ML use across medical fields, while usefulness assesses the effectiveness and impact of ML in disease diagnosis.

3. Research Problem/ Research Questions: Given the limitations posed by a large number of overlapping structures and cases, distractions, tiredness, and limitations with the human visual system, the provision of a second opinion can come in handy. This article addresses the research problem of how to effectively integrate ML-based tools that monitor continuously increasing volumes of data streams for patterns, assist clinicians in decision making ,or automatically adjust the settings of bedside devices. The research questions focus on how these integrations can improve patient treatment outcomes and significantly lower overall treatment costs.

4. Approach: A thorough literature review was conducted to obtain all the information used in this review. The data was gathered from credible sources such as peer-reviewed journals, online scholarly databases, and books.

5. Experiment/Methodology: A comprehensive literature review was conducted to gather information for this review, sourcing data from credible outlets such as peer-reviewed journals, scholarly databases, and authoritative books. Renowned databases including PubMed, SCOPUS, and Science Direct were instrumental in collecting relevant information on the role of ML in diagnosing various chronic diseases. Given the specificity of this topic, fewer articles were found compared to broader subjects in ML. Approximately 30 articles were initially screened based on their titles and keywords, and 10 papers were ultimately included in this review. Two researchers independently completed the screening and extraction processes, with any disagreements resolved through discussion. While the topic is specialized, the limited number of articles might reflect the highly focused criteria used for selection rather than an absolute scarcity of research. This specificity ensured that only the most relevant and high-quality studies were included.

6. Results: In the context of disease diagnosis using ML, we would like to know which diseases were considered more. Furthermore, one of the goals of this study is to determine which medical disciplines researchers were most interested in. As a result, the eligible articles in this study were classified according to diseases and the use of ML methods. We analyzed the articles based on medical disciplines to better understand the distribution of ML for disease diagnosis.

Fig. 1 represents the pie chart for the frequency of medical disciplines. Based on the diseases, 18 medical disciplines were identified. It is observed that 13.64% of studies were carried out in cardiology and endocrinology. Infectious disease, oncology, and pulmonology were ranked second with 9.09%. With a 6.82%, dermatology and nephrology were ranked third. Neurology, rheumatology, and urology were ranked fourth with 4.55%. At last, critical care, gastroenterology, hepatology, ophthalmology, pediatrics, periodontology, vascular surgery, and virology were ranked at 2.27% each. (Bhavsar et al., 2021)From our analysis, as presented in Fig. 2, we find that researchers prefer Support Vector Machine (SVM), Convolution Neural Network (CNN), and Random Forest (RF) over other ML methods. We identified 12 different ML methods that were applied in our eligible papers. These are Artificial neural network (ANN), Deep artificial neural network (deep ANN), Bayesian classifier (BC), Classification and regression tree (CART), Convolution neural network (CNN), Deep convolution neural network (deep CNN), Decision tree (DT),Gradient boosting (GB), XG Boost, Random forest (RF), Support vector machine (SVM), Other/hybrid.
Although these 12 methods are mostly used ML methods for disease diagnosis, we limit our findings only to medical diagnosis and do not generalize them. (Bhavsar et al., 2021)

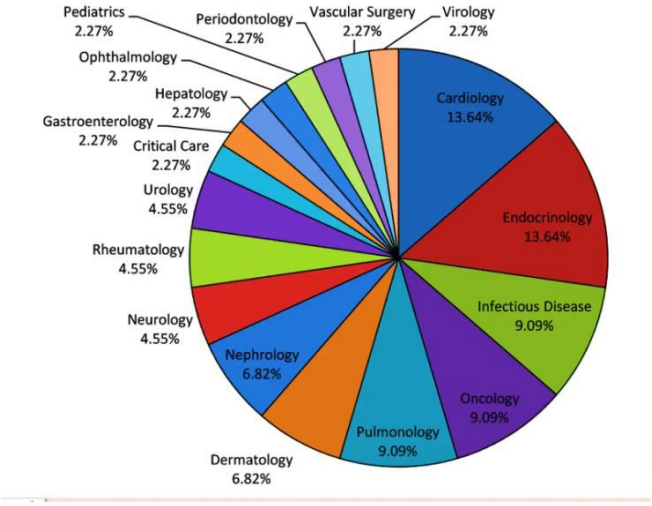

Fig 1: The frequency of medical disciplines

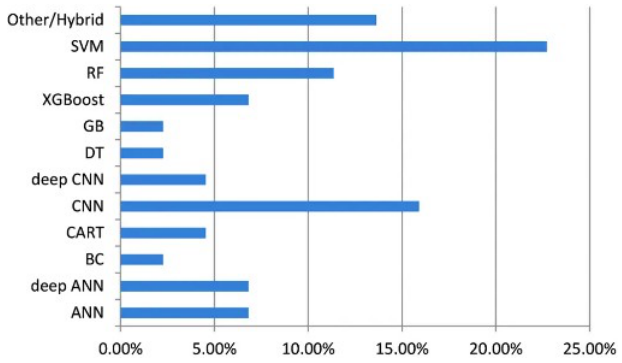

Fig 2: The frequency of machine learning methods impact

7. Conclusion and Future Work: This study reviewed the use of machine learning (ML) in disease diagnosis, finding that ML consistently enhances diagnostic accuracy and reduces treatment costs. It identified the top ML methods and their benefits, including improved early detection and support for clinicians. Future research should focus on developing advanced ML algorithms, integrating diverse data sources, and conducting extensive clinical trials. Additionally, addressing ethical concerns and ensuring model transparency will be essential for widespread clinical adoption.

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