RESEARCH ARTICLE

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Development of Mobile Application Based System for Improving Population Based Cancer Screening by Community Health Workers

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Abstract

Objective: Cancer remains a leading cause of morbidity and mortality globally, with India experiencing a significant cancer burden. Effective population-based cancer screening is crucial for early detection and reduction of cancer-related deaths. This study aims to develop a mobile application-based Cancer Screening and Surveillance System (CSMS) to enhance the efficiency and effectiveness of population-based cancer screening by community health workers (CHWs). **Methods:** An applied research approach was employed, integrating traditional cancer screening procedures with a newly developed mobile application system. The CSMS includes an Android-based mobile application and a web portal designed for real-time data collection, monitoring, and rapid referral of screen-positive cases. The system was piloted in the Cachar district of Assam and training sessions were conducted to equip CHWs with traditional cancer screening procedures and the necessary skills to utilize the mobile application for cancer screening. 199 CHWs were trained and screened eligible population of 73,630 individuals. **Results:** The mobile application facilitated efficient data collection and synchronization with a central server, enabling timely referrals and follow-ups. The system supported comprehensive data management, ensuring patient privacy and data security. The pilot implementation demonstrated improved screening coverage and streamlined referral processes, highlighting the system's potential to enhance cancer screening programs. **Conclusion:** Mobile application-based Cancer Screening and Surveillance System provides a cost-effective and robust solution for population-based cancer screening. The developed system can improve data accuracy, facilitate timely referral and aid in early detection of cancer. Further studies should be conducted to evaluate the impact of the developed system and its scalability in more diverse settings.

Keywords: Cancer screening- oral cancer- cervical cancer- breast cancer- mobile application- cancer prevention

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Introduction

Cancer remains a significant cause of morbidity and mortality globally. According to the GLOBOCAN 2022 estimates of cancer incidence, mortality, and prevalence worldwide, there were approximately 19.9 million new cancer cases and 9.7 million cancer-related deaths in 2022 [1]. In India, the cancer burden is projected to rise from 26.7 million disability-adjusted life years (DALYs) in 2021 to 29.8 million in 2025 [2]. Furthermore, the Global Burden of Disease study reports that between 1990 and 2016, cancer deaths in India increased by 112 percent, while the incidence of cancer cases rose by 48.7 percent [3]. Breast, oral and cervical cancers constitute 32.8% of all cancers among Indians and to bring down the deaths due to cancer [4].

In 2016, Government of India (GOI) started national program for population-based cancer screening, and operational framework [5]. It is focused on strengthening infrastructure, human resource development, health promotion, early diagnosis, management and referral.

Traditionally, cancer screening in India is conducted at Primary Health Centers (PHCs) by Non-Communicable Disease (NCD) nurses or at sub-centers by Auxiliary Nurse Midwives (ANMs) or Mid-Level Health Providers (MLHPs) [5]. However, this pilot study introduced an innovative approach by involving Accredited Social Health Activists (ASHAs) as primary screeners for oral, breast, and cervical cancers, in addition to screenings for diabetes and hypertension. ASHAs received specific training to perform Visual Inspection with Acetic Acid (VIA), Clinical Breast Examination (CBE), and oral

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screenings. Their involvement represents a novel and scalable model aimed at enhancing early cancer detection, particularly in underserved and remote areas. This approach was designed to address workforce constraints in remote settings, where access to ANMs and NCD nurses may be limited. The unconventional use of ASHAs in this context, particularly for VIA and CBE, is highlighted to discuss its feasibility and potential for scaling up population-based cancer screening efforts.

In 2019, reviews of cancer prevention and screening studies conducted in states like Punjab, Sikkim, and Delhi highlighted the need for a comprehensive system that includes community interventions, cancer registries, medical training, population-based screening, early detection, and referral for treatment [6]. To support these objectives, a robust and cost-effective screening, intervention, and referral system is crucial. Evidence suggests that electronic data collection tools are more efficient and reliable compared to traditional paper-based methods [7, 8].

This study outlines the development and implementation of a mobile application-based Cancer Screening and Surveillance System (CSMS). The tool facilitates real-time data monitoring, data analysis, and rapid referral of screen-positive cases, aiming to improve population-based cancer screening and its early detection.

Materials and Methods

To achieve the objectives of the study it was envisaged that a mobile application bases system will be developed to record the observations of cancer screening in the field. The screening procedures will be prepared as per the National cancer screening guidelines. Training on population-based cancer screening will be provided to the grass root health workers and to record the observations at the Mobile Application. Grass root health workers will conduct the cancer screening in population and record their observations at the mobile application. The Mobile Application will transfer the collected information to the physicians of CCHRC through Project Website. Suspected participants will be referred to the CCHRC. The physician will thoroughly screen and investigate the referred participants and put the confirmed cases on treatment.

