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ABSTRACT

In the last decade, there has been an epidemiological shift from communicable to non-communicable disease and the impact of this shift is more evident in India which is witnessing rapid urbanization and lifestyle changes. NCDs are the leading causes of morbidity and mortality in India of which the 4 major NCDs (Cardiovascular Diseases, Respiratory diseases, Diabetes, and Cancer), contribute to 60% of the total deaths in the country. The key priority areas of the primary health systems in India has been the maternal health and family planning programs while the other infectious and non-infectious disease prevention had taken a back seat. Though there were structural and operational limitations in delivery of effective primary Healthcare, new age screening solutions are offering sustainable and scalable solutions with quantitative & accurate clinical decision making, referrals, data collection and disease awareness. This study examines the NCD screening solution developed by Narayana Health through the socio technical systems perspective in low resource settings.

Methods and materials: The data collected from screening solution that was developed using socio-technical system was used to assess the screening solution in addressing the gaps in NCD screening. A cross sectional study was carried out from June 2019 to January 2020 in the urban Bangalore district.

Results: A total of 16,635 individuals for screened for NCDs of whom 22.6% were hypertensives, 9.1% were diabetic, 25% were Overweight and Obese. Anaemia was prevalent in 36% of the population of which 0.4% were severe anaemics, 3.5% were moderate anaemics and 32% were mild anaemics. Of the total population screened for oral and breast cancer 98 were found to have precancerous oral lesions and 50 received confirmatory diagnosis for severe dysplasia. The innovative development of screening kit and workflow process brought in a lot of traction to the program in increasing awareness, early identification and referral to higher government health centres for confirmatory diagnosis.

Conclusion: The NCD screening solution that was developed using the socio-technical system was seen to be acceptable by the population and the low-cost model was beneficial in low resource setting.

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I. INTRODUCTION

Increasing urbanization, environmental and lifestyle changes around the world combined with rapid demographic, sociocultural, and economic transitions led to the surge in non-communicable diseases (NCDs) in the past few decades[1]. The increasing prevalence can be attributed to behavioural and biological risk factors like use of tobacco, alcohol, physical inactivity and obesity.The incidence of NCDs like diabetes, cardiovascular disease, chronic lung diseases, and cancer are skyrocketing, with a staggering 71 percent of global deaths due to NCDs.[2] To increase availability of NCD services directly to more people and decrease the inability to pay for the screening services for NCDssmart digital tools can be used to deliver quality health care services at doorstep. Early identification, self-care interventions, community mobilisation, and

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health education are identified as low cost solutions to reduce the NCDs.[3]

The government's ability to limit the burden of NCDs limited owing the diverse socio economic and cultural issues spread regions in India. TheMinistry of Health and Family Welfare has initiated action on many fronts, such as introduction of National Action Plan and Monitoring Framework for Prevention and Control of NCDs, m-Diabetes, digital and broadcast media campaigns, reduction measures for the harmful use of tobacco and alcohol, community based screening of NCD's, among others.[4] In 10 years Diabetes, heart disease and stroke cost India US$ 237 billion (2005 to 2015). India is estimated to lose US$ 6.2 trillion due to NCDs during the period 2012-2030, whereas India could lose US$ 4.8 trillion in lost economic output by 2030 due to NCDs.[5]

Healthcare systems often face challenges with limited resources that restrict the reach of the healthcare services to the last individual. The gap to address these challenges increases in the under-developed and developing countries.[6] There is need for innovative solutions to respond to the challenges the public health is facing today. Non communicable disease screening in India had been a challenge given the public health force is completely dedicated and occupied with Reproductive and family planning services and the current pandemic services [7]. India had spent 13,200 crores under CSR act in the financial year 2018-2019 of which 38.6% is spent under education and health related sectors.[8]

II. MATERIALS AND METHODS

A socio-technical approach was adopted for the population based NCD screening program. The model leverages technological developments in the space of point of care tests to make screening services available to the larger population. Technology acts as the bridge that makes screening services available and accessible to deprived populations. It is widely acknowledged that adopting a socio-technical approach to system development leads to systems that are more acceptable to end users and deliver better value to stakeholders.[9]

Technology acts as the interface that helps the organization to materialise its driving factors to a process that helps society overcome its limiting factors. Technology also aids in addressing overlying systemic challenges that exist in the broader environment of NCD screening.

