A digital health intervention model using community health workers: findings from primary health services in rural Bangladesh

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Research Article

Keywords: Digital health inclusion, Digital Health intervention model, Clinical Decision Support System (CDSS), Non-communicable diseases (NCD), Community health workers (CHWs), Primary healthcare, Health Equity, Universal health coverage, Sustainable development goals

Posted Date: November 19th, 2024

DOI: https://doi.org/10.21203/rs.3.rs-5391957/v1

Additional Declarations: No competing interests reported.

A digital health intervention model using community health workers: findings from primary health services in rural Bangladesh

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Abstract

Objective: This paper aims to understand people's health conditions after a digital health intervention model was implemented in a rural area of Bangladesh. We analyzed the health conditions of the served population 18 months after the operation.

Methods: The data presented in this paper are obtained from the model's pilot implementation in one area in Bangladesh. Community health workers provided monthly health services at doorsteps while collecting various sociodemographic, health, economic, and environmental data. We presented the findings from the collected data on user health. Sociodemographic and health measurement data were presented as proportions with 95% confidence intervals (CIs). Multivariate logistic regression was used to analyze the association between diseases and their respective risk factors. We compared the health vitals across three consecutive periods to determine improvements in health outcomes over time.

Results: The model served 32,581 people from 7,090 households during this operation. We found that 21.76% of the served population were overweight, 8.18% had prehypertension, 16.45% had high blood glucose, and 11% children were malnourished. From the analysis of risk factors, we found that people aged > 40 were associated with developing hypertension, diabetes, and cardiovascular diseases(CVD). CVD was associated with hypertension and stroke. Comparative analysis of different periods showed improved BMI, BP, and MUAC. Blood glucose measurements did not show significant improvement.

Conclusion: The implemented model provided regular health screenings, consultancy services, and digital referrals. The features included in the model are unique and designed according to the needs of the rural population. Findings from the operation identified demographics who were at high risk of developing NCDs. The comparative analysis found a positive impact on the health conditions of the rural people who took regular health measurements.

Keywords: Digital health inclusion, Digital Health intervention model, Clinical Decision Support System (CDSS), Non-communicable diseases (NCD), Community health workers (CHWs), Primary healthcare, Health Equity, Universal health coverage, Sustainable development goals

1 Introduction

Primary healthcare (PHC) is an integral part of the healthcare system that addresses a community's primary health problems. However, primary healthcare in rural areas of Bangladesh needs to catch up to healthcare facilities in urban regions. Some reasons for this situation are- the shortage of healthcare professionals in rural areas compared with those in urban areas[1], the health-seeking behaviour of rural people[2], and the unawareness of health conditions and outcomes. Rural people often practice self-care and self-medication for treatment. They seek health services from local pharmacists, religious healers, and "witches"[3, 4]. As people lack access to quality health care, these are the only sources of medical services they have. Besides, due to the absence of proper health education, they are often ignorant regarding the severity of chronic diseases. Consequently, these patients suffer from these diseases at an advanced stage.

The recent shift in disease burden from communicable diseases to noncommunicable diseases (NCDs) has raised concerns about the preparedness of health facilities for many low-and middle-income countries (LMICs), including Bangladesh [5]. A total of 73.4% of global deaths are due to NCDs and 77% of all NCDs deaths occur in LMICs [6, 7]. Currently, in Bangladesh, NCDs are responsible for approximately 67% of total deaths [8]. The current healthcare system in Bangladesh, especially in rural areas, is yet to be well equipped to address such a load of fatal diseases.

Digital health has become a new standard for the 21st century. Like many other developing countries, Bangladesh has adapted digital technologies to improve its health system management in the last decade by introducing national eHealth policies in 2011 [9]. Consequently, many organizations have launched digital health solutions. In 2014, 26 eHealth and mHealth services were reported to operate in Bangladesh, including government and private initiatives [10]. Recently, some digital healthcare service providers have excellently transformed the healthcare industry [11, 12]. These operators focus on telemedicine, online consultation services, sample collection from home, report and medicine delivery, etc.[13–15]. Even though these initiatives offer excellent health services to the people, rural people's access to these services has not been assessed[16]. Most specialized health services are only available in urban areas, so the importance of digitalizing health care in rural demographics is often neglected.

"CMED Health", a leader in healthcare services in Bangladesh, proposed and implemented a digital health intervention model of community health workers (CHWs) integrated with digital technologies to provide comprehensive, preventive, and primary healthcare services to the rural people of Bangladesh [17, 18]. The model was designed aligning with the latest ideas of digital health technologies. These concepts included- easy access to information, digital diagnostic devices, telemedicine services, data-centric service models, etc.[19]. Digital health interventions also provide cost-effective ways to promote healthy behavior [20]. In the 21st century, new IoT, big data, and data-driven decision-making systems trends have emerged in the era of smart healthcare [21]. Thus, data-driven decision-making for risk assessment was also incorporated into the model.