(A) Type of study

This study is an applied research wherein mobile application based system is being used along with the traditional procedures of population-based cancer screening, early diagnosis and its referral. The developed CSMS is applied at Cachar district of Assam in pilot mode. This project was registered under Clinical Trial Registry of India (CTRI) and has been approved by the ethical committee of National Institute of Cancer Prevention and Research (NICPR) and of Cachar Cancer Hospital and Research Center (CCHRC).

(B) Study setting

The study has been implemented in a rural setting of one block (Dholai) in Cachar district of Assam, India.

(C) Inclusion and Exclusion Criteria for Screening

As per the guidelines of the NCD Control program of the Ministry of Health, GOI (NPCDCS) screening for oral cancer will be performed on all men and women of 30 to 65 years of age who are habitual users of tobacco/alcohol. Cervical and breast cancer screening will be provided to the women between 30 to 65 years of age.

(D) Development of the Mobile Application Based System for recording Cancer Screening details

The mobile application based system is developed by designing a web server for hosting project website, a mobile application, and internet based synchronization system between project website and mobile application. The data flow diagram is shown in Figure 1.

The details of each component developed in CSMS system are as follows:

(E) Development of Project Website

A Windows Server operating system based Server is developed at NICPR, Noida. Apache web server is installed on this server to host project website. The project website is developed using PHP, Scripting languages with MySQL database at its backend. The project website is designed with the following features:

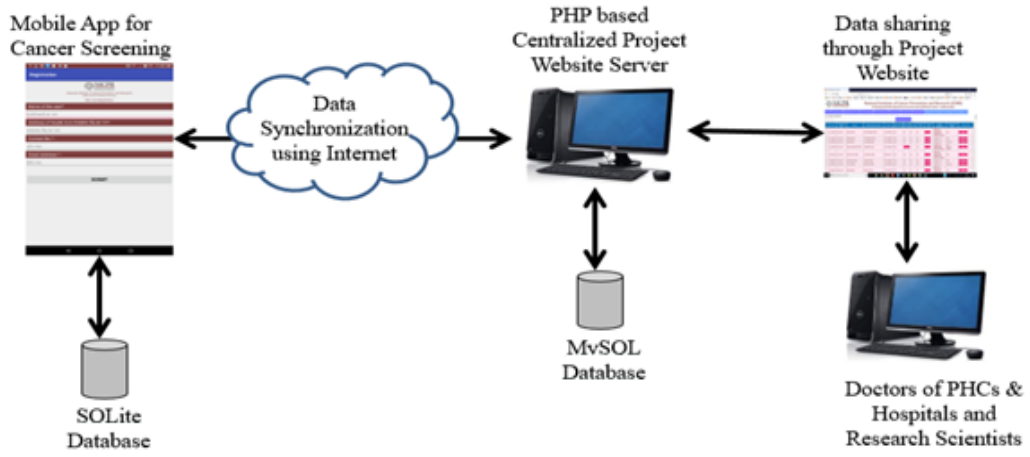

Figure 1. Data Flow Diagram of Mobile Application based CSMS

Webpage for Registration of Authorized users of the Project website

This page is designed to record the details of Physicians working at CCHRC, Principle Investigators and Co- Principle Investigators (PI and Co-PI) of the project and the grass root health workers associated with the project. This registration authorizes grass root health workers to install and use the Project Mobile Application. The registration of Physicians, PI and Co-PI authorizes them to view and taken further action on the participant information shared through Mobile Application by the grass root health workers.

API for authenticating user of Project Mobile Application

An Application Programming Interface (API) is designed to authenticate the user credentials during first time installation of Project Mobile Application. After verifying user credentials as specified in above para, the details of grass root health worker and user unique id are returned back by the Project Website to the Mobile Application. The Mobile Application associates the user unique id with all the information recorded by the Mobile Application. In this manner a relationship is established between the data shared by Project Mobile Application at the Project Website.

API for receiving Cancer Screening Information from Project Mobile Application

Another API is designed to receive the Cancer Screening Information shared by the grass root health workers through Project Mobile Application. During data synchronization between Project Website and Project Mobile Application, a Unique-id is generated by Project Website for all the participants. This Unique-id is returned back by the Project Website to the Mobile Application and the Mobile Application associates this unique-id with the participant information available at the Mobile Application. In this manner a relationship is established between the participant information available at Project Mobile Application and the Project Website.

Webpage to view Cancer Screening details for Physicians

This webpage is designed to display the Cancer screening details of the participants provided by grass root health workers through Mobile Application. Please see Figure 2.

