A Model of Cost and Time-Effective Disease Screening for Non-Communicable Diseases in India

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Abstract: Background: India has the largest burden of the NCDs globally. Screening and identification of clusters with the common risk factors are crucial for early detection, prevention, and control at both individual and population levels. Objective: This study documents a model of cost and time-effective disease screening for NCDs. The model uses a combination of mobile health clinics-based point-of-care diagnostic technologies. The model, for its easy-to-use, cost and time effective operation, should be scalable as a tool for community-based disease screening and population level NCD surveillance. Method: The study documents the materials and processes of NCD screening camps conducted in Bangalore, India. A time and motion study analysis and cost analysis were undertaken to establish the time and cost effectiveness. Results & Discussion: The Study found out a baseline time and cost components for a camp based NCD screening strategy using the mHealth tools and mobile health facilities. This reinforces the potentials of integration of the NCD screening into the public primary health care centres for effective scaling up and achievement of surveillance as well as monitoring and evaluation of the NCD prevention and control programs in the country.

1 INTRODUCTION

This paper presents a model for population-based screening for non-communicable diseases (NCD) in India based on a combination of mobile health clinics-based point-of-care diagnostic technologies and mHealth applications. It describes the context of NCD in India, the technology used in screening camps, the data from the camps, a framework to conceptualize the application, and conclusion about generalizing the model.

1.1 Non-Communicable Disease Burden and Response in India

The demographic transition in the low- and middle-income countries has been accompanied by increasing health risks in the form of NCD burden (OMS, 2011; Shah & Mathur, 2010). Majority of the low and middle-income countries have devoted considerable attention to communicable diseases as against NCDs. This is increasing the burden on their health care systems and ultimately on the quality of life in these countries (Kroll et al., 2015). India has the largest burden of NCDs globally (Menon et al., 2014). The disease burden is expected to worsen due to the rapid urbanization, accompanying lifestyle changes, and inadequacy in health system preparedness (Prakash Upadhyay, 2012). The disease burden in the country also poses the need for scalable and affordable methods for NCD prevention and control that can be expanded into the remote and rural parts of the country. The National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke (NPCDCS) was

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launched by the government to combat the risk through strategies such as surveillance, early diagnosis, and universal availability of treatment at primary, secondary and tertiary levels of health facilities (Ministry of Health and Family Welfare, Government of India, 2017). Population-based screening as part of comprehensive primary health care has been recommended for the strategic management of the disease. However, in contexts such as India, it has been difficult to implement such measures in a sustainable way.

1.2 Prevention and Control of NCDs through Surveillance

NCDs have multiple causes, the combined effects from which lead to a disease rate in the population. Estimates from habit and risk factors are needed to plan public health interventions and clinical programmes (Kontis et al., 2014). It has been identified that interventions to prevent and treat NCDs at the earlier stages are cost-effective (Ministry of Health and Family Welfare, Government of India, 2017). Integrating the NCD screening and diagnosis at existing primary healthcare centres has been suggested (World Health Organization, 2010). However, operational issues persist in terms of implementing population-level screening, especially in resource-limited settings (Deepa et al., 2011). This requires scalable and cost-effective models of population-based screening of NCDs in various regions in the country with divergent ground-realities. Screening and identification of clusters with common risk factors are crucial for early detection, prevention, and control at both individual and population levels (Ahmed et al., 2009) to reduce morbidity and mortality. Innovative methods using cutting-edge technologies to enhance screening capabilities have been on the rise. They include non-laboratory-based diagnostics, point-of-care technologies, mobile health clinics. and mHealth applications in the pursuit of achieving access and scale-ups (Bertoncello et al., 2020; Gaziano et al., 2008; Malcolm et al., 2019; Pandya Ankur et al., 2014). Apart from their screening capabilities, the methods are considered effective vehicles for information and awareness-raising strategies as well (Bertoncello et al., 2020). However, challenges persist on the field in terms of their cost-effectiveness and broadening access to them. This demands scalable methods that consider issues of cost-effectiveness, access, and scalability (Subramanian et al., 2018) and can be institutionalized as part of the public health care systems.