CMED partnered with Palli Karma-Shahayak Foundation (PKSF), an organization working for the development of rural Bangladesh [22], and launched this model in the Somvag Union (the smallest administrative unit of a rural area) in Bangladesh [23]. Faruque et al. conducted a feasibility study to assess the usability and efficacy of the model in preventing NCDs. They reported ease and increased speed in data collection by health workers while delivering services[24]. Similarly, recent research in Bangladesh also has recommended community-led approach to improve healthcare[25]. Under this project, people in this area were provided doorstep health services, vital health measurements, consultation, and digital referrals if required. The services were designed to focus on preventive care, particularly on prevention and management of NCDs.

In this paper, we analyzed the data from the operation of this project. We performed a descriptive analysis of the vital health measurements to understand the health conditions of the populations. We identified NCDs risk factors by applying a multivariate logistic regression. To measure the impact of the intervention model on improving health outcomes, we performed a comparative analysis of three consecutive periods during the 18 months of operation.

2 System Overview

The model used a bottom-up approach with patients flow from the household levels to the upper levels. Community health workers (CHWs) visited each household once a month and conducted primary health screening using the smart health kit (see supplementary material, figure 1) and "Enriched Sastho" mobile application developed by CMED. The smart health kit contained analog and smart measurement devices for measuring height, weight, temperature, oxygen saturation (SpO_2), blood pressure (BP), blood glucose, and electrocardiogram (ECG). After conducting the health screening, the health workers assessed health risks using an AI-based clinical decision support system (CDSS). Based on risk assessment, the patients were provided digital referrals to either medical assistants or GP doctors. Medical assistants provided limited interventions, which included prescribing over-the-counter (OTC) medication. GP doctors provided comprehensive treatment, including available diagnostic tests and medicines over telemedicine or in person. Upon requirement, the GP doctors also referred the patients to secondary and tertiary care facilities. Figure 1 illustrates the architecture of the implemented system in the Somvag union.

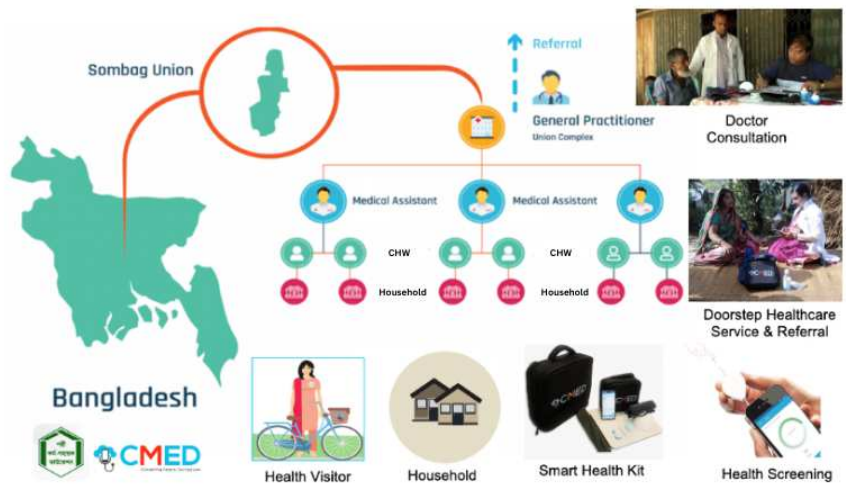

Fig. 1: CMED digital health interventions model and system architecture

The CHWs had at least eight years of schooling and underwent a two-week training program for the required skills. Medical Assistants were trained professionals who received Medical Assistant Training School (MATS) certification.

3 Methodology

3.1 Served Population

This paper presents data collected from July 1, 2018, to December 31, 2019. During this period, services were provided to 32,581 people from 7,090 households. Of these, 21,026 took the service at least once.

3.2 Data Collection Procedure

Community health workers (CHWs) visited the households and took several measurements of the people. The measurement data presented in this paper are- body mass index (BMI), blood pressure (BP), blood glucose, and mid-upper arm circumference (MUAC). BMI was calculated by dividing the weight in kg by the square of the height in meters. To measure height, each participant was requested to remove their footwear and headgear, stand straight with their feet together and heels on the floor, and look straight ahead with their eyes and ears at the same level. A standard height scale was used to measure height in centimeters (cm). Weight was measured in kilograms (kg) using a digital weighing scale. Each participant stood still on the scale wearing light clothing and barefoot. BP was measured using an IoT-enabled sphygmomanometer, which automatically entered the data into the Enriched Sastho app. CHWs used a single lancet to draw blood from patients' fingertips and use it in a smart IoT-enabled glucometer to measure blood glucose levels. MUAC was measured for children under the age of seven, using a standard measuring tape, with the arm hanging straight down at the midpoint between the olecranon process and acromion. The people were also asked if they had any prior history of hypertension, diabetes, cardiovascular disease, and stroke. After all the tests, the data were stored in "Enriched Sastho" mobile application.