Webpage for recording detailed Screening and Investigation details by physicians

This webpage is designed for Physicians of CCHRC to record the details of Screening and Investigation conducted by the physician at the hospital for the suspected participants referred by Grass Root Health Workers through Mobile Application. The website contained investigations pertaining to further evaluation of screen positive patients such as colposcopy, cervical biopsy, oral mucosal biopsy, breast ultrasound and breast tissue biopsy.

Webpages for Principle Investigators and Co- Principle Investigators

This webpage is designed for PI and Co-PI of the Project to monitor the activities being conducted by grass root health workers and physicians of the CCHRC. It enables PI & Co-PI to view the Cancer Screening and Investigation details of the participants and the overall execution of the project.

Webpage to check Data Consistency and Duplicity

This webpage is designed to highlight the inconsistent data and duplicate data based on certain criteria.

(F) Development of Project Mobile Application

In India, 95% mobile phones are based on Android Operating System (OS) [9]. Thus project mobile application is designed for Android OS-based devices. Considering the specifications of devices easily available during execution of the project, the Mobile Application

Figure 2. Project Website- Participant detail Screenshot

is designed which is compatible with OS version 4.0 or higher and having at least 4" screen size. The SQLite database is used for recording data in Mobile Application. A user-friendly interface is designed so that even an un-skilled grass root health worker can operate it. The details of the features designed are as follows:

Registration of Mobile Application

As the Mobile Application is meant for the health workers associated with the project only, the Mobile Applications installation file was made available only at Project website after getting login with authorized user credentials. During first time installation, the Mobile application asks for user credentials which are verified by the project website through internet. The Mobile Application works only if the user credentials are verified by the Project website. On success, the user details along with user-id (User-ID) received from the Project website are recorded in the Mobile Application in its SQLite database. In this manner the one-time registration process gets completed. Please see Figure 3.

Home Page of the Application

This page provides the buttons for navigation between the different pages. The "Add New" button provide the option to add general details of the participants and the "Add More Info" button provide the option to record Cancer screening details. The "View" and "Delete" button provide the option view or delete the recorded details. The option for exporting the data are provided. The "Export to Phone" option is provided to export data to the Mobile Phone itself. The "Export to Server" option is provided to export the data to the Project website. The "Export via Email" option is provided to export data to the PI of the project through auto generated Email. Please see Figure 3.

Pages for recording Cancer Screening details of the participant

The console and questionnaires of Mobile Application is designed in three languages English, Hindi and Bangla. The feature of voice recorded questions in Bangla is also developed in the app. Pages are designed to record details of participant about their sociodemographic profile, tobacco use, reproductive health history, personal medical history and common symptoms of common cancers. Format for reporting general examination, oral examination, breast examination and cervical examination are also developed. Provision is made to record if the participant is suspected for Cancer based on examination by the health worker. Please see Figure-4-8.

Most of the questions were having pre-defined answers. Such questions were designed as multiple choice questions using radio-button for single answer and check-box to record one or more than one answers. To record the abnormal point in Mouth, Breast and Cervix, figures were used where in health worker can record the abnormal point by simple touching on that point in the figure. The Figures used for Mouth, Breast and Cervix are as shown in Figure 1, 2 and 3 respectively.

The complete Mobile Application is designed to work in offline mode so that grass root health worker need not to depend upon availability of internet in the study area. Each participant is provided a unique serial number (Record-ID) by Mobile Application. This serial number may repeat if we compile data from two Mobile Applications. Thus along with unique serial number (Record-ID), provision is made to record the unique id of the user of the application (User-ID) and Date-Time stamp during creation of the record. Thus, the combination of Record-ID, User-ID and Date-Time stamp become a Unique identifier for each record. At the time of creation of each record, a field namely Server-ID is also created with default value as zero.

Synchronization of Participants information from Mobile Application to project website

A "Sync" button is designed in the Mobile Application. On pressing Sync button, the cancer screening details of the participants is transferred to project website by calling API made for synchronization purpose at project website. The project website identified each participant record considering Record-ID, User-ID and Date-Time stamp as mentioned in above para and provided a unique-id (Server-ID) to each record. This Server-ID is returned back to Mobile Application during synchronization process. This Server-ID is associated with the participant record in the Mobile Application. This Server-ID field in the mobile Application confirms that either the participant's details are updated at project website or not. Thus, on each repeated use of Sync button, only those records of participant are moved to project website whose Server-ID is zero.

Home page of the App

The home page of the Mobile application is designed wherein the Application user can view the list of all the participants recorded by the user in the form of a radio-button. It also displayed the Server-ID against each record, which confirmed if the record is synchronized with Project website or not.

Page to view the participant details recorded by the user

As mentioned above the Home page displayed the list of participants in the form of a radio-button. The user can select the radio-button of the desired participant and can the "View" button available at the Home Page. By pressing this button, the mobile application is designed to display the Cancer Screening details recorded by the user.

