Jose *et al. BMC Primary Care* (2024) 25:380
https://doi.org/10.1186/s12875-024-02631-x

BMC Primary Care

RESEARCH

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Redesigning telemedicine: preliminary findings from an innovative assisted telemedicine healthcare model

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Abstract

Background Telemedicine holds immense potential to revolutionise healthcare delivery, particularly in resource-limited settings and for patients with chronic diseases. Despite proven benefits and policy reforms, the use of telemedicine remains low due to several patient, technology, and system-level barriers. Assisted telemedicine employs trained health professionals to connect patients with physicians, which can improve access and scope of telemedicine. The study aims to describe the design, service utilisation and chronic disease outcomes following the implementation of an assisted telemedicine initiative.

Methods This is an observational implementation study. Barriers and potential solutions to the implementation of telemedicine were identified through interviews with key stakeholders. The assisted telemedicine solution using an interoperable platform integrating electronic health records, point-of-care diagnostics, and electronic clinical decision support systems was designed and piloted at three telemedicine clinics in Tamil Nadu, India. Nurses were trained in platform use and facilitation of tele-consultations. Health records of all patients from March 2021 to June 2023 were included in the analysis. Data were analysed to assess the utilisation of clinic services and improvements in health outcomes in patients with diabetes mellitus and hypertension.

Results Over 2.4 years, 11,388 patients with a mean age of 45 (± 20) years and median age of 48 years, predominantly female (59.3%), accessed the clinics. The team completed 15,437 lab investigations and 26,998 consultations. Among 5542 (48.6%) patients that reported chronic conditions, diabetes mellitus (61%) and hypertension (45%) were the most frequent. In patients with diabetes mellitus and hypertension, 43% and 75.3% were newly diagnosed, respectively. Diabetes mellitus and hypertension patients had significant reductions in fasting blood sugar (-33.0 mg/dL (95% CI (-42.4, -23.7, $P<0.001$)), and systolic (-9.6 mmHg (95% CI (-12.1, -7.0), $P<0.0001$)) and diastolic blood pressure (-5.5 mmHg (95% CI (-7.0, -4.08), $P<0.0001$)) at nine months from first visit, respectively.

Conclusions The 'Digisahayam' model demonstrated feasibility in enhancing healthcare accessibility and quality by bridging healthcare gaps, diagnosing chronic conditions, and improving patient outcomes. The model presents

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a scalable and sustainable approach to revolutionising patient care and achieving digital health equity, with the potential for adaptation in similar settings worldwide.

Keywords Digital health, Digital equity, Telemedicine, Health technology, Healthcare access, Guideline adherence

Background

In healthcare, digital technologies have the ability to transform aspects of patient care, guide researchers, and refine administrative processes within providers, payers, and pharmaceutical organisations [1]. Telemedicine is one of its earliest applications and has tremendous potential to improve access to care, lower direct and indirect healthcare costs, lead to better use of limited human and infrastructure resources, and reduce the impact of healthcare on climate change [2, 3]. Today, telemedicine is a vital component of India's healthcare plan, trying to solve challenges in a vast and diverse nation [4, 5]. Given the robust Information Technology infrastructure and widespread use of smartphones, telemedicine is an excellent medium for achieving universal health coverage [6, 7]. However, despite proven benefits, policy reforms, and the overwhelming need posed by the COVID-19 pandemic, the penetration and acceptance of telemedicine in India are far below its true potential [8].

Specifically, telemedicine is beneficial for the prevention and management of chronic conditions such as diabetes mellitus, hypertension, and other cardiovascular diseases [9] which are major contributors to the country's morbidity and mortality. These patients often require regular follow-ups, titration of medicines, and monitoring of adherence to healthy lifestyle practices and pharmacological treatment. The role of telemedicine in revolutionising care for chronic conditions was further highlighted by the COVID-19 pandemic [10].

The Telemedicine Pilot Project 2001, followed by the National Rural Telemedicine Network and the National Telemedicine Task Force in 2005, paved the path for telemedicine in the country [4]. During the COVID-19 pandemic, the Medical Council of India released the 'Telemedicine practice guidelines'—a practical framework of telemedicine to restore interrupted health services and ensure adequate access to quality care via telemedicine [11]. Today, India boasts several telemedicine providers, both in the public and the private sector. "E-Sanjeevani", the National Telemedicine Service of India, is the most extensively documented telemedicine implementation for primary healthcare globally and serves over 114 million patients [12].

However, most telemedicine applications in India today are primarily patient-facing, making literacy, digital literacy and ownership of a smartphone with an internet connection a basic requisite for its use. Several barriers to quality telemedicine care at patient-level (low digital literacy among the aging population, poor reliability on technology, privacy and confidentiality concerns, lack of readily available technical support, diverse languages), provider-level (lack of access to good quality clinical history, relevant demographic and laboratory data, time constraints, poor integration of digital technologies with existing healthcare system), and system-level (ill-trained staff, the time and resources required to develop technological skills for setting and use of equipment, protection of healthcare information) limit the widespread use of telemedicine in Low-and-Middle Income Countries (LMICs) such as India [8, 13, 14]. Assisted telemedicine, in which a health worker facilitates patient-doctor interactions, can bridge this digital health divide by making it more accessible to those who may struggle with technology [15, 16].

In an effort to mitigate these challenges, 'Digisahayam' ("Digi" for "Digital" and "sahayam" meaning "help" in several South Indian languages)—an assisted telemedicine solution, was designed and implemented by the Centre for Chronic Disease Control and the Public Health Foundation of India during the COVID-19 pandemic as part of a corporate social responsibility grant. The objective of the program was to improve healthcare access for individuals living in urban and rural settings of India, and health outcomes for patients with chronic conditions. We aim to describe the design and service utilisation of this assisted telemedicine project implemented in urban and rural areas of Tamil Nadu state in South India, and its impact on health outcomes among a sub-group of patients living with hypertension and diabetes mellitus.