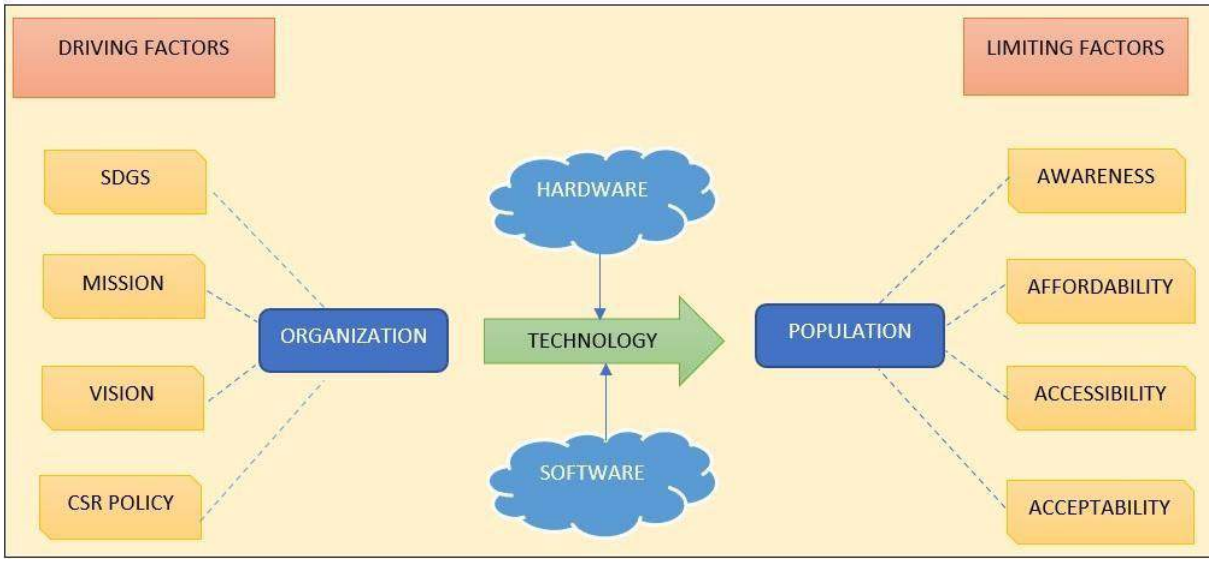

Figure 1: Conceptual Framework of Socio-Technical approach for NCD screening

The socio-technical structure considers the human, social and organisational factors as well as the contributing technological factors. This NCD screening model discusses how technology

was used to link the motivating factors of the organization to address the limiting factors of the general population thus establishing a socio -technical system for NCD screening. 'Socio' refers to both the implementing organisation, the stakeholders as well as the benefactors while technology takes on the challenge of meeting their requirements and objectives.

Organization: NCDs pose a major risk to the health of the nation and the health systems. While the government has launched programs targeted towards reducing the mortality and morbidity due to NCDs, several other non-profits as well as corporates through their CSR have dedicated efforts to achieve the same goal. Sustainable Development Goal 3.4 targets to reduce premature mortality due to NCDs by a third by 2030. [10]

The CSR law mandates all organizations with net worth of 500 crore or 1000 crore turnover or 5 crore profitto spend 2% of their last three years and the social impact of the spend should be captured through measurable indicators.[11] This law mandates all organizations falling the purview of the above conditions to identify the gaps and address them through scalable and sustainable solutions.This helped us to develop this model to deliver high quality affordable healthcare services to the broader population. Through the aegis of CSR, we engaged in population-based preventive and screening activities.Narayana Health during the same financial year spent 21.2% of its total CSR expenditures in NCD Program[12] of which 5% was used in the present study. It was envisioned that the program identifies an acceptable solution for population screening in a low resource setting. The team was formed, and the objectives were laid out to understand the gaps in existing healthcare delivery and develop solutions that are scalable in low resource setting.