Alert to follow the participants referred to visit CCHRC

An alert is designed to remind Health worker to follow the participants who have been referred to visit CCHRC.

(G) Data Security and Patient's privacy

The project website is protected using strict user credentials, firewall and security policies. JavaScript Object Notation (JSON) encryption is used for synchronization of information between project website and mobile application. The screening details of participants are visible to concerned physicians only. The activation of

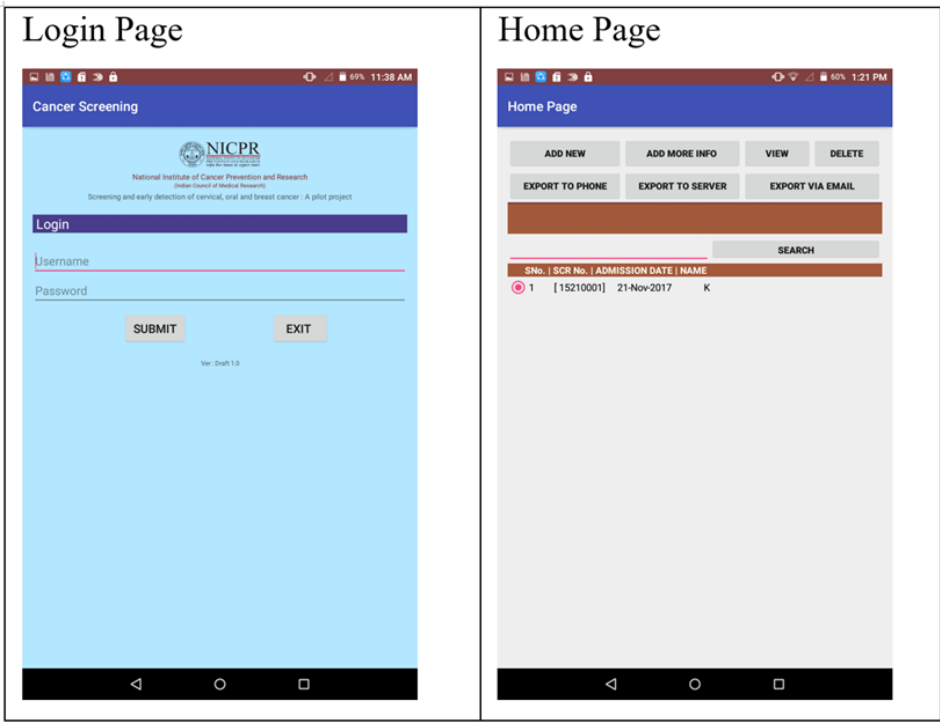

Figure 3. Mobile Application - Login & Home Page

mobile application is also restricted for authorized users only.

(H) Implementation of Study

Accredited Social Health Activist (ASHA) are the grass root level health workers in India. They are community health worker (CHW) who functions as the main link between community and the public health system. CHW helps Auxiliary Nurse Midwife (ANM) for various health programs. Thus CHW workers were selected as the main implementation force for the program.

After development of Project website and Project Mobile Application, the Mobile Application based system is verified by the associated PI, Co-PI and Physicians. After successful verification, the physicians of CCHRC were registered with the website and given training on project website and the use of Mobile Application.