Materials and methods

Intervention design

The design and development of the programme were carried out in phases. The formative phase included informal interviews with various stakeholders, including patients, physicians, and policy makers, to identify barriers to access to and quality of telemedicine care. This was followed by the development phase in which a telemedicine platform and training modules for health workers were created to help address the barriers identified. The deployment phase included identifying and training health workers, testing the technology platform, establishing telemedicine clinics, dry running the clinic workflow, refining standard operating procedures, monitoring, quality assurance and data analysis.

The 'Digisahayam' telemedicine technology platform was designed to be inter-operable and integrates task-shifting enabling mechanisms, electronic health records

(EHR), point-of-care diagnostics, electronic clinical decision support systems (eCDSS) [17], and state-of-the-art health technologies [18, 19]. Technologies with Application Programming Interfaces (APIs), such as a digital stethoscope for remote auscultation and a physician-controlled camera (Table S1), were identified and integrated into the platform. All data collected on the platform was stored securely on an Amazon Web Services server.

The telemedicine system and implementation plan were designed to address some of the barriers identified in the formative phase, such as digital literacy, technology and language barriers among patients; lack of insight into the clinical history, physical examination and laboratory findings for physicians; and poor interoperability of digital technologies and poor integration of telemedicine models in the care pathway and clinic workflow.

The eCDSS has been developed and tested extensively by the Centre for Chronic Disease Control and All India Institute of Medical Sciences, New Delhi [17, 18]. The eCDSS software uses thousands of embedded case studies and evidence-based guidelines to generate clinical decision recommendations. The recommendations include optimal drugs and dosages, follow-up plans, and personalised lifestyle advice for diabetes mellitus and hypertension. The eCDSS was incorporated into the telemedicine platform after formative interviews with physicians that identified barriers and facilitators to its use [20]. Efforts were made to enhance its ease of use and interoperability by ensuring appropriate task-shifting in patient data collection via integrations in the nurse's history-taking template, easy accessibility of clinical recommendations on the physician-facing interface and tailoring the drug recommendations according to local availability.

Telemedicine nurses were trained to collect patient history using a customised symptom-based structured template, perform physical examinations, and conduct lab investigations before initiating tele-consultations whenever necessary. All patients were screened for medical or surgical emergencies using a triaging template and referred to a tertiary care centre if there were symptoms or signs of a medical or surgical emergency. The telemedicine nurse was trained to connect the patient to the physician, convey the findings, facilitate physician-patient interactions, and prevent unnecessary visits. A laboratory technician was appointed to perform the relevant point of care testing of 13 common laboratory investigations and electrocardiograms (ECGs). In addition to the detailed history and examination findings provided by the trained nurses, the data from the integrated devices provided the physician with information on vital signs, basic laboratory results, ECG with artificial intelligence-based interpretation and the ability to auscultate the patient remotely. Consultations were first done by a primary care physician and, if further referred, by a specialist or sub-specialist physician.

The telemedicine nurses were also trained to make reminder calls and send messages to patients with diabetes mellitus and hypertension due for follow-up visits. The telemedicine platform and connected devices were both 4G enabled and battery-powered, allowing portability. Therefore, in addition to the assisted telemedicine consultations facilitated at the clinics, doorstep consultations were carried out at the homes of elderly and bedridden individuals living in the areas surrounding the clinic. The clinic processes were monitored and supervised by an experienced senior nurse designated as a quality assurance officer.

A comprehensive community program, including outreach telemedicine clinics and health promotion campaigns in the areas surrounding the clinics, was also instituted fortnightly. Regular household visits were also done to educate the community on healthy lifestyle practices. Every month was dedicated to raising awareness of a specific disease entity.

Study areas

Three telemedicine centres were established to provide free healthcare to disadvantaged communities in the Kodambakkam and Nanganalloor areas of the Chennai district, as well as Pasuvanthanai village of Thoothukudi district in the state of Tamil Nadu, India. The sites were selected to demonstrate the feasibility and functioning of this model in both urban (Chennai clinics) and rural (Pasuvanthanai clinic) settings. The clinics functioned between 8am to 5pm on all days of the week, except on Mondays and public holidays. The laboratory service was available from 8am onwards and consultations were available from 9am onwards. The clinics were kept open on Sundays to allow working individuals to avail services.

Study population

De-identified data from the records of all patients who visited the telemedicine centres over a span of 28 months (March 2021 to June 2023) was extracted from the telemedicine platform. Written informed consent for assisted telemedicine consultations was taken from all patients. To study the feasibility of implementation, the utilisation of services was analysed using the health records of all patients and device data extracted from the telemedicine platform. The impact of the initiative on chronic disease care was analysed using health records data of all patients above the age of 18 years with diabetes mellitus or hypertension. The Centre for Chronic Disease Control Institutional Ethics Committee (IRB00006330) gave ethics approval for the analysis.

Data collection and analysis

Consultations done by primary care physicians were labelled as "general" consultations, and those by a physician with a specialized degree were labelled as "specialist" consultations. Previous history of one or more "chronic conditions", namely, diabetes mellitus, hypertension, stroke, vascular diseases, coronary artery disease, chronic obstructive pulmonary disease, asthma, liver failure and chronic kidney disease, were collected from all patients during their first visit. The demographic profile of the patients who attended the clinics, utilisation of laboratory services, and follow-up visit rates were analysed.