Population: The target population for the screening program were people from deprived/low resource settings. The program activities focused on rural and urban slum locations. A pilot project conducted in Bangalore found that awareness regarding NCDs was low. Prevalence of NCDs in the pilot population was found to be 29%.[13]Poor access to screening and general healthcare facilities was one of the major limiting factors to getting screened for NCDs. The cost involved in getting tested/screened was another deterring aspect. When the service was made available, issues related to acceptability arose, low acceptability to screening facilities was found to be associated with the low levels of awareness.

Technology: The technology system designed and developed comprised of various hardware devices that use different software applications to give immediate results. These devices were assembled into a kit that could be operated by frontline healthcare worker. The NCDs targeted through the intervention included diabetes, hypertension, cardiac disorders, anaemia, breast cancer and oral cancer. Family history, habit history and other demographic details are also factored in the screening process to gain better understanding of risk. Learnings from the pilot were crucial in enhancing and customising the technology and system for screening NCDs. As helpful as technology is, it does not solve problems on its own — it is only as good as its implementation. This can be achieved by marrying human values with the specific technological solutions .

Hardware & Software: The community needs were understood by secondary data research and an NCD screening app was developed to screen the NCDs prevalent in the community through point of care devices. Point of care medical devices with AI interpretation were used to screen NCDs. The Major NCDs screened and the devices used

Blood Pressure – Non-Invasive Blood Pressure (NIBP) device

Electronic BP devices. Non-Invasive Blood Pressure devices are used to measure and display arterial BP by automated and semi-automated inflation and deflation of a cuff applied to an extremity and through oscillatory method by transducing vibrations into electrical signals produces a digital readout of systolic and diastolic pressures.[14]

Hemoglobin - Hemoglobinometer

Hemoglobin - Hemoglobinometer

Small handheld hemoglobin analyser with less than 2 seconds measuring time used as a point of care device. A fast ergonomic and easy to use portable device is used to measure the HB levels in the blood. The device uses photometric azide methaemoglobin method to assess the HB using the reagent free cuvette with unique design and uses only one drop of blood needed.[15]

Blood Sugar - Glucometer

The device uses glucose dehydrogenase/flavin dinucleotide chemistry, automatic test strip calibration, and auto compensation for haematocrit. The strip requires a small blood sample (0.6 µl), and its test strips have a separate electrode that measures haematocrit so that the meter reports a haematocrit-compensated BG. Results are available in 8 seconds. A test strip that collects 0.6 µl through capillary method and the results and are displayed on the screen in 8 seconds.[16]

Weight - Weighing scale

Digital scales work with the use of a strain gauge load cell. Whereas analog scales use springs to indicate the weight of an object, digital scales convert the force of a weight to an electric signal. The weight of the person can be recorded in different measurement scales like lbs, Kgs, Pounds etcs. [17]

Height - Digital height device

The device used to measure the height digitally uses the ultrasonic method to estimate the height in centimetres and meters. [18]

SP02 - Pulse oximeter

The oximeter utilizes an electronic processor and a pair of small light-emitting diodes (LEDs) facing a photodiode through a translucent part of the patient's body, usually a fingertip or an earlobe. Oximeters operate based on this principle of different absorption and light emission. *[19]*

ECG – 6 lead ECG

An electrocardiogram (ECG) is a recording of the heart's electrical activity. It is totally painless and can be performed quickly. The heart's electricity is detected by adhesive electrodes attached to the skin. The resulting measurements are referred to as leads and uses Ethiopiantriangle to assess the ECG and the AI interpretation is done using Glasgow algorithm. The leads were colour coded and labelled to reduce confusion. The leads come with clamps are attached to fore-arms and legs. [20]

Vision (Refractive Index) - Phoropter

A low-cost folding phoropter was used to understand the prevalence of refractive errors in the population.[21]

Breast Cancer screening

Clinical breast examination and a Handheld device was used to screen for breast cancer. The frontline health worker was trained in CBE for 3 months under an oncologist. The handheld device uses pressure mapping to detect lumps in the breast through its sensors.

Oral Cancer screening

The frontline health care worker was trained to identify the precancerous lesions in the oral cavity. He also takes the pics on field and uploads them on the dashboard for diagnosis by the oncologist at a later stage.