3.3 Data Analysis

The collected data through the "Enriched Sastho" app were kept in Amazon Web Service (AWS). We collected the data as a dump file from AWS and stored them in MySQL server. After that, MySQL (a structured query language) was applied to extract our data. Then, the data were processed and analyzed using Python in a Google Colaboratory environment[26]. We used conditional logic to clean the data for any invalid observations, inconsistencies, and outliers. For a better understanding of the behavior trends of the population, the collected data was divided into three periods based on operation time: the first period from July 1, 2018 to December 31, 2018; the second period from January 1 to June 30, 2019; and the third period from July 1 to December 31, 2019. Since the assessments were conducted monthly, each participant had multiple instances of health measurements. For analysis, we only considered the latest instances of each period. We used descriptive statistics to understand the characteristics of the study population. The sociodemographic data and the measurement results were segregated by sex and age. Categorical frequencies and proportions were calculated with 95% confidence intervals (CIs). To find the association of diseases and respective predictors, we performed multivariate logistic regression and calculated the odds ratio (OR) along with the 95% CIs. We compared the measurement results between periods one, two, and three to evaluate the outcomes of the intervention. Numerical variables were tested for normality with the D'Agostino and Pearson's test. The normally distributed variables were subsequently analyzed using the Student's t-test. Wilcoxon signed-rank test was applied to compare non-normal distributions. We tested the difference in BMI between males and females during the same period using

Welch's t-test. Two proportion z test was performed to compare the percentage of a categorical variable across different periods.

4 Results

4.1 Sociodemographic characteristics of the study population

Table 1 shows the served population (32,581 people) segregated by age group. The number of male and female participants was almost equal. Ages 18-35 were the most prevalent age group, accounting for 32.25% of the total served population.

Table 1: Age-wise distribution of the served population

	Male (%)	**95% CI(Male)**	**Female (%)**	**95% CI(Female)**	**Total (%)**	**95% CI (Total)**
Total population	16508(50.67)	50.13-51.21	16073(49.33)	48.79-49.87	32581	
Age group						
0-6	2135(12.93)	12.42-13.44	1996(12.42)	11.91-12.93	4131(12.68)	12.32-13.04
7-17	3260(19.75)	19.14-20.36	2931(18.24)	17.64-18.84	6191(19.00)	18.57-19.43
18-25	1974(11.96)	11.46-12.46	2591(16.12)	15.55-16.69	4565(14.01)	13.63-14.39
26-35	2906(17.6)	17.02-18.18	3037(18.90)	18.29-19.51	5943(18.24)	17.87-18.66
36-45	2417(14.64)	14.1-15.18	2108(13.12)	12.60-13.64	4525(13.89)	13.51-14.27
45-55	1709(10.35)	9.89-10.81	1446(9.00)	8.56-9.44	3155(9.68)	9.36-10.0
56-65	1193(7.23)	6.83-7.63	1187(7.39)	6.99-7.79	2380(7.3)	7.02-7.58
66-75	660(4.00)	3.70-4.30	530(3.30)	3.02-3.58	1190(3.65)	3.45-3.85
>=75	254(1.54)	1.35-1.73	247(1.54)	1.35-1.73	501(1.54)	1.41-1.67
Total	16508		16073		32581	

4.2 Health Measurement Results

Health measurements of BMI, BP, blood glucose, and MUAC are shown in Table 2, segregated by sex. Excluding MUAC, all measurements in this table are for people aged 18 years or older.

MUAC was measured for only children under the age of seven years. Total measurements of different health vitals were BMI 14670, BP 15549, blood glucose 1775, and MUAC 1009. 68.02% had normal BMI, but 21.76% were overweight. Among the