Sub-group analysis of outcomes in patients with diabetes mellitus and hypertension

Patients were considered to have hypertension if they either had a known history of hypertension and were on treatment or if their Systolic Blood Pressure (SBP) was above 140 mmHg and/or Diastolic Blood Pressure (DBP) was above 90 mmHg during the visit. Patients with a known history of diabetes mellitus or Fasting Blood Glucose (FBG) value of >126 mg/dL or random/post-prandial blood glucose value>200 mg/dL were considered to have diabetes mellitus. Those with the precursory diagnostic cut-offs but without a known diagnosis of hypertension or diabetes mellitus were labelled as "newly detected hypertension" and "newly diagnosed diabetes mellitus", respectively, after opportunistic screening. The patients detected with diabetes or high blood pressure were treated as per the national guidelines in the National Programme for Non-Communicable Disease (NP-NCD). The eCDSS embedded in the telemedicine platform also follow the same guidelines. The guidelines take into consideration individuals who suffer from both diabetes and hypertension, and recommends simple yet effective drugs accordingly. The data on blood pressure readings in patients with hypertension and FBG in patients with diabetes mellitus were cleaned before analysis to drop outliers. The patients aged<18 years and those with SBP<40mmHg and DBP<35mmHg were excluded. The duration between the baseline and subsequent visits was calculated in months and days. The follow-up duration was categorised as baseline visit (first visit), < 1-month visit, ≥ 1-month and <2-month visit, and so on. If a patient had multiple visits in the same time duration, the mean value of SBP, DBP, and FBG for that patient during the specified time period was included. The follow-up duration was limited to ≥8 months and <9 months, as beyond these time durations, there were not enough observations to make meaningful interpretations.

A descriptive analysis was done to determine the number of visits each patient had and the number of patients in different follow-up durations. Mean (Standard Deviation (SD)) and median (Inter-Quartile Range (IQR)) values of SBP, DBP and FBG were calculated for follow-up duration. Box plots were used to show the data distribution of SBP, DBP and FBG across follow-up visits. Generalized Estimating Equation (GEE) analysis accounted for the correlation between different time points. The model included outcome variables (SBP/DBP/FBG) and time as the covariate. The analyses were conducted using the Stata (17.0) version, and plotting was conducted using PYTHON 3.10.

Results

Feasibility of the intervention

As of June 2023, the clinics at Kodambakkam, Nanganalloor and Pasuvanthanai locations had been operational for 14 months, 28 months and 23 months, respectively. A total of 11,388 patients visited the three clinics during this period, with similar rural (50.4%) and urban (49.6%) distribution. The cohort had a mean (±SD) age of 45 (±20) years, a median age of 48 years and the majority were female (59.3%) and belonged to the 41–60 years age group (Table 1).

The three clinics, over a cumulative period of 65 months, completed 26,998 consultations, which included 21,165 general and 5,833 specialist consultations (Table 2). The most consulted specialist physician was an internal medicine physician (MD) with a total of 4401 (75.5%) consultations. Doorstep consultations were carried out for 335 bedridden and elderly patients unable to visit the clinic.

A total of 3647 (32%) patients visited the clinic more than once (Fig. 1), of which 1392 (38.2%) patients were those visiting for a prescribed follow up visit for diabetes mellitus or hypertension. A total of 18,020 investigations were conducted (Table 3). The panel's most used lab investigations were blood sugar (70.3%), followed by haemoglobin (15.3%). 12-lead ECG was done for 2,583 (14.3%) patients. The average duration of a patient visit, from registration to final prescription as per the time stamps on the telemedicine platform, was 34 min for general consultations and 45 min when followed up with a specialist consultation.

Impact on chronic condition care

A total of 5542 (48.6%) patients reported one or more chronic conditions. Diabetes mellitus (61%) and hypertension (45%) were the most common chronic conditions seen. A total of 1717 (31%) patients had been diagnosed previously and were aware of their condition. Information regarding body mass index was available for 7231 patients, of whom 25.4% were underweight, 24.5% were overweight, and approximately 12% were obese.

Table 1 General characteristics of patients at clinics

	Urban* (n=5647)			Rural # (n=5741)			Total (n=11,388)		
Gender (n, %)	Male (2509, 44.4%)	Female (3136, 55.5%)	Other (2, 0.04%)	Male (2128, 37.1%)	Female (3612, 62.9%)	Other (1, 0.00%)	Male (4637, 40.7%)	Female (6748, 59.3%)	Other (3, 0.00%)
Mean age years (SD)	45 (20.46)	45 (16.04)	43 (4.24)	46 (20.67)	45 (17.99)	Not available	46 (19.12)	45 (17.84)	43 (4.24)
Age distribution									
0–18 years n (%)	336 (13.4%)	340 (10.8%)	0 (0%)	295 (13.9%)	324 (9%)	0 (0%)	631 (13.6%)	664 (9.8%)	0 (0%)
19–40 years n (%)	551 (22%)	870 (27.7%)	1 (50%)	434 (20.4%)	1078 (29.8%)	0 (0%)	985 (21.2%)	1948 (28.9%)	1 (33.3%)
41–60 years n (%)	975 (38.9%)	1278 (40.8%)	1 (50%)	817 (38.4%)	1471 (40.7%)	0 (0%)	1792 (38.6%)	2749 (40.7%)	1 (33.3%)
61+years n (%)	638 (25.4%)	635 (20.2%)	0 (0%)	577 (27.1%)	731 (20.2%)	0 (0%)	1215 (26.2%)	1366 (20.2%)	0 (0%)
Unavailable data n (%)	9 (0.3%)	13 (0.4%)	0 (0%)	5 (0.2%)	8 (0.2%)	1 (100%)	14 (0.3%)	21 (0.3%)	1 (33.3%)