1.3 Objective

This study documents a camp-based population screening model tested for NCD surveillance in India. The model is a combination of mobile health clinics-based point-of-care diagnostic technologies and mHealth applications. The model ensures cost effective NCD screening. For its easy-to-use, cost and time effective operation, the model should be scalable as a tool for community-based disease screening and population level NCD surveillance using community health resources. Integrating this into the public health care systems should provide individual and population level insights on NCD risk factors on a routine basis at primary care centres. In this respect, the study will set the baselines regarding the materials, tools, and human and financial resources incurred for the same. It will also compare them with the existing standards available and contribute to improving the existing NCD prevention and control strategies.

2 METHODS AND MATERIALS

The study will describe the method and materials utilized during the population-based NCD screening camps conducted in Bengaluru, India. Using the time and cost related data from the mobile health camps, it will undertake time and motion study and cost effectiveness analysis to understand and analyse the uniqueness of the model, explore the scope for future improvements, and provide learning for existing practices.

2.1 NCD Screening Camps

The NCD screening camps were conducted in the city of Bengaluru, Karnataka, India as part of the Harnessing Oncological Preventive and Early detection services (HOPE) program. The HOPE program, as a population-based opportunistic screening program for underserved populations, aspires to improve awareness of oral and breast cancer, initiating early detection through appropriate technologies, and creating a continuum of follow-up, further investigations, and curative services for relevant cases. The program recognises the need for lifestyle modification and behaviour change to manage NCDs. It therefore focuses on creating and spreading awareness about oral cancer, breast cancer, and other NCDs amongst the general population.
Taking into consideration the shortage of health care human resource in the country, all the devices and

software taken on are simple. The screening is conducted by a trained staff who do not necessarily have to be from a medical/paramedical background. The staff are trained on use of point-of-care devices, mHealth technologies, interpretation of results, and basic counselling of respondents.

The program aims to reach semi-urban and rural populations as well as low income groups who would not have access to routine screening and diagnosis for NCDs. This is achieved through a screening procedure that includes NCD screening (blood pressure, SPo2, blood sugar, body mass index, Haemoglobin, and vision testing), along with the one-on-one counselling at the end of the screening process, as well as scheduled periodic follow-up with identified high-risk cases. A mobile Mammography Bus is part of the screening camps conducted across urban and rural regions in the state of Karnataka, India (including Bengaluru). It makes use of software applications with integrated medical devices, available on offline basis to enable capture of clinical data, data management, remote monitoring, and evaluation of data. Using systematic documentation, training, and special referral protocols, dedicated follow up of cases is done by a separate team that helps track cases across locations. In the long run, it aims at training frontline healthcare workers from the public sector. Also, creating awareness of risk factors is emphasised in all the screening camps. Apart from screening camps, the awareness sessions are also conducted in schools and colleges. It has been conducted in various settings such as factories, educational institutions, and community living spaces.

The list of activities undertaken during the camps are as follows in their respective order: Registration/Consent form filling, height and weight measurement, MAC/Hip/Waist measurement, Pulse-Oximeter reading, six-lead ECG, Blood pressure, HB and blood sugar test, vision test, and explanation of results with reference scale to the beneficiary.

The data collected using the model are demographic, medical history, community risk assessment, physical and behavioural risk factors, habit history and physical measurements following the WHO STEP guidelines(*NCDs | STEPS Manual*, 2002.).

2.2 Materials and Resources

The device kit being used by the trained staff (Figure 1) includes the following devices:

- 6 lead ECG: Used to collect the 15 secs ECG record which is then interpreted using the Artificial Intelligence tools based on the Glasgow algorithm
- Digital BP Device: Used to collect Blood pressure reading. It operates on oscillometric method with options for manual reading as well
- Glucometer: Used for measuring blood glucose level, either random or fasting. A single drop of blood needs to be drawn from the individual by means of a small prick on their finger
- Haemoglobinometer: used to measure the hemoglobin level, also measured from a drop of blood
- Digital stadiometer: used to measure height
- Digital weighing scale: used to measure weight
- Tablet loaded with NCD screening software application: for data entry purposes and inference of results.