Using the cascade approach of training, initially

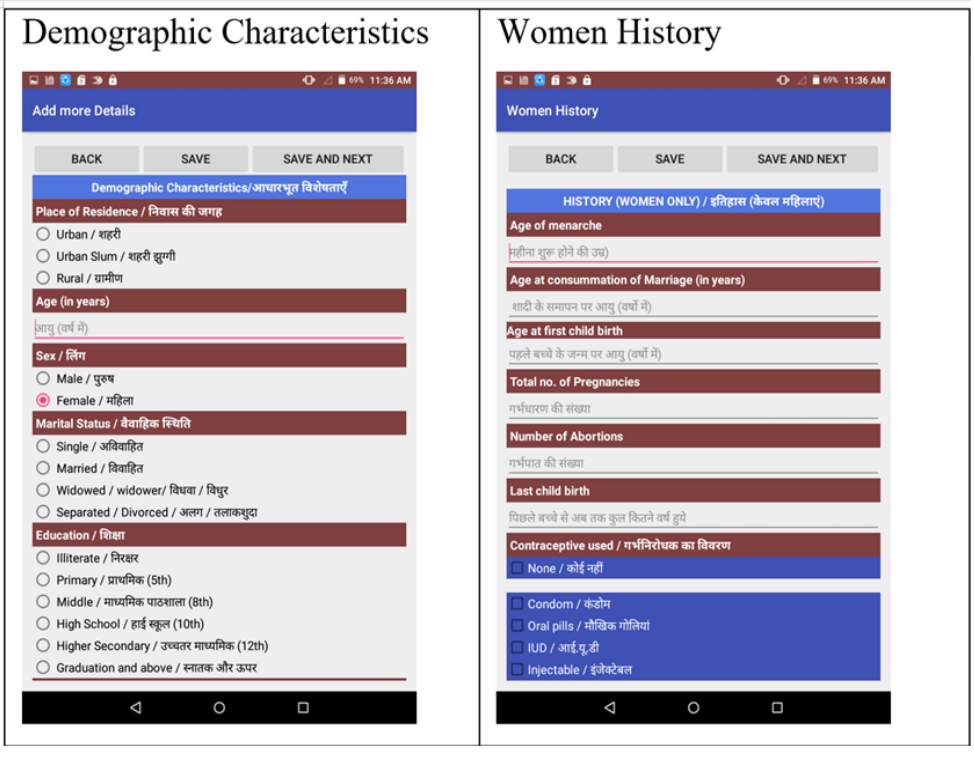

Figure 4. Mobile Application – Demographic Characteristics

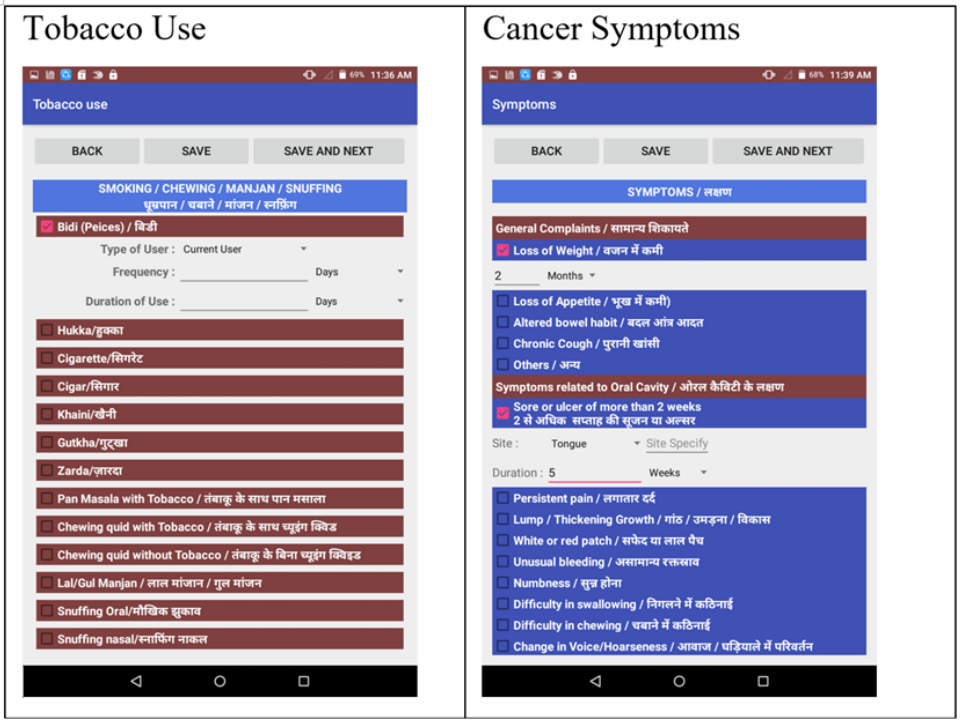

Figure 5. Mobile Application – Tobacco Use & Cancer Symptoms

15 CHW were trained as master trainers. These master trainers were given a hands-on training for the screening process and data collection on tablet using the project mobile application. The master trainers in turn then train CHWs to screen the eligible population under them and to collect data on the tablet. IEC material (pamphlets, flip charts & brochures) on information regarding oral, breast and cervical cancer, their risk factors, warning signs, screening tests, self-breast examination were formulated in the local language.

199 CHWs were trained in the study. The details of CHWs were registered with Project Website. Tablets with pre-installed Mobile Application were issued to each CHW. Before issuing Tablet, the Mobile Application is activated by putting the CHW credentials as per Project website. During activation the credentials of CHW were verified by the Project website. In this manner a link is created between CHW and the data to be submitted by