*The urban sites are the clinics at Kodambakkam and Nanganalloor

The rural site is the clinic at Pasuvanthanai

Table 2 Distribution of consultations

	Urban*	Rural#	Total
All consultations	N=14,813	N=12,185	N=26,998
General Consultations	10,515 (70.9%)	10,650 (87.4%)	21,165 (78.4%)
Specialist Consultations	4298 (29.1%)	1535 (12.6%)	5833 (21.6%)
Distribution of specialist consultations			
	N=4298	N=1535	N=5833
General Medicine	3407 (58.4%)	994 (17.0%)	4401 (75.5%)
Dermatology	318 (5.5%)	166 (2.8%)	484 (8.3%)
Pain medicine	112 (1.9%)	40 (0.7%)	152 (2.6%)
Ophthalmology	107 (1.8%)	229 (3.9%)	336 (5.8%)
Paediatric	88 (1.5%)	1 (0.0%)	89 (1.5%)
Orthopaedics	181 (3.1%)	94 (1.6%)	275 (4.7%)
Gynaecology	74 (1.3%)	03 (0.1%)	77 (1.3%)
General surgery	08 (01%)	08 (0.1%)	16 (0.3%)
Dental	03 (01%)	00 (0.0%)	03 (0.1%)

*The urban sites are the clinics at Kodambakkam and Nanganalloor

The rural site is the clinic at Pasuvanthanai

Diabetes mellitus

A total of 1817 (16%, $n=11{,}388$) patients had diabetes mellitus. The mean (±SD) age of the patients with diabetes mellitus was 53 (±20) years, and they were majority female (56%). Of these, 1035 (57%) were known cases and 782 (43%) were newly diagnosed. The mean (±SD) age of the newly detected patients with diabetes mellitus was 54 (±12) years.

Overall, 396 patients with diabetes mellitus had fasting blood glucose values from more than one visit (Table 4). The number of patients that visited at <1-month intervals was 218 (55.1%), and at ≥8 & <9 months was 70 (17.1%). The mean FBG level at baseline was 180.0 (SD=63.1) mg/dL, and the median FBG was 164.5 mg/dL (133.0-213.2). If the blood sugar was controlled (<126 mg/dl), they were scheduled for follow up at six months or one year. Thus, there were only small numbers at 8–9 months. For the interval of ≥8 & <9 months, the mean FBG decreased to 143.3 mg/dL (SD=41.3), with a median of 133.5 mg/dL (116.0-168.9) (Table 4).

The percentage of uncontrolled diabetes mellitus declined from 83% among the baseline patients to 63% at the time interval≥8 & <9 months. A steady and statistically significant ($p<0.001$) decline in FBG was seen at all time intervals from baseline. At the <1 month interval, FBG was reduced by 19.5 mg/dL compared to baseline (95% CI: -27.8 to -11.2, $P<0.001$). The ≥8 & <9 months interval showed a 33.0 mg/dL decrease in FBG (95% CI: -42.4 to -23.7, $P<0.001$) (Fig. 2) (Table S2).

Hypertension

A total of 3132 (27.5%, $n=11{,}388$) patients had hypertension, of whom 24.7% had a known history of hypertension and 75.3% were newly diagnosed. The mean (±SD) age of all the patients with hypertension was 56 (±16) years, and the majority (54%) were female. The mean (±SD) age of newly detected hypertension patients was 53 (±14) years. Approximately 32% of all patients with hypertension visited the clinic more than once, with the average number of follow-up visits being 4.

Overall, 996 patients with hypertension had SBP /DBP readings for more than one visit. The <1-month visit measures were available for 629 (63.1%) patients and for ≥8 & <9 months of 132 (13.3%) patients. If the BP was controlled (SBP<140 mmHg and DBP<90 mmHg), they were scheduled for follow-up at six months or one year. Thus, there were only small numbers at 8–9 months.

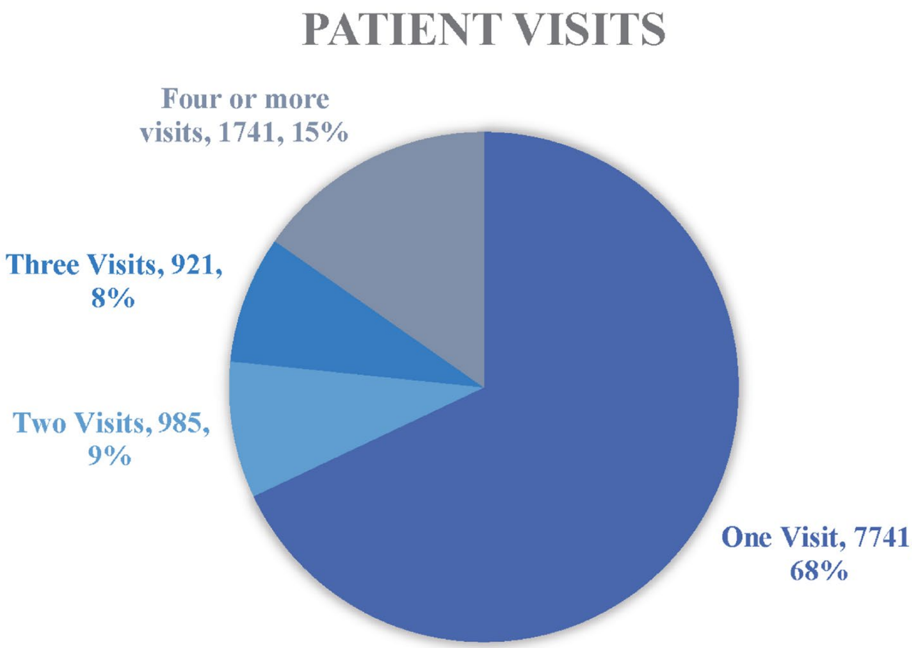

Fig. 1 Patient Distribution as per number of visits

Table 3 Number of lab tests and ECGs performed

	Urban* (n = 8601)	Rural# (n = 9419)	Total (n = 18,020)
Postprandial blood glucose	2788	3790	6578
Fasting blood glucose	2840	652	3492
Random blood glucose	1139	1457	2596
Haemoglobin	1027	1733	2760
Others (Urine pregnancy test, rapid typhoid test, rapid HIV test and rapid malarial test)	5	6	11
ECGs	802	1781	2583