Table 2: Summary of Health Metrics for Participants

Category	Male	95% CI (Male)	Female	95% CI (Female)	Total	95% CI(Total)
BMI						
(age $\leq$ 18**)**	8474 (40.3)	39.64 - 40.96	12552 (59.4)	59.04 - 60.36	21026	
Underweight	294 (5.82)	5.17 - 6.47	493 (5.13)	4.69 - 5.57	787 (5.36)	5.00 - 5.72
Normal	3752 (74.25)	73.04 - 75.46	6225 (64.75)	63.80 - 65.70	9979 (67.27)	67.02 - 68.77
Overweight	869 (17.20)	16.16 - 18.24	2323 (24.13)	23.30 - 25.02	3192 (21.09)	21.76 - 22.43
Obesity	114 (2.26)	1.85 - 2.67	482 (5.01)	4.57 - 5.45	596 (4.06)	3.74 - 4.38
Highly Obese	19 (0.38)	0.21 - 0.55	68 (0.71)	0.54 - 0.88	87 (0.59)	0.47 - 0.71
Morbid Obesity	5 (0.10)	0.01 - 0.19	24 (0.25)	0.15 - 0.35	29 (0.20)	0.13 - 0.27
BP						
(age $\geq$ 18**)**	5677		9872		15549	
Low	208 (3.66)	3.17 - 4.15	604 (6.12)	5.65 - 6.59	812 (5.22)	4.87 - 5.57
Normal	4453 (78.44)	77.37 - 79.51	7705 (78.05)	77.23 - 78.87	12158 (78.54)	77.54 - 78.84
Mild High	373 (6.57)	5.93 - 7.21	637 (6.45)	5.97 - 6.93	1010 (6.50)	6.11 - 6.89
Moderate High	89 (1.57)	1.25 - 1.89	154 (1.56)	1.32 - 1.80	243 (1.56)	1.37 - 1.75
Severe High	23 (0.41)	0.24 - 0.58	31 (0.31)	0.20 - 0.42	54 (0.35)	0.26 - 0.44
Prehypertension	531 (9.35)	8.59 - 10.11	741 (7.51)	6.99 - 8.03	1272 (8.18)	7.75 - 8.61
Blood glucose						
(age $\geq$ 18**)**	649		1126		1775	
Low (Hypoglycaemia)	8 (1.23)	0.38 - 2.08	36 (3.20)	2.17 - 4.23	44 (2.48)	1.76 - 3.20
Normal	447 (68.88)	65.32 - 72.44	807 (71.67)	69.04 - 74.30	1254 (70.65)	68.53 - 72.77
High	109 (16.80)	13.92 - 19.68	183 (16.25)	14.10 - 18.40	292 (16.45)	14.73 - 18.17
High (Borderline)	40 (6.16)	4.31 - 8.01	50 (4.44)	3.24 - 5.64	90 (5.07)	4.05 - 6.09
Pre-Diabetic	13 (2.00)	0.92 - 3.08	14 (1.24)	0.59 - 1.89	27 (1.52)	0.95 - 2.09
Diabetic (need confirmation)	32 (4.93)	3.26 - 6.60	36 (3.20)	2.17 - 4.23	68 (3.83)	2.94 - 4.72
MUAC						
(age $<$ 7**)**	512		497		1009	
Nourished	456 (89.06)	86.36 - 91.76	426 (85.72)	83.08 - 89.16	884 (87.61)	85.58 - 89.64
Malnutrition	52 (10.16)	7.54 - 12.78	59 (11.87)	9.03 - 14.71	111 (11.00)	9.07 - 12.93
Severe Malnutrition	4 (0.78)	0.02 - 1.54	10 (2.01)	0.78 - 3.24	14 (1.39)	0.67 - 2.11

women, 24.16% were overweight. 78.19% of people had normal blood pressure. 70.65% had normal blood glucose, and 16.45% had high blood glucose. 87.61% of children were nourished, and 11% were malnourished. The cut-off values of the categories are provided in the supplementary material.

4.3 Analysis of risk factors

We performed a multivariate logistic regression analysis of NCDs (hypertension, diabetes, CVD, and stroke) and their risk factors. Sex, age over 40, and obesity were selected as the risk factors. We also analyzed the associations of hypertension and diabetes with other diseases. Among the total served population, hypertension patients were 2384, diabetic 940, CVD 95, and stroke patients were 84. The results in Table 3 show association of risk factors and diseases in the form of odds ratios. Age ≥40 years of age was associated with hypertension (OR: 13.56; CI 95%: 12.06-15.24) and diabetes (OR: 3.96; CI 95%: 3.35-4.69). CVD was strongly associated with hypertension (OR: 12.50 CI 95%: 7.45-20.73). Stroke and CVD were associated with each other (OR: 8.12 CI 95%: 3.76-17.54). Hypertension and diabetes were also associated with each other (OR: 7.16 CI 95%: 6.13-8.36).

Table 3: Analysis of risk factors

Disease	Factor	B	Odds Ratio	P-value	95% CI for OR	
					Lower bound	Upper bound
Hypertension	**Sex**					
	Female	0.98	2.67	<0.01	2.42	2.95
	Male (*Ref.*)					
	Age					
	≥40	2.61	13.56	<0.01	12.06	15.24
	<40 (*Ref.*)					
	Diabetes					
	Diabetic	2.00	7.35	<0.01	6.30	8.59
	Non-Diabetic (*Ref.*)					
	Obesity					
	Obese	0.92	2.51	<0.01	2.18	2.88
	Not Obese (*Ref.*)					
Diabetes	**Sex**					
	Female	0.02	1.02	0.74	0.89	1.18
	Male (*Ref.*)					
	Age					
	≥40	1.38	3.96	<0.01	3.35	4.69
	<40 (*Ref.*)					
	Hypertension					
	Hypertensive	1.97	7.16	<0.01	6.13	8.36
	Non-Hypertensive (*Ref.*)					
Cardiovascular Disease	**Sex**					
	Female	0.57	1.77	<0.05	1.16	2.71
	Male (*Ref.*)					
	Age					
	≥40	1.48	4.41	<0.01	2.35	8.29
	<40 (*Ref.*)					
	Hypertension					
	Hypertensive	2.53	12.50	<0.01	7.54	20.73
	Non-Hypertensive (*Ref.*)					
	Diabetes					
	Diabetic	0.66	1.94	<0.05	1.16	3.24
	Non-Diabetic (*Ref.*)					
Stroke	**Sex**					
	Female	0.24	1.28	0.29	0.82	2.00
	Male (*Ref.*)					
	Age					
	≥40	1.77	5.90	<0.01	3.10	11.21
	<40 (*Ref.*)					
	Hypertension					
	Hypertensive	1.76	5.82	<0.01	3.49	9.72
	Non-Hypertensive (*Ref.*)					
	Diabetes					
	Diabetic	0.50	1.64	0.11	0.90	3.01
	Non-Diabetic (*Ref.*)					