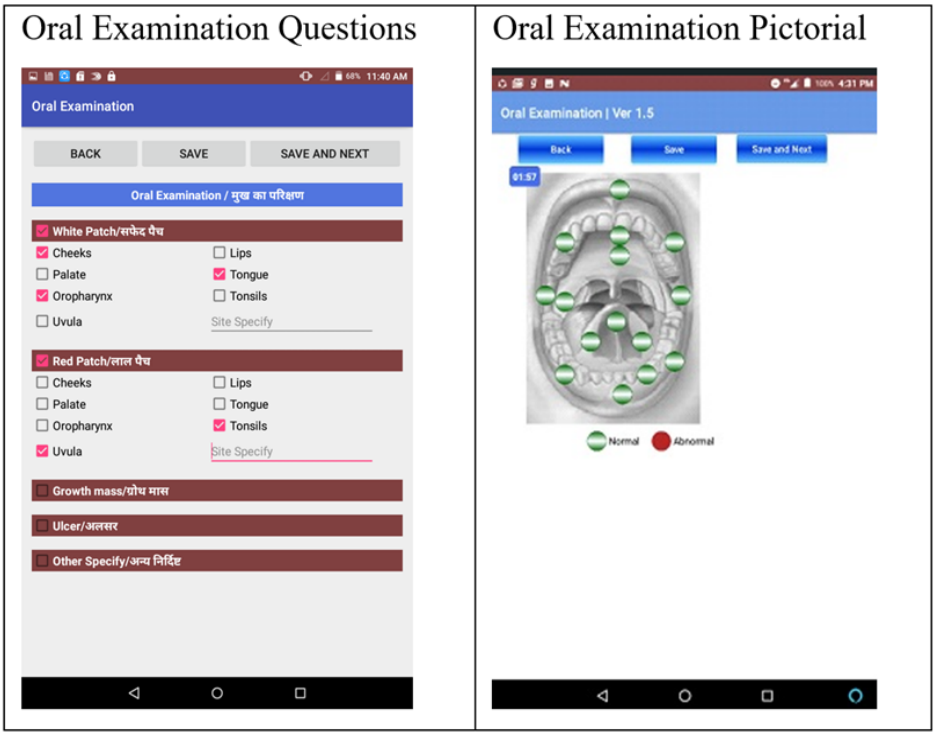

Figure 6. Mobile Application – Oral Examination

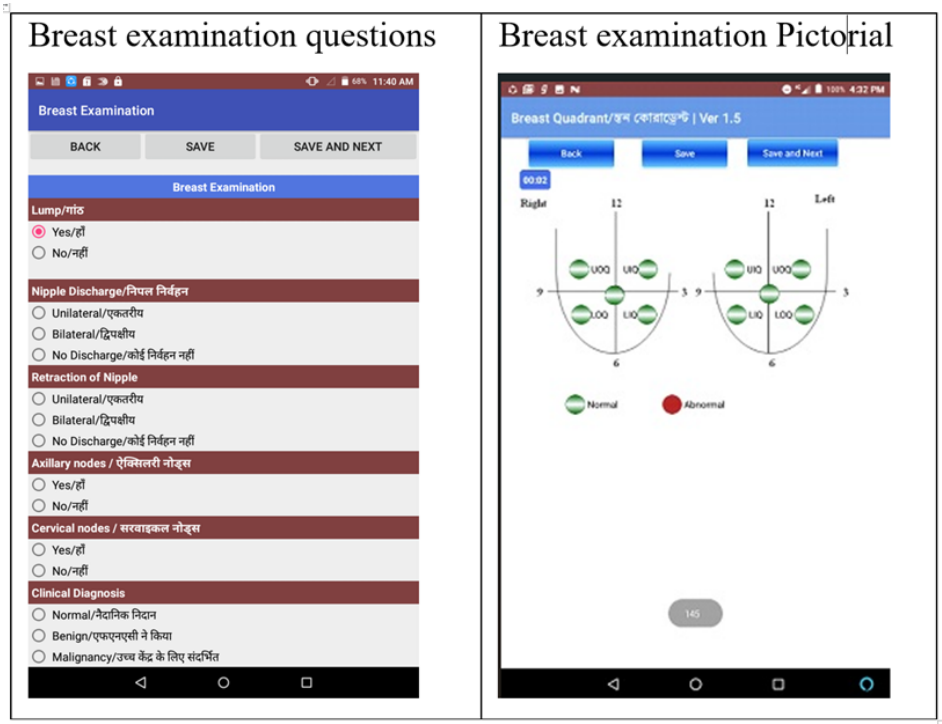

Figure 7. Mobile Application – Breast Examination

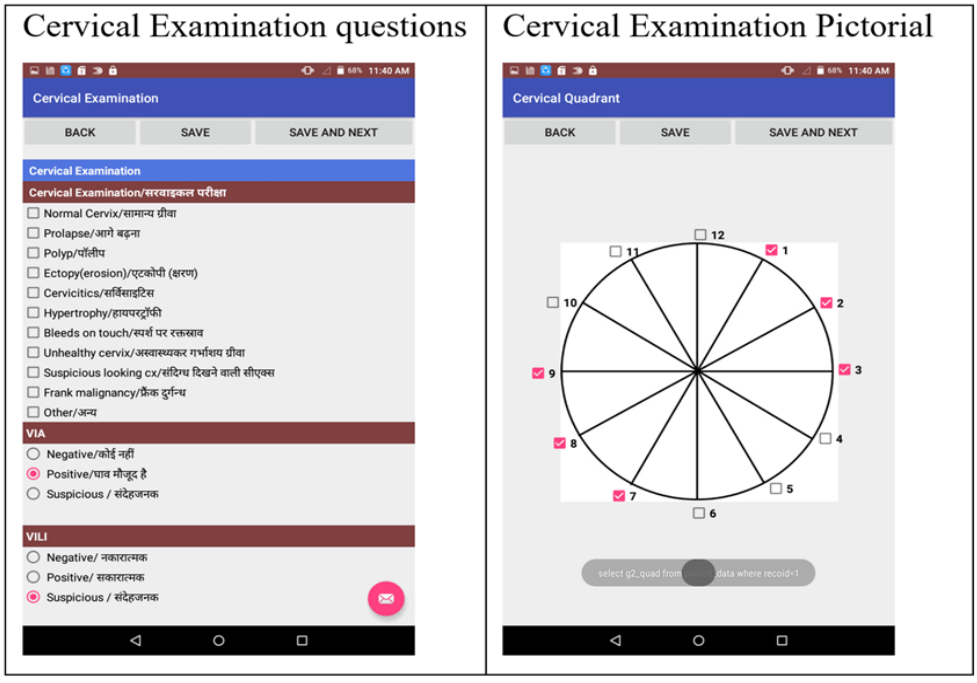

Figure 8. Mobile Application – Cervical Examination

CHW to Project Website through Mobile Application.

Results

Trained CHWs successfully conducted door to door screening for Cancer in rural setting of Dholai Block in Cachar district of Assam, India. They counsel and motivated eligible men and women to undergo screening using the IEC material. CHW successfully used Project Mobile Application to record data during home-based screening. Individuals who were eligible and shown willing to undergo the screening procedure were invited to the screening venue (Public Health Centre and District Hospital). The venue identified for screening were equipped to perform the screening tests and the staff were trained by the master trainers to perform oral visual examination, VIA and CBE.

After signing the consent form, the eligible participants were registered in the Project Mobile Application. The sociodemographic details, tobacco use, reproductive health history, personal medical history and common symptoms of common cancers were recorded for the

participants. Thereafter the participants were examined for oral, Breast and Cervical Cancer and the observations regarding general examination, oral examination, breast examination and cervical examination were recorded in the Mobile Application in offline mode. A health message is provided to all individuals enrolled in the study regarding the warning signs and asked to approach the health facility if any sign or symptom is experienced.

CHW used touch screen of the Tablet to record the location of abnormal points observed during Oral, Breast and Cervical Cancer screening by touching on pictorial based console in Mobile Application. Screen positive or suspected individual identified during screening were issued a registration and referral card and referred to CCHRC for further evaluation. Thereafter, the Mobile Application regularly displayed alert as reminder for CHW to follow the participant who have referred to visit CCHRC but not visited to the facility. It enabled CHWs to motivate