*The urban sites are the clinics at Kodambakkam and Nanganalloor

The rural site is the clinic at Pasuvanthanai

Table 4 Mean and median fasting blood sugar levels over visits

Visits	N	Mean ± SD	Median (IQR)
Baseline	396 (100%)	180.0 ± 63.1	164.5 (133.0-213.2)
< 1 month	218 (55.1%)	163.1 ± 53.9	146.5 (126.2-193.5)
≥ 1 & <2 months	125 (31.6%)	162.4 ± 49.5	152.5 (128.0-173.0)
≥ 2 & <3 months	84 (21.2%)	151.0 ± 45.4	137.0 (121.8-177.8)
≥ 3 & <4 months	87 (22.0%)	156.2 ± 56.5	139.0 (118.0-174.5)
≥ 4 & <5 months	78 (19.7%)	148.5 ± 40.6	141.0 (123.0-162.1)
≥ 5 & <6 months	80 (20.2%)	154.7 ± 53.4	144.5 (119.0-176.2)
≥ 6 & <7 months	73 (18.4%)	146.8 ± 43.1	137.0 (122.0-162.0)
≥ 7 & <8 months	63 (15.9%)	157.7 ± 44.0	145.0 (133.0-188.5)
≥ 8 & <9 months	70 (17.7%)	143.3 ± 41.3	133.5 (116.0-168.9)

Table 5 shows the number of patient visits and the mean (SD) /median (IQR) for SBP and DBP over the visits. At baseline, the mean SBP was 151.2 mmHg (SD = 20.5). This decreased to 141.9 mmHg (SD = 18.0) at ≥ 8 & <9 months. The baseline mean DBP was 85.4 mmHg (SD = 12.1), decreasing to 78.5 mmHg (SD = 11.3) at ≥ 8 & <9 months.

As seen in diabetes mellitus patients, there was a decline in uncontrolled hypertension from 72% among the baseline patients to 61% at the time interval ≥ 8 & <9 months. Both SBP and DBP significantly reduced ($P < 0.001$) compared to baseline at all time points. Greater reductions were observed with a longer duration of the intervention. At the < 1 month interval, SBP was lower by 4.2 mmHg (95% CI: -5.5 to -3, $P < 0.0001$), and DBP was reduced by 1.8 mmHg (95% CI: -2.5 to -1.1, $P < 0.0001$). Significant reductions persisted beyond six months, with a 9.6 mmHg decrease in SBP (95% CI: -12.1 to -7.0, $P < 0.0001$) and a 5.5 mmHg decrease in DBP (95% CI: -7.0 to -4.1, $P < 0.0001$) at ≥ 8 & <9 months (Fig. 3) (Table S2).

Discussion

Our study provides some important insights from the assisted telemedicine (Digisahayam) initiative that aimed to bridge the gap between digital health, community, and the health system whilst ensuring digital health equity through task-sharing. First, the initiative successfully demonstrated its applicability in both rural (51% of patients) and urban (49% of patients) settings. It provided healthcare to 11,388 patients (including approximately 59% female and 23% elderly patients) with 26,998 consultations (including 335 doorstep consultations) and 18,020 investigations over 2.4 years. The ability of the platform and devices to carry out consultations at the patient's doorstep greatly enhances its application.