Figure 1: Device kit used for Screening.

All devices in the kit have been approved by standards control bodies. The methodology of operating the device and interpreting results is straightforward and undemanding. The output from the software application is colour-coded enabling the healthcare worker to easily make an inference.

The data collected through the application can be broadly classified into the following groups:

1. Socio-demographic details: for following up and monitoring the program
2. Past Medical History: to identify newly detected cases, understand management of existing cases

3. Community based risk assessment: risk profiling is conducted in line with the protocol adopted by the National Health Mission
4. Habit History: behavioural aspects and risk factors known to directly impact onset of NCDs
5. Vital Parameters: to understand the current health status of the beneficiary

More than sixty-five variables are collected. The number of variables is higher for women as breast and cervical cancer screening are also done.

The screening process involves history taking, risk assessment, performing tests and counselling based on the results. The data collected using a mobile application are stored in a local mobile database. When the internet is available this local database is pushed to the server database using application interfaces. The data is populated from the server database to the dashboard using the Angular and Java programming languages.

Taking into consideration the large number of data variables collected and tests performed, it is necessary to optimise the process workflow to ensure that quantity was increased without denting the quality. A time and motion study was undertaken for this purpose.

2.3 Time and Motion Analysis

The time and motion study intends to set a baseline that can be used for future application of the presented model on a larger scale. The analysis used data from the screening camps conducted in 3 NCD mobile camps conducted in Bengaluru, India. Data from the screening of a total of 70 individuals are considered. The data was recorded by observing the time taken for each designated activity individually. The activities are scheduled according to the order of data to be entered in the mobile application being used for documentation. The study analysed two person-device kits combinations. (i) 2 resource persons and 2 kits, as well as (ii) 3 resource persons and 2 kits. The process chart along with observed timings using the second combination has been illustrated in Figure 2. The differences in the outcomes are explained in the results of time and motion analysis.

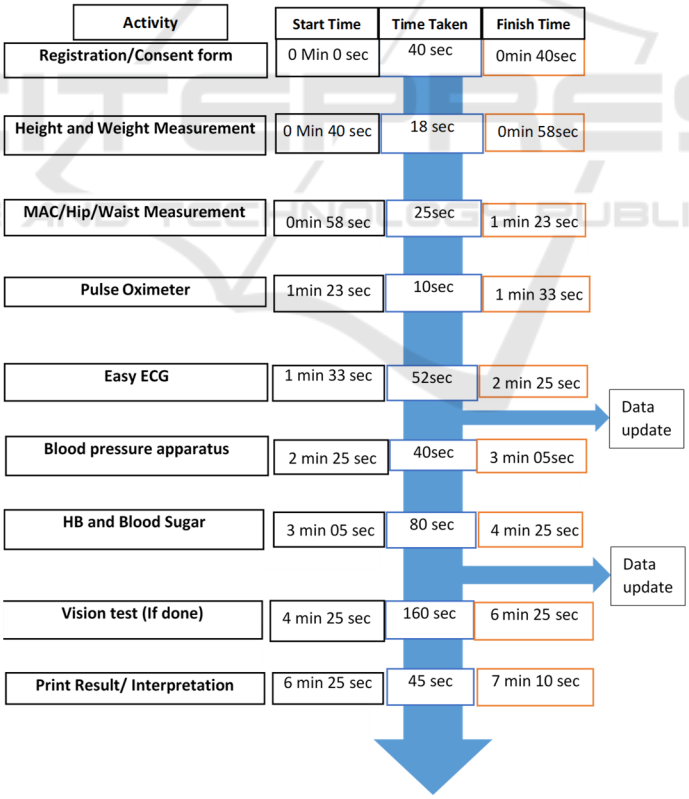

Figure 2: Time and Motion Study Results.

2.4 Cost Analysis

The overall cost incurred for the screening program was recorded. The average screening cost was derived using the average number of screening that could be done in a month, considering the time observed in the study. Costs incurred for human resources payments and other consumable resources have been factored for calculating total costs.