Disease	Factor	B	Odds Ratio	P-value	95% CI for OR	
					Lower bound	Upper bound
	Obesity					
	Obese	-0.59	0.55	0.17	0.23	1.30
	Not obese (*Ref.*)					
	CVD					
	CVD	2.09	8.12	<0.01	3.76	17.54
	No CVD (*Ref.*)					

4.4 Comparison of BMI measurement

In period one, two, three, 15144, 12309, and 9426 people took BMI measurement services respectively. This included people both over and under the age of 18. We presented the percentage of people with different BMI levels during three different periods in Figure 2. It shows that the proportion of underweight people had decreased, and normal BMI increased over time. Two-proportion z-tests showed an increase in normal BMI percentage and decrease in underweight percentage, which were statistically significant. Cutoff values are given in supplementary material(Table 1).

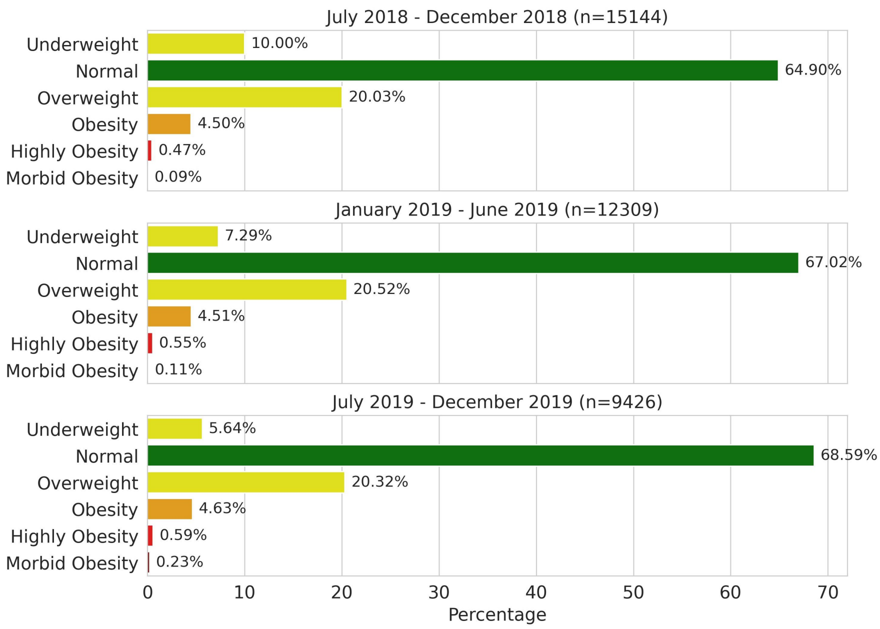

Fig. 2: BMI measurement results across three periods

4.5 Comparison of blood pressure measurement results

Figure 3 shows the percentages of people with different blood pressure levels in three periods. 14288, 11134, and 8593 people took blood pressure measurement services in periods one, two, and three respectively. It was observed that the proportion of people with normal blood pressure had increased over time. In addition, the proportion of people with prehypertension and mild high blood pressure also decreased. Wilcoxon signed-rank test revealed significant increase in diastolic BP (p-value <0.001) and a substantial decrease in systolic BP (p-value <0.006) between periods one and three. The two-proportion z-test revealed that the proportion of people with normal BP significantly increased over time and that the proportion of prehypertensive patients decreased. Cutoff values are given in supplementary material(Table 2,3)