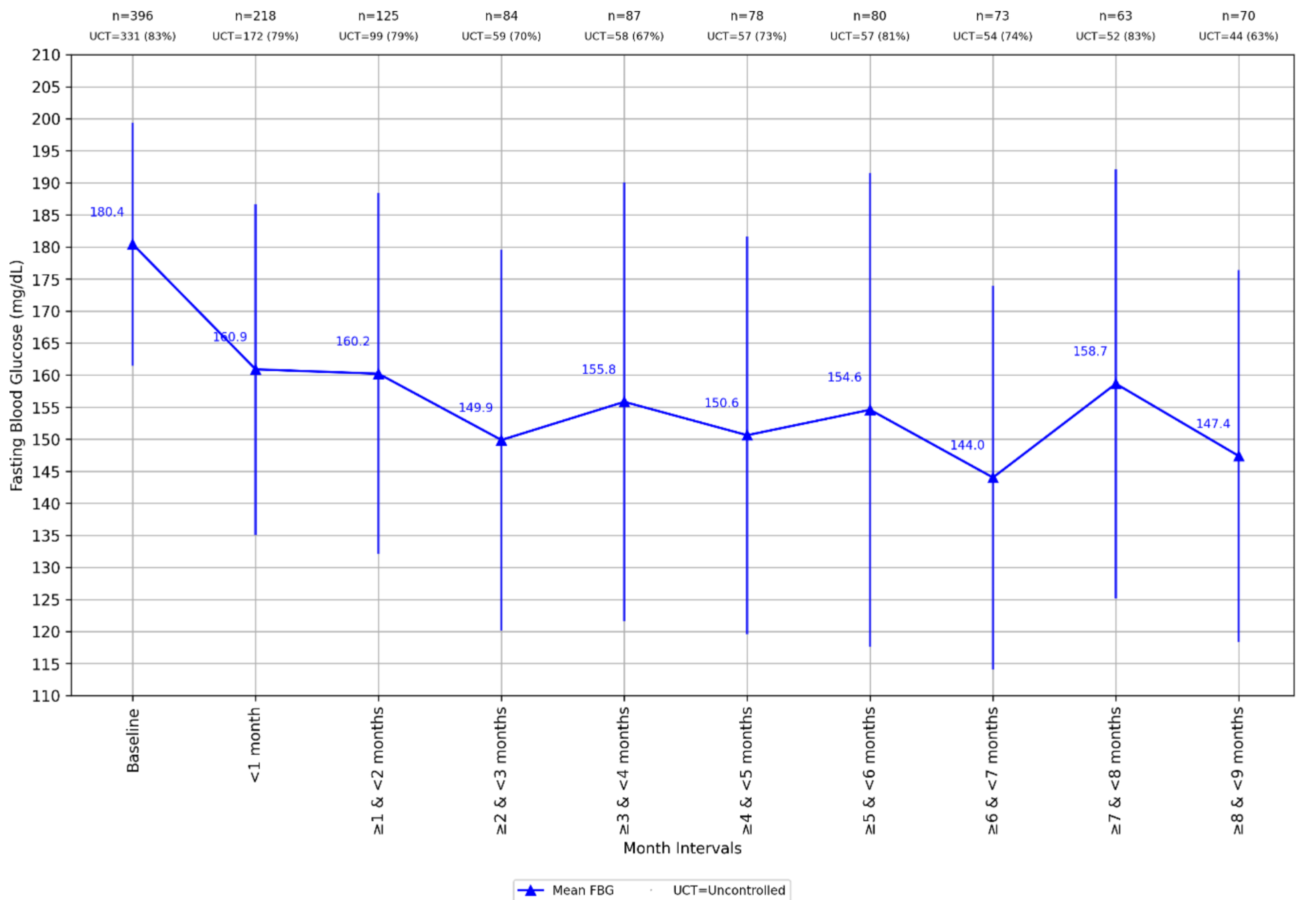

Fig. 2 Mean fasting blood glucose (mg/dL) over time

Table 5 Mean and median systolic and diastolic blood pressure of hypertension patients over visits

	SBP			DBP		
Interval	**N**	**Mean ± SD**	**Median (IQR)**	**N**	**Mean ± SD**	**Median (IQR)**
Baseline	996 (100%)	151.2 ± 20.5	150 (137.0-163.0)	996 (100%)	85.4 ± 12.1	85 (77.0–93.0)
< 1 month	629 (63.1%)	147.2 ± 17.5	146 (135.0-158.0)	629 (63.1%)	83.7 ± 10.6	84 (76.0–91.0)
≥ 1 & <2 months	274 (27.5%)	144.9 ± 17.1	143 (133.1–155.0)	274 (27.5%)	80.9 ± 10.8	80 (73.0–88.0)
≥ 2 & <3 months	198 (19.9%)	143.8 ± 16.7	142 (133.1-154.8)	198 (19.9%)	81.4 ± 11.0	81 (74.0–89.0)
≥ 3 & <4 months	182 (18.3%)	144.7 ± 18.7	143 (133.0-154.0)	182 (18.3%)	81.8 ± 10.9	81 (74.0–90.0)
≥ 4 & <5 months	171 (17.2%)	145.3 ± 20.3	143 (133.0-156.0)	171 (17.2%)	80.0 ± 10.3	79 (73.5–86.0)
≥ 5 & <6 months	152 (15.3%)	142.6 ± 16.9	142 (129.9-153.2)	152 (15.3%)	79.8 ± 10.2	80 (72.0–87.0)
≥ 6 & <7 months	154 (15.5%)	143.2 ± 18.2	143 (130.2-153.8)	154 (15.5%)	79.1 ± 11.1	79 (72.1–86.0)
≥ 7 & <8 months	121 (12.2%)	144.1 ± 18.2	142 (130.3–154.0)	121 (12.2%)	80.1 ± 10.2	79 (73.0–88.0)
≥ 8 & <9 months	132 (13.3%)	141.9 ± 18.0	142 (130.0-151.0)	132 (13.3%)	78.5 ± 11.3	78 (71.0-86.7)

Second, the model demonstrated its feasibility and proved to be an invaluable public health screening tool by aiding in detecting hypertension and diabetes mellitus in this community cohort. Third, the initiative led to appropriate multi-speciality consultations, relevant testing, high rates of follow-ups, and significant reductions in SBP, DBP, and FBG among patients with hypertension and diabetes mellitus, respectively. While other digital health initiatives have demonstrated the first two points, the enhanced compliance with medical check-ups and large improvements in clinical outcomes are particularly noteworthy.

Telemedicine can improve access to healthcare by reducing the distance travelled to access in-person care, especially specialist care which is difficult to access in rural areas. It can also reduce indirect healthcare costs due to loss of daily wages and travel. Conventional telemedicine, including patient-initiated audio or audio-visual conferencing platforms, is valuable but has several shortcomings. Importantly, access to and proficiency in