3 RESULTS

3.1 Time and Motion

The results of the time and motion study are illustrated in Table 1. It details the activity-wise duration for screening process, parallel activities if any, and the number of personnel involved at each step. The total duration of each screening activity was found to be 430 seconds. When the tolerance time of 45 seconds is added the total screening, time is 475 seconds i.e. 8 minutes approximately. This is including the vision screening, without which the duration taken was 5 minutes 56 seconds for one screening using one kit. 10 screenings can be done using one kit; hence two kits can do up to 20 screening in the specified time frame. The results were achieved when 3 personnel were involved in the screening. When compared with the combination of two kits and two personnel, the results also showed that optimal time utilization was achieved when 3 personnel and 2 kits were used for the screening. Thus, the latter combination is considered for further analysis.

3.2 Cost

The NCD screening model is a minimalistic, low resource model. The operational expenditure of the model comes down to the human resource cost of the team (Rs. 48000/Month and Rs.16/screening) and the consumables required for conducting the tests (Rs.34/screening) namely, cotton swabs, needles for pricking, blood glucose and haemoglobin testing strips to mention a few. This model relies on other stakeholders, such as the community partner or organising partner, to bear the cost of transport. Therefore, the latter costs have not been factored. The optimal performance of a team of 3 members would be to conduct 20 camps a month screening at least 150 people at each camp. The cost for screening per person would be Rs. 50 (0.68 USD). This includes follow up of high-risk cases at least 3 times.

Table 1: Results of Time and Motion Study Personnel-Wise.

Session	Sl. No	Activity	Duration	Parallel Activity	Personnel In Work
1	Step-1	Registration/Consent form	40sec		1
	Step-2	Height and Weight Measurement	18sec		
	Step-3	MAC/Hip/Waist Measurement	25sec		
		Total Time For 1st staff	1 min 23sec		
2	Step-4	Pulse Oximeter	10 secs		2
	Step-5	Easy ECG	52 secs	Details to be updated in Tablet (1-min)	
	Step-6	Blood pressure apparatus	40 secs		
		Total time for 2nd staff	1 min 42 sec		
3	Step-7	HB and Blood Sugar	1 min 20 sec (80 sec)	Details updated in Tablet (30sec)	3
	Step-8	Vision test (If done)	2 mins		
	Step-9	Print Results + Explanation with reference scale	45 secs		
		Total time for 3rd Staff	4 min		
	Total Duration		430 Seconds (7 Minutes 16 seconds)		

4 DISCUSSION

This study documents a camp-based population screening strategy for NCD risk factors. The cost, time, and human resource factors involved in the model were documented and analysed. These factors are critical for wide-scale operational feasibility of the disease screening and thus have implications in addressing the disease surveillance for NCDs in the country.

The study documents a baseline for the resource requirements for the population-level NCD screening for risk factor assessment. It identifies its uniqueness in terms of non-requirement of the medical professionals for screening. Trained community workers or volunteers can contribute to the human resource requirements in the model which throws open possibilities of operationalizing routine screening in resource constrained conditions. This is achieved through the utilization of a combination of point-of-care and mHealth technologies woven together into an efficient process.

While the study could not compare the cost with existing standards in the Indian context due to the non-availability of data (apart from Amarchand et al. 2015 which identified below 1 USD per-screening without collecting blood pressure and sugar levels), it provides a baseline for research and operationalization of the screening activities on similar lines. The study found out the costs for human resources and consumables are below 1 USD. International comparisons are consumer side payments which has been documented as 4 USD in Kenya (Subramanian et al., 2018) and as 3.95 USD per person identified when an all-inclusive NCD screening was integrated into existing HIV screening in South Africa (Golovaty et al., 2018).

The cost analysis in the study only considered the human resources and other consumable costs only since the other costs for the presented model were provided by the community. The study thus, was not able to account for the other costs, especially infrastructure and other fixed costs. However, the model presented collects a lot of important data including the blood pressure, blood glucose level and ECG etc. and should provide a solid baseline for wide-scale operationalization.