them to visit to the facility. All the screening procedures specified in the National cancer screening guidelines were followed. The information collected through Mobile Application is synchronized with Project website using internet periodically depending on the availability of internet. The CHW successfully screened 73,630 individuals and submitted their screening details to the project website through mobile application in 2 years till 2020. 2535 individuals were found suspected for Oral cancer, 576 individuals were found suspected for Breast Cancer and 928 individuals were found suspected for Cervical Cancer. All suspected individuals were referred to the CCHRC. The complete analysis of Screening data is being published in the other paper.

As the physicians of CCHRC were provided to assess the Project website, thus, whenever a participant visited physician after referral, the physician was able to assess his complete details submitted by CHW through Mobile Application. The physicians thoroughly screened and investigated the referred participants. The confirmed cases were put on treatment.

Discussion

Electronic data collection has been found to be superior to paper-based data collection as it has been found to be faster and more accurate [8]. Electronic data collection has been successfully demonstrated in rural health settings utilizing CHWs for areas other than cancer screening [10, 11]. Studies from community cancer screening in rural setting have showed delays in referrals for screen positive patients as one of the challenges which could be solved by a flagging of the referrals in electronic medical records [12]. The Indian public health system has introduced digitalization in many programs such as Health Management and Information System (HMIS), Nikshay for tuberculosis and m-cessation program to quit tobacco however they do not involve CHWs to collect data electronically [13-15]. A qualitative study done in India on possible usage of information communication technologies (ICT) for rural healthcare service delivery showed that the use of ICT such as mobile phones by CHWs would have benefits of opportunity production, capabilities enhancement, social enabling, knowledge generation and improved motivation and empowerment [10, 11, 15].