Tablet with NCD app

An app was developed to ease the process of data collection and decision making in the field. The app interface was easy to use and the segregation of the app into pages for demographics, Past medical history, Habit history and Vitals with underlying condition to minimize data entry errors. The back end has dashboard with infographics to segregate the high-risk individuals for referral to public health institutions.

The following criteria were taken into consideration while selecting devices to perform tests:

- Certification and approval by agencies and authorities
- Point of care yielding immediate results
- Portable light-weight devices
- Field hardy
- Long battery life
- Easy to use and interpret results

Figure 2 and 3: NCD kit with Handheld breast cancer screening device and back pack with point of care device

III. RESULTS

Through the NCD program a total of 16,635 individuals have been screened, camps were organized with 63factories/NGOs/civil societies etc,. A team of 4 people were working for 6-8 hrs a day with 1-hour lunch break and two 15 min tea break. A CSR budget of 10,00,000was spent to screen the 16635 individuals that includes HR cost, Travel, and food expenses which translates to 60 rupee per beneficiary.

Task/Outcomes

Between June 2019 and January 2020 over 16000 individuals were screened for major NCDs at the communities, factories, urban slums, villages etc., The following indicators were monitored to assess the program

No of screening camps done -198
No of organizations approached -45
No of health awareness session – 78
No of breast cancer screening done -6538
No of Mammograms done (for suspected) – 1299
No of breast cancer cases – 02 (1 benign and 1 IInd stage cancer)

Between June 2019 and January 2020 over 16000 individuals were screened for major NCDs at the communities, factories, urban slums, villages etc., of these 32% (5335) were men and 68% (11300) were women. High BP was found in 22.6% (3757) respondents of which 29.8% (1121) were unaware of their condition. Diabetes was found in 9.1% (1522) and prediabetes was found in 5.5% (924) participants of which 37.2% (911) were unaware of their high blood sugar levels. The prevalence of hypertension among the men 30.9% (1650 out of 5335) and women 18.6% (2107 of 11300) was below the average national prevalence. The prevalence of Diabetes among the men 12.3% (661 out of 5335) and women 7.6% (861 of 11300) was above the average national prevalence. There were 25.1% overweight (BMI -25-30) and 7.8% obese (BMI >30) individuals in the study. Anaemia was prevalent in 36.4% (n= 6057) individuals of which 32.3% (n=5386) were mild anaemic, 3.4% (n=574) were moderate anaemic and 0.48% (n=97) were severe anaemic.

Table 1: Prevalence of major NCDs among the population screened

Vitals (N=16635)		Males (N=5335)	Females (N = 11300)	Total prevalence (N=16635)	Individuals not aware of their underlying condition
High Blood Pressure	Systolic	9.9%(n=1650)	12.6% (n=2107)	22.6%(n=3757)	1121
	Diastolic	3.2%(n=535)	2.4% (n=405)	5.6%(n=940)	694
Diabetes	Pre-Diabetes	2.3%(n=387)	3.2%(n=537)	5.5%(n=924)	
	Diabetic	3.9%(n=661)	5.1%(n=861)	9.1%(n=1522)	911
Body Mass Index	Overweight	7.8%(n=1312)	17.2% (n=2867)	25.1%(n=4179)	
	Obese	2.3%(n=397)	5.5%(n=914)	7.8% (n=1311)	1200
Anaemia	Mild	4.6%(n=770)	27.7%(n=4616)	32.3%(n=5386)	5386
	Moderate	0.3% (n=51)	3.1%(n=517)	3.4% (n=574)	574
	Severe	0.08%(n=14)	0.4%(n=83)	0.48%(n=97)	97
ECG	Referred	0.06%(n=11)	0.08% (n=14)	0.15%(n=25)	25
Oral Cancer screening	Follow up	5.19% 864	5.53% 920	10.7% 1784	1784
	Pre-Cancerous lesions	0.25% (n=42)	0.27% (n=46)	0.58% (n=98)	98
	Oral cancer	0	1	1	1

Follow-up with identified high-risk cases is an important aspect of this initiative and is necessary to complete the loop of this process. 80% of the respondents who were identified as high risk were followed-up with at least thrice. Follow up is done by the frontline healthcare workers through a call. The person is encouraged to adopt lifestyle modifications and seek treatment at their nearest healthcare facility.