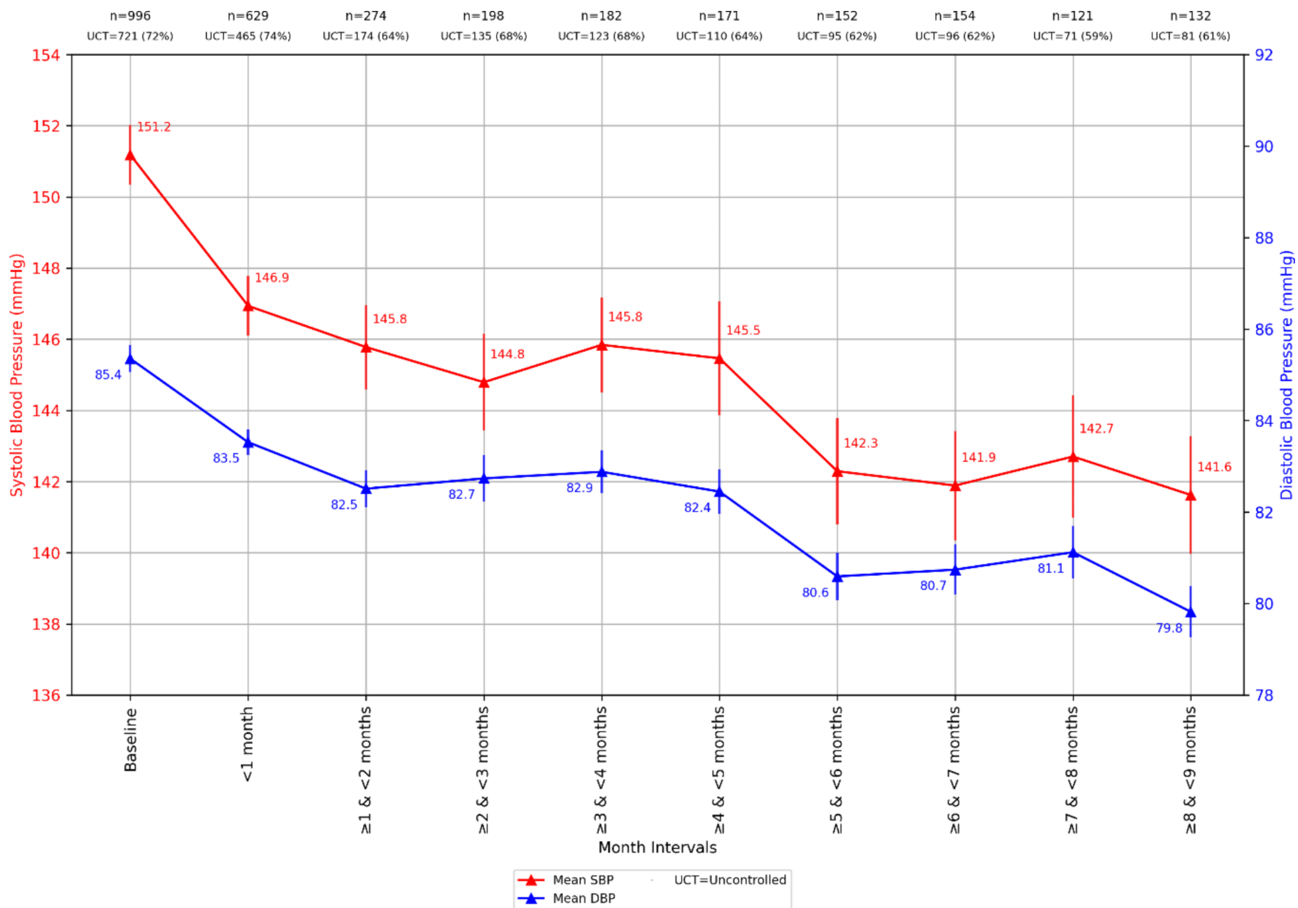

Fig. 3 Mean systolic and diastolic blood pressure (mmHg) over time

digital devices and internet connectivity is a pre-requisite and can exclude segments of the population with limited digital literacy or resources, such as elderly patients. In addition, with most patient-initiated telemedicine platforms being in the English language, the use of telemedicine is still limited to a very small section of India's population. Although there was a reported increase in telemedicine consultations by approximately 500% during the COVID-19 pandemic, the number can be misleading due to the small proportion of individuals who used telemedicine pre-pandemic [21]. In the Digisahayam model, the trained telemedicine nurse was instrumental in bridging the barriers to accessing healthcare by facilitating doctor-patient interactions, conveying lab findings to the physicians, ensuring regular follow-ups, and reducing unnecessary visits to tertiary care centres. The ease of access in the Digisahayam model is evident from the rapid expansion of its patient base (over 11,000 patients in two years of operation) and ensuring regular follow-ups (32% of patients visited the clinic more than once). This is particularly remarkable considering that access to healthcare was severely compromised during this time due to recurrent waves of the COVID-19 pandemic. Almost three-fifths of all patients were female, and one-fourth were above the age of 60 years. This unique sociodemographic profile of the patients visiting the clinics is a testament to its role in reducing digital inequity, as these two groups typically represent an otherwise disadvantaged section of society regarding telemedicine usage [14, 22].

Additionally, the portability of the platform and connected devices add another layer of accessibility, with over 300 specialist-level doorstep consultations being performed for the elderly and bedridden patients. The study demonstrated the feasibility of carrying out specialist consultations at the patient's home using three simple innovations - a platform that works on a widely available internet bandwidth (4G), battery-operated integrated point-of-care devices, and an EHR that trained low-skilled health workers can use. Thus, the initiative is an astute example of how empowering the gatekeeper function of primary care can enhance access and reduce inequities in healthcare.

In India, there are about 560 million internet users [23]. Although internet accessibility has increased from 25% to over 50% in the past five years, further penetration, especially in the rural areas where 64% of India's population resides, is still an aspirational goal [24]. Though there are no reported numbers of telemedicine users in rural India, this is presumed to be very low considering barriers to internet access and poor or weak internet connectivity that limits the possibility of video consultations [25–28]. Interestingly, our study observed equal coverage of patients in rural (Pasuvanthanai) and urban (Chennai) areas. The number of patients who attended a single rural clinic-site over 23 months (n=5,741) was higher than that of patients who visited two urban clinic sites over 42 months (n=5,647). This indicates the value and potential of assisted telemedicine facilities in rural areas facing poor access to quality healthcare and the digital divide. Our model suggests that task sharing and shifting among various stakeholders can help overcome some of these challenges in implementing digital health interventions in resource-constrained settings and LMICs.

Another novel feature of the Digisahayam model was its design, specifically related to improving the quality and comprehensiveness of information available to physicians, enabling evidence-based decision making and reducing the need for in-person consultations for specialist consultations at tertiary care centres. Furthermore, with over a fifth of the total consultations conducted by specialists during the study period, we successfully demonstrated that providing easy online access to specialist-level consultations in remote areas is possible as long as necessary information and resources are made available to the treating physician.

In the context of managing chronic diseases and public health interventions, we demonstrated that assisted telemedicine could provide an opportunity for early screening and intervention at the community level, enhance patient engagement, and improve health outcomes. In our study, approximately 75% and 43% of the patients were not aware of their hypertension and diabetes mellitus status, respectively. Once the patients were diagnosed with a chronic condition, our model encouraged prescribed follow-up visits and enabled dose adjustments and reinforcement of healthy lifestyle practices, potentially contributing to the notable reductions in blood glucose and blood pressure values. Integrating eCDSS tremendously helped standardise the treatment algorithms and ensured high-quality care for diabetes mellitus and hypertension by avoiding errors of omission and commission, prescription, and incorrect diagnosis. However, we observed that a large percentage of patients did not come for a second visit (80% patients with diabetes mellitus and 68% of patients with hypertension). A possible explanation for this could be that we had no provision to dispense medications at the clinic due to funding constraints. Patients were often referred to the public health system for medications and drug refills. In addition, some patients were detected through screening camps conducted in surrounding areas and were referred to the nearest health facility and not necessarily to the Digisahayam clinic for follow-ups and continued treatment.