A systematic review on the barriers and facilitators of health information exchange in Low- and Middle-income countries (LMICs) has shown that simple and user-friendly technology, incentivizing the staff, training the staff and perceived usefulness of technology are the facilitators [16, 17]. This study is unique as the android app has been designed for the data capture by CHWs. In most of national health programs in India, the ANM gives her reports on papers and conversion of data to electronic format takes place at Primary Health Centers or Community Health Centers [18]. Our study is one of the few ventures where the data from community is collected by CHW in an electronic format. Few other apps have been developed for collecting data on NCD risk factors in India such as m-STEPS but this does not cover cancer screening [19].

The GOI launched the NCD app for the NPCDCS program in 2021. However, the app is designed to be filed by the ANM.

Our study takes a distinct approach, focusing on a pilot model for home-based cancer screening conducted by ASHA workers. This model differs significantly from the facility-based screening approach currently supported by the National NCD app, as it seeks to expand coverage to underserved areas where access to health facilities is often limited.

In addition, the design of this application addresses usability issues specific to ASHA workers, who are not typically trained to manage complex data entry requirements. The National NCD app includes a comprehensive range of data fields that, while suitable for in-depth facility-based assessments, can be time-consuming for field-based ASHA workers to complete effectively. By contrast, our application is streamlined to include only essential parameters, making it more user-friendly and efficient for ASHAs to use during home visits. This simplified interface reduces the time burden on ASHAs, enabling them to focus more on the actual screening and patient interactions.

The outcomes of this study can inform national strategies by offering a complementary, community-focused approach to cancer screening that aligns with the goals of increasing early detection and accessibility in remote and underserved populations.

Cancer screening apps have been developed in other countries which apply to single cancers where most of them deal with disease and treatment information, disease management and awareness raising, alternative or homeopathic medicine [20-23-27]. Few apps have been designed for the providers for efficient detection of cancers [21, 24-26]. The android application was targeted for data collection by the CHWs whose basic qualification is tenth grade. Many of the elderly CHWs in the study were using the tablets for the first time and had never used smartphones earlier. The master trainers had to train and retrain the CHWs continuously which was required to ensure appropriate data collection on the tablet and to minimize errors. A study from India on maternal and child

health issues involved digital technology to collect data which was done by CHWs showed that the initial concerns of CHWs not being able to navigate technical interfaces could be overcome with training and was found to be the most important facilitator in another study too [17, 27]. The dashboard of the application gives regular alerts to the CHW if their follow up visit is pending to CCHRC/ Sub-Center clinic. CHW then regularly undertakes home visits for motivating these individuals and hence decreasing the loss to follow up. Studies on community-based cancer screening has shown that home visits done by CHWs was an effective intervention to decrease loss to follow up [28]. The Mobile Application Based Cancer Screening System was effectively utilized by CHWs. They found the system user-friendly and efficiently recorded cancer screening data. The CHWs successfully employed the tablet's touch screen to document the locations of abnormal points identified during oral, breast, and cervical cancer screenings, using a pictorial-based interface within the mobile application. Individuals who screened positive or were suspected of having cancer were referred to the CCHRC for further evaluation. The application's alert-based reminder system enabled CHWs to follow up with participants who had been referred to CCHRC but had not yet visited the facility. Additionally, the mobile application functioned in offline mode, allowing CHWs to operate it without an internet connection.

In conclusion, the developed system and the integration of doctors and nurses in the system has shown that digitalization of data collection is possible in rural community setting of LMICs and the system may be replicable in community interventions of other LMICs. As most LMICs face challenges in collection of health-related data, this app may provide a solution in the field of cancer screening. The described application has been implemented successfully in the current study, hence the same may be used by CHW in other LMIC for seamless collection and monitoring of data for population-based cancer screening.

Author Contribution Statement

RH: Conception and design of the study, manuscript editing, procured the funding and approval of final version. MSC: Development & implementation of CSMS, manuscript drafting and editing. AK: Manuscript drafting, editing and technical inputs in modification of CSMS. RK: Implementation of CSMS, technical inputs for modification of CSMS, manuscript editing. VK: Development of CSMS, manuscript drafting. SG: Implementation of CSMS, data collection, manuscript editing. RT: Implementation of CSMS, technical inputs for modification of CSMS, manuscript editing

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General

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Approval

This study was approved by NICPR Scientific Advisory Committee.

Ethical Declaration

This study was ethically approved by NICPR Ethical Committee.

Study Registration

The study is registered with Clinical Trials Registry – India with CTRI number - CTRI/2018/04/013144.

Conflict of Interest

There is no conflict of interest.

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