IV. DISCUSSION

The results from NCD screening solution showed the desired outcomes the potential of the model to substitute the disease screening programs in a low resource setting. The emerging technologies in medical field and their complexity in adapting to a low-cost solution is addressed using a socio-technical system. The observations from the implementation of the NCD screening program helped us in understanding the community needs, user experiences and the continuing change to address the emerging needs.

4.1 People

The interaction between people and technology is important for any solution to reach its objectives. The following people from the program implementation were interacting with the technology

4.2 Frontline Health workers

The screening solution was developed to equip the frontline health workers with an innovative kit that would screen all the four major non communicable disease conditions. The kit interface was developed such that even a person with minimal technological understanding can use it efficiently. The NCD screening kit interacts

with the program personnel, end user and beneficiary to increase time efficiency, conditional clauses to reduce errors in data entry, new age medical devices that uses AI interpretations, decision making through interactive visualization, empowers the frontline health workers in NCD screening. Each NCD kit was operated by three front line healthcare workers in the camp to reach out to the maximum number of beneficiaries. A team each with three healthcare workers, a camp coordinator and two kits over a period of 6 months were able to reach out to 16335 beneficiaries.

1. Consent form collection
2. Weight measurement
3. Height measurement
4. Waist and Hip measurement
5. Blood pressure recording
6. Pulse oximeter recording
7. 6 lead ECG recording
8. Hemoglobin reading
9. Blood sugar reading
10. Oral cancer examination
11. Thermal print out of results
12. Explaining the results

4.3 Beneficiaries

The target population was from low socioeconomic background who are usually missed out in the screening drives conducted by the government health workers. The groups were reach out by organizing camps in the urban slums, villages, Industrial areas, in collaboration with the microfinance organizations and NGOs working with the marginalized. A total of 16,335 beneficiaries are screened for Non communicable diseases of whom 11300 were females and 5335 were males. The average age of the beneficiaries was 40.1 years and 90% of them have never been screened all the major NCDs.

4.4 Camp coordinator

Monitoring and evaluation were carried out through NCD screening app that synchronizes data to the dashboard where through data visualization the high-risk individuals were identified and reached. The coordinator also monitors the number camps being conducted and the beneficiaries reached each week.

4.5 Technology & Time efficiency

One of the major obstacles in NCD screening is the time and effort involved in screening everyone. If the waiting time is longer then it is difficult to reach more beneficiaries and the cost per screening also increases decreasing the traction to the program. To decrease the time per screening we have leveraged on technological and process innovation. Leveraging on technology we were able to get the HB results in 2seconds, Blood sugar results in 8 seconds, Blood pressure in 40 seconds, ECG in 45 seconds. Each frontline health worker with a single kit takes approximately 7.45minutes to screen one person which is ideal for house to house screening. Though this model could benefit the frontline health workers of LMIC it may not be acceptable in community screening due to increased waiting time as large number of people gather to get screened. Different process was tried and tested and was found out with additional 2 staff the screening time per individual can be drastically reduced to 3 minutes.

4.6 Interactive Visualization for decision making

The results were displayed on the tab in color coding as red, yellow and green indicating severe risk, moderate risk and no risk, respectively. This helps the frontline workers to identify the high-risk individual and refer them to the nearest health center. The results were then printed on to a 2-inch roll that contains the reference range, and the high-risk values are bolded. At the backend, the program personnel can print out the results for the area or location and the inbuilt programs gives out the results as mild, moderate and severe on five disease conditions.

V. CONCLUSION

NCDs are the major causes for mortality and morbidity across the world and in India. The healthcare services available for the public for early identification of NCDs in India remain unreachable to large sections of the community. The proposed NCD solution hopes to address the challenges in accessibility and affordability by reducing the time of screening and cost involved.

The portability of the kit enables the screening to be conducted at the convenience of the individual through multi stakeholder alignment.

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