Strengths and limitations

To the best of our knowledge, this is the first study from India to describe the design, utilisation and impact of an assisted telemedicine model using trained nurses and an interoperable disease-independent telemedicine platform with connected devices. Results from this feasibility study suggest that the Digisahayam model assures quality standards, real-time monitoring, feedback mechanisms, and supportive supervision. While it was possible to indirectly assess the equity of the platform through patient retention and sociodemographic factors, no pre- and post-data on access to care were collected from the patients to make this comparison. Additionally, since this was an observational implementation study and was not done under clinical trial settings, it is difficult to determine if the favourable effects on diabetes mellitus and hypertension control were due to care received from our clinics alone or an alternate source of care during the same timeframe. Given the diversity of languages, education, and cultural background, scaling up the model across the country will be challenging. It would require the utmost contribution from various key stakeholders in the public as well as private sector. The telemedicine platform is not compliant with the newly initiated Ayushman Bharat Digital Mission (ABDM) of India. Although this is not mandatory for digital health innovations, compliance with ABDM norms greatly enhances interoperability and safe transfer of data between various Health Management Information Systems (HMIS). The "Digisahayam" telemedicine platform is currently being upgraded to a new platform called "DigiSetu" *("Digi" for "Digital" and "Setu" meaning "bridge" in Hindi).* The new platform will expand the list of connected devices and will be ABDM compliant. It is also important to note that all the services in the current programme were provided free of cost. This may have influenced the acceptance and adoption of the program. In addition, the ability to offer specialist consultations in real-time was facilitated by partnering with an existing telemedicine service with an expansive panel of specialists. This greatly enhanced the effectiveness of the program, and a similar partnership is recommended while planning deployment or scale-up.

Conclusion & future directions

The "Digisahayam" assisted telemedicine solution is an innovative and scalable healthcare delivery model that has the potential to promote equitable healthcare access, and improve health outcomes and continuity of care for patients living with chronic conditions, specifically for patients with hypertension and diabetes mellitus. The model of healthcare leverages digital health while overcoming the barriers of digital literacy, language and technology. The innovations in the "Digisahayam" model include the symptom-based history taking template that allows for capture of comprehensive patient information by trained healthcare workers, the evidence-based recommendations through the eCDSS and the interoperability of the platform that allows direct integration of multiple digital health technologies. The compact and portable nature of the platform enable its implementation in various settings. The model also reduces the burden of frequent in-person visits for specialist consultations or drug refills at tertiary care centres, commonly seen among patients with chronic conditions.

It will be important to conduct well-designed quasi-experimental studies using innovative study designs such as stepped wedge studies, to help verify the true impact of this healthcare model. Future studies should also assess financial metrics such as reduction in indirect costs, out-of-pocket expenditure, and distress financing or catastrophic health expenditures as a consequence of early detection and intervention through these assisted telemedicine initiatives. It will be important to assess the model's application in gathering longitudinal data for disease surveillance and building digital disease registries. An analysis of environmental impacts, as well as the carbon footprint of the model as compared to conventional healthcare, would be helpful to demonstrate its potential use in reducing the harmful effects of healthcare on the environment. Finally, an analysis should be conducted to determine the need for large-scale capacity building programs for healthcare personnel to scale up such initiatives.

The "Digisahayam" model exemplifies how redesigning health systems using simple innovations and age-old public health principles such as task-sharing and team-based care can greatly impact healthcare, especially in LMICs.

Abbreviations

LMICs	Low-and-Middle Income Countries
EHR	Electronic Health Records
eCDSS	electronic Clinical Decision Support Systems
API	Application Programming Interfaces
ECG	Electrocardiogram
SBP	Systolic Blood Pressure
DBP	Diastolic Blood Pressure
FBG	Fasting Blood Glucose
SD	Standard Deviation
IQR	Inter-Quartile Range
GEE	Generalized Estimating Equation
ABDM	Ayushman Bharat Digital Mission
HMIS	Health Management Information Systems

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12875-024-02631-x.

Supplementary Material 1

Author contributions

APJ and DP were involved in the conception and design of the work, acquisition and analysis of data, interpretation of data, creation of the telemedicine platform, and drafting the final manuscript. AK was involved in acquiring and analyzing data, interpreting data, and drafting the final manuscript. HT and TVDW have been involved in the analysis and interpretation of data and made substantial revisions to the final manuscript. NP, AS, RS and NA have been involved in acquiring and analyzing data, creating the telemedicine platform, and revising the final manuscript. SK and DK have been involved in data acquisition and analysis, interpretation of data, and revision of the final manuscript. AC has been involved in data analysis and interpretation and made substantial revisions to the final manuscript. All authors have approved the submitted version and have agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

Funding

The Digishayam project was funded through a Corporate Social Responsibility grant of Star Allied and Health Insurance and a grant from the World Health Organization.

Data availability

The datasets generated and analysed during the current study are not publicly available as they are patient health records and are protected. De-identified data are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Ethics approval for the study (Study ID CCDC_IEC_08_2024) was given by the Centre for Chronic Disease Control Institutional Ethics Committee (IRB00006330). De-identified patient records were used for analysis. Informed consent was taken from all patients before the teleconsultation as per the telemedicine practice guidelines in India [29].

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Received: 10 June 2024 / Accepted: 15 October 2024
Published online: 23 October 2024

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