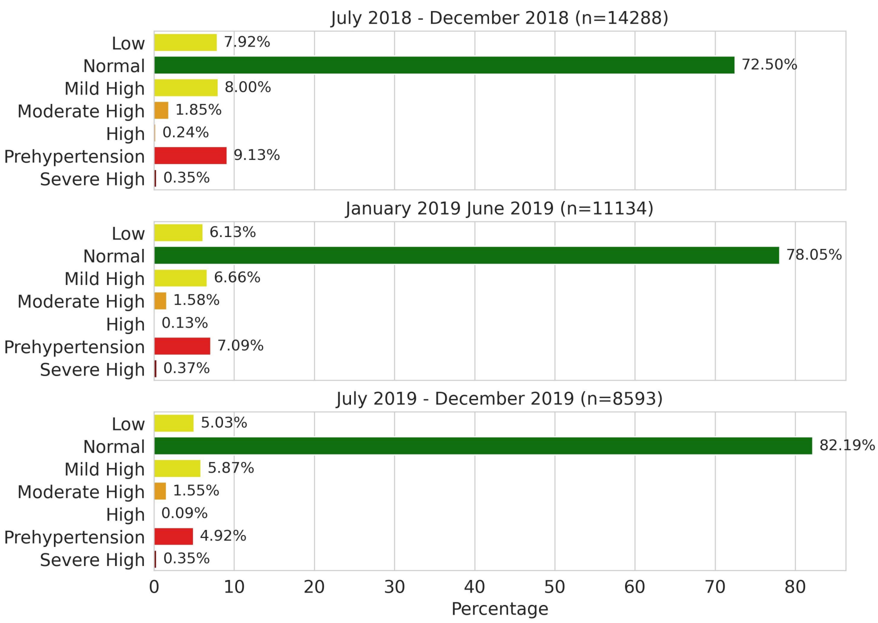

Fig. 3: Blood pressure measurement results across three periods

4.6 Comparison of blood glucose measurement results

Figure 4 shows the proportional distribution of blood glucose measurement results over three periods. The number of people whose blood glucose levels were measured in periods one, two, and three was 1442, 435, and 220 people, respectively. We observed an increase in the percentage of people with high blood glucose and a drop in the rate of people with normal blood glucose levels. Cutoff values are given in supplementary material(Table 4,5)

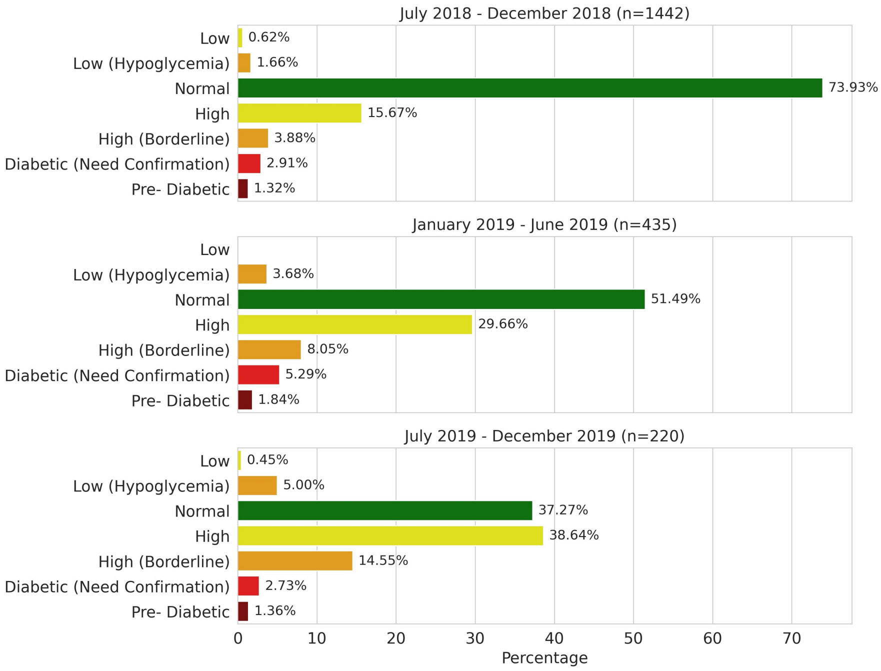

Fig. 4: Blood glucose measurement results across three periods

To investigate why, we identified the people who measured blood glucose and categorized them into diabetic and non-diabetic. We found that in period one, most people who measured blood glucose did not know whether they had diabetes. So, when they found they had normal blood glucose levels, most of them thought it unnecessary to keep taking the blood glucose measurement service. In the following periods, the majority of the people who took this service had confirmed diabetes. And since they had diabetes, they had uncontrolled blood glucose levels, which was reflected in figure 4 where the percentage of high blood glucose patients increased in period two and three. Two proportion z tests showed that the percentage of normal blood glucose decreased, and the percentage of high blood pressure increased over time

4.7 Comparison of MUAC measurement results

Periods one, two, and three had MUAC measurements of 689, 383, and 410 children (aged less than seven), respectively. Over time, the proportion of nourished children increased, whereas the proportion of malnutrition and severe malnutrition decreased (Figure 5). This trend indicates the increase in general awareness of children's nutritional status in the family and the positive outcome of the intervention. Cutoff values are given in supplementary material(Table 6)