Also, the time taken for the disease diagnosis and screening has a significant impact on the behavioural trends of the patient population especially in the context of low- and middle-income countries such as India. Time taken for Out-Patient Department (OPD) and their impact on the health seeking behaviour has been studied. It was found out that the longer waiting time and affordability significantly impact the health seeking behaviour among the target population. Lower waiting times at OPDs for instance, results in higher satisfaction rate among patients (Aswar et al., 2014). The time motion study results provided show the very little time required for the screening.

Monitoring and evaluation of the NCD interventions are crucial for learning and improvement. Evolving sustainable systems for surveillance aligned to the national health programs is one of the way forward (Krishnan et al., 2011). In this context, integrated disease surveillance has become crucial in deciding and planning strategies for NCDs especially in the wake of Covid-19 (Mathur & Rangamani, 2020) which has exacerbated the vulnerabilities due to NCD risk factors (Gopalan & Misra, 2020). The need for implementation and operational research on the disease screening has become ever more critical.

Functions		Data		Setting		Instruments		Resources		Outcome	
Identification	[of]	Determinants	[information from]	Individual	[setting through]	Questionnaire	[using]	Tools/Devices	[for]	Efficient	[NCD Surveillance]
Collection		Socio-Economic		Household		Clinical Examination		mHealth		Affordable	
Curation		Income		Community		Biochemical Tests		Imaging Technology		Effective	
Analysis		Urban/Rural		Institutional				GIS		Accessible	
Interpretation		Demographic						Services			
Application		Age						EHR			
Feedback		Gender						SMS			
		Literacy						Social Media			
		Risk Factors						Models			
		Physical						Health Care Center			
		Behavioral						Mobile Health Clinics			
		Biochemical						Point of Care			
								Human Resources			
								Community Health Workers			
								Volunteers			

Figure 3: Ontological framework of the NCD screening model.

As such, the documented model along with its baseline figures regarding the operational details could be useful for the integration of the monitoring and evaluation of NCD programs with the primary, secondary, and tertiary health care centres especially in the rural areas. It has been found that integrating the NCD screening and awareness components into the existing primary health care system is the way forward for its cost-effectiveness (Amarchand et al., 2015). The WHO PEN recommends using the technology supported solutions for scaling up of disease screening for risk factors using person-oriented risk factor screening(World Health Organization, 2010).

Modelling future disease trends is a useful tool for policymakers so that they can allocate resources effectively and implement policies to prevent NCDs. Future research will allow real policy interventions to be tested; however, better surveillance data on NCDs and their risk factors are essential for research and policy (Webber et al., 2014). The screening process facilitates collection of data that can be deployed for modelling and risk prediction.

We frame the overall assessment of the model presented by the paper in the form of an ontological framework in Figure 3. It lists the dimensions and elements of the aspired NCD screening strategy. The assessed model undertakes functions of collection, interpretation, application, and feedback on a real-time basis and collects data pertaining to all elements in the Data dimension of the framework which is based on the WHO STEP Manual. In terms of Setting, while the model was tested in institutional settings it can be scaled up into other settings as well. It used all the instruments listed including questionnaires, clinical examination and biochemical tests using mHealth devices, Point-Of-Care Technologies. While the model has proved to be efficient and affordable in terms of time and cost, other aspects of the outcomes needs to be further researched.

While the lack of extensive comparative analysis and the resulting inability to provide uniform baselines are limitations, the study provides insights into the operational issues of NCD risk factor surveillance. It adds evidence regarding the scope for integrating screening into the existing public health system for routine and informed decision making.

5 CONCLUSIONS

This paper systematically documents the NCD screening process followed by a population-based screening program. It sets an operational baseline in terms of the cost and time for the camp-based population NCD screening. The process was analysed for their uniqueness in terms of time and cost effectiveness in the context of their scalability and applicability for large scale NCD surveillance in low- and middle-income countries. The analysis and discussion have been framed in the form of an ontology which illustrates the existing and future potentials of the surveillance models in the NCD scenario.

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