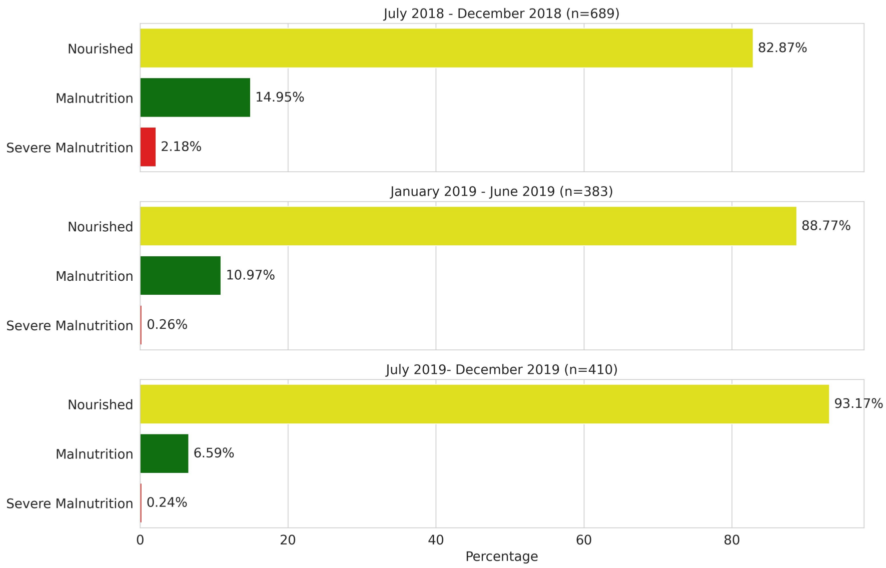

Fig. 5: MUAC measurement results across three periods

Two proportion z tests showed that the percentage of nourished children increased while the percentage of malnourished children decreased significantly.

5 Discussion

The CMED digital health intervention model provided health services to 32,581 people in 18 months of operation. We provided descriptive findings of the served population and the vital health measurements. From the self-reported data of hypertension, diabetes, CVD, and stroke, we calculated the association of different risk predictors of NCDs, such as sex, age over 40, and obesity. We also calculated the association among the NCDs, as they are related to each other. Finally, we conducted a comparative analysis of the vital health measurements to evaluate the model's performance.

The descriptive analysis of the served population revealed that almost 64% of the served population were under the age of 35. That means a large proportion of people were still in their reproductive age, indicating an expansive population progression. This large population would require access to quality healthcare in the future.

The results of the measurement analysis from Table 2 showed that the majority of the participants over 18 years who took these services were women (59.70%). This skewness of the data can be explained by the time the health measurements were conducted. Since the services were provided during the day, mostly women were at home while men were at work. From BMI analysis, we found 21.76% overweight and 4.06% obese patients. This is similar to findings from a national study on the prevalence of overweight and obesity prevalence, which are reported to be 18.90% and 4.60% respectively [27]. The national prevalence of hypertension rose from 25.70% to 39.40% between 2011 to 2017 [28]. Thus, it was essential to monitor blood pressure regularly and take preventive action to prevent hypertension. Findings from blood pressure measurements show that 9.13% people had prehypertension and 8% had mild high blood pressure initially. They account for more than 17% people at risk of developing hypertension. At the end of the program period, we found a significant reduction in these percentages, indicating that regular blood pressure monitoring resulted in a decrease in their progression rate toward hypertension. For blood glucose measurements, it has to be noted that our system could not afford blood glucose tests free of cost. Therefore, we charged a small fee for conducting the test, and we noticed a reluctance among the patients to perform it. This suggests the general tendency of people toward paid medical tests. Among 1775 patients who took the test, 16.45% had high blood glucose, similar to the national finding of 7.8% pre-diabetes and 10.10% diabetes patients [29]. However, regular screening helps to identify people at risk and these people were provided medical consultation services and referrals to diagnostic centers for confirmatory tests.

We calculated odds ratios (ORs) using a multivariate logistic regression model to find the risk factors of different NCDs. Sex, older age, and obesity were considered for analysis as they were reported to be the risk factors associated with NCDs in Bangladesh [30]. Our study also showed similar results. Hypertension and diabetes were found to have a strong association with age over 40 years. Diabetes and hypertension were associated with each other. Hypertension and CVD were highly correlated with each other, and stroke was associated with CVD. These diseases significantly reduce the quality of life for patients. In 2017, Ischaemic heart disease, which is a form of CVD, ranked 1st and stroke ranked 3rd in terms of the number of years of life lost (YLL)[6]. Thus, people with these risk factors should be provided special care and consultation.

We visualized the impact of the services on improving health outcomes. To assess the intervention's result, we compared the percentages of different health vitals during different periods. We divided the data obtained from 18 months of services into three periods, six months per period. Then, we took the latest measurement instances from each period and compared the percentage of different vital health results. Our analysis shows our model positively impacted BMI, BP, and MUAC measurements. BMI measurements showed that the proportion of normal BMI levels increased over time while the proportion of underweight people decreased, suggesting that it had a positive impact on people's overall health. Blood pressure measurements showed that the proportion of prehypertension decreased over time, and normal BP increased significantly. The people who were found to be in the prehypertension stage were given consultation and required medication. This helped the population prevent the progression toward hypertension within the served population. Blood glucose measurements did not impact health outcomes as intended. As stated before, most people did not want to perform the paid blood glucose test for diabetes, and those who opted to test initially were uninterested in continuing with follow-up assessments. The contrast of health-seeking behaviour of diabetic and non-diabetic people affected this result. Most diabetic patients continued to take the services, but most non-diabetic people did not in the later periods. Since diabetic patients had uncontrolled blood glucose levels, the high blood glucose levels seemed to have increased, and normal blood glucose decreased in the later periods. MUAC measurements were only taken for children aged less than seven. Data showed that the percentage of nourished children gradually increased while the rate of malnourished children gradually decreased. The reason was that when the family found their children were malnourished, they started giving more attention to their children's nourishment.

To the best of our knowledge, the CMED digital health intervention model is a unique approach to provide easy access to healthcare in rural regions. Our model offers preventive and primary healthcare, combining unique features - monthly health screening using community health workers, AI-based risk assessments, digital referrals, and preventive health counseling in rural regions. Improvement of health outcomes shows the model's promising ability to address healthcare challenges in LMICs rural areas by providing accessible and effective primary healthcare services.

5.1 Challenges and limitations

The system has several limitations as well as operating challenges. The imbalance ratio of men and women can be overcome by multiple visits at different hours. Self-reported diseases, such as diabetes, hypertension, stroke, and CVD, may be subject to recall bias and should be interpreted with caution. One challenge of the system is that people were impassive about their diabetes checkups because it requires tests. Thus, the intervention did not perform well in terms of blood glucose measurements. Many people did not follow up on referrals. A lower retention rate is a big challenge in providing long-term services. The referral rate to secondary or tertiary facilities could not be retrieved because of server issues, which is a limitation of this paper. The findings contain data from only one union and thus do not represent the national population. In addition, the operation was limited to rural areas, and some of the services and collected data were designed to address the needs and attributes of that particular demographic. Therefore, the findings should be interpreted as consideration of the implemented area.

5.2 Future Work

Number of additional features will be added to enhance the "Enriched Sastho" app for more user engagement and better usability. We plan to expand our current services, including early risk prediction for diseases like health attacks. It is also for empowering users and providing information through Bangla medical-GPT for writing and extracting information and making it available, as well as a symptom checker for anytime risk assessment and referrals. To ensure the accountability of the providers, we plan to integrate face recognition of the user account opening to ensure we create accountable service delivery and capture the user's satisfaction. This will allow us to show better transparency and responsibility. Sociodemographic data will be used to design AI-based personalized health insurance for the people. This will help people who cannot afford quality medical services and ensure health equity. It will also allow the government to aid certain families in need and move one step forward to achieving universal health coverage (UHC) and Sustainable development goals (SDGs).

6 Conclusion

A modern healthcare system relies on the effectiveness of the primary healthcare infrastructures. However, due to lack of access, health awareness, and an ineffective referral system, the rural people in Bangladesh do not receive proper primary healthcare. We proposed and implemented a digital health intervention model to address the needs of the people in rural Bangladesh. In this paper, we presented the findings of this model found in one union in Bangladesh. 32,581 people were served, and 21,026 underwent vital health measurements at least once. From the health data, we analyzed the association of risk predictors of diseases. People over 40 years old were at high risk of all the diseases. Hypertension was associated with CVD and stroke, suggesting that people with hypertension should be careful about their health and take regular health check-ups. Comparing health outcomes across three periods, each corresponding to six months of health services, evidence supports that regular health check-ups positively impact population health. The percentages of high-risk patients gradually decreased over the periods who took health checkups regularly. Nevertheless, blood glucose measurement findings verified the common tendency of rural people to avoid paying for medical tests. Although we only conducted this service as a pilot program in one area, the model can clearly improve health outcomes in rural regions on a large scale. CMED Health is trying to integrate the model with existing healthcare infrastructure so that every rural person can have easy, affordable access to quality healthcare.

Ethics approval and consent to participate

Data were collected after consent was obtained from the participants. The ethical review board of United International University (UIU) (ref no.IREB/2023/008) of the United International University (UIU), Dhaka, Bangladesh, provided ethical approval to conduct the study.

Abbreviation

CVD : Cardiovascular Disease; CI : Confidence Interval; CDSS : Clinical Decision Support System; NCD : Non-communicable disease; BMI : Body mass index; BP : Blood pressure; MUAC : Mid upper arm circumference; LMIC : Low middle income country; PKSF : Palli Karma Shahayak Foundation; SpO_2 : Oxygen saturation; ECG : Electrocardiogram; OTC : Over the counter; GP : General practitioner; CHW : Community health worker; YLL : Years of life lost; OR : Odds ratio; UHC : Universal Health Coverage; SDG : Sustainable development goals; GPS: Global Positioning System

Acknowledgment

The authors are grateful to the Enhancing Resources and Increasing Capacities of Poor Households Towards Elimination of their Poverty (ENRICH) program of PKSF; PKSF management; Partner Organization SOJAG; and United International University, Bangladesh for their support and cooperation in successfully implementing the program.

Funding

The project was funded by Institute of Advaned Research (IAR), United International University under project code UIU-IAR-02-2023-SE-32.

Data availability

The datasets are available from the corresponding author upon reasonable request.

Authors contribution

MZ: Conceptualization, Methodology, Writing- Review; RAR: Data analysis, Writing: Original draft and editing; RAB: Data analysis, Writing - Review and Editing; CAG: Investigation, Methodology, Writing- Review; MMR: Conceptualization, Investigation, Methodology; SMSI: Investigation, Writing - Review and Editing, Supervision; FS: Investigation, Methodology; KAM: Conceptualization, Investigation, Methodology, Formal Analysis, Writing- Original draft, review and editing, Supervision

Declaration of interests

All the authors declare no conflict of interest.

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