Exploring the potential of telemedicine for improved primary healthcare in India: a comprehensive review

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Summary

Telemedicine is a promising solution to the challenges of delivering equitable and quality primary healthcare, especially in LMICs. This review evaluated peer-reviewed literature on telehealth interventions in Indian primary care published from Jan 1, 2011 to Dec 31, 2021, from PubMed, Scopus, TRIP, Google Scholar, Indian Kanoon, and Cochrane database The majority of Indian studies focus on key health issues like maternal and child health, mental health, diabetes, infectious diseases, and hypertension, mainly through patient education, monitoring, and diagnostics. Yet, there's a lack of research on telemedicine's cost-effectiveness, communication among providers, and the role of leadership in its quality and accessibility. The current research has gaps, including small sample sizes and inconsistent methodologies, which hamper the evaluation of telemedicine's effectiveness. India's varied healthcare landscape, technological limitations, and social factors further challenge telemedicine's adoption. Despite regulatory efforts, issues like the digital divide and data privacy persist. Addressing these challenges with a context-aware, technologically driven approach is crucial for enhancing healthcare through telemedicine in India.

Keywords: Digital health; Telemedicine; Health emergencies; Primary healthcare services

Introduction

With a significant shortage of healthcare providers in primary care, particularly in rural regions, telemedicine offers a promising solution to bridge this gap in India, enhancing access to healthcare services.[1] Telemedicine is ideally suited to overcome the challenges of healthcare delivery in these areas, especially for primary care settings.[2] Primary care physicians, as frontline healthcare providers, offer initial and continuous medical care for patients across all ages. They serve as the first point of contact for medical treatment, diagnosing and treating a broad spectrum of illnesses and injuries, managing chronic diseases, and promoting preventive health practices. While research on the effectiveness of telemedicine interventions in India, especially in rural and remote locations, remains sparse,[3,4] the COVID-19 pandemic has underscored telemedicine's capacity to deliver primary care services effectively while enforcing social distancing and minimizing the risk of infection.[5] What is lacking is a bird's eye overview of how telemedicine has been used in primary care research in India.[6–8] Furthermore, it is essential to delineate the barriers to telemedicine implementation and to assess the strengths, weaknesses, opportunities, and threats associated with telemedicine in primary healthcare in

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India.[7] Pursuant to this, the scope and potential of telemedicine for enhancing healthcare outcomes, focus specifically on which diseases have been investigated by whom in telemedicine research.

Therefore, a systematic review will help identify the current knowledge, address unique challenges and opportunities, and evaluate evidence of telemedicine's potential benefits. This will guide future research relevant to implementing telemedicine in the under-served areas of India.[7] This review aims to provide a comprehensive overview of telemedicine studies in India, examining the various diseases researched, m-tools used, study designs, WHO building blocks of intervention that have been measured, outcomes, the domain of telemedicine targeted, and, finally, the barriers to telemedicine implementation. Following from the above, our research questions are:

1. What are the inadequacies and gaps in the existing evidence in telemedicine research in primary healthcare in India?
2. What barriers exist to conduct telemedicine research on primary healthcare in India?
3. What are the strengths, weaknesses opportunities, and threats for telemedicine research in primary healthcare in India?
4. What are the common diseases and outcomes targeted in telemedicine research in primary healthcare in India and what is the potential for impact on public health?

Characteristics of the telemedicine studies in India

Table 1 highlights the various characteristics of telemedicine studies in India in primary care conducted in rural, semi-urban, or urban settings. More than 70% of the studies were designed in tertiary centers (n = 279; 71.9%) and more than half (57%) of the studies were implemented in rural areas. Cross-sectional observational studies (n = 133; 34.3%) were the most common, followed by qualitative investigations (n = 51; 13.1%), longitudinal cohort designs (n = 48; 12.4%), and randomized control studies (n = 26; 6.7%). Several study designs were utilized, including exploratory (n = 60; 15.5%), pre-post intervention (n = 22; 5.6%), quasi-experimental (n = 17; 4.5%), Case-control (n = 9; 2.3%) and diagnostic studies (n = 7; 1.8%) (Table 1).

Fig. 2 illustrates the distribution of telemedicine studies in India across 22 distinct health disorders. Maternal and child health issues received the most attention, with 160 studies (35.24%). Diabetes mellitus and mental disorders were next, with 47 studies each. On the other hand, endocrine problems, palliative care, and dentistry received very little attention, with only 2 studies each. Notably, there were no studies focused on telemedicine in respiratory diseases in primary care.

Based on WHO building blocks of healthcare intervention, service delivery was the main emphasis of the interventions (n = 271; 66.1%), followed by health workforce (n = 58; 14.1%), and health system information (n = 48; 11.7%). A small fraction of interventions focused on medical products, vaccines, and technology (n = 11; 2.7%), finances (n = 9; 2.2%), and leadership and governance (n = 4; 1.0%). Among m-tools used, the most widely used were smartphone apps (n = 171; 39.6%) followed by feature phones (n = 103; 23.8%) and computer-based software (n = 73; 16.9%).

A bulk of interventions (n = 170, 26.1%) focused on client education and behavior, followed by provider-to-provider communication (n = 121, 18.6%) and tele-follow-up (n = 74, 11.4%). Common intervention objectives were electronic decision support (n = 79, 12.1%), data collection and reporting (n = 52, 8.0%), and electronic health records (n = 44, 6.8%). Other interventions focused on point-of-care diagnosis (n = 49, 7.5%) and provider training education (n = 62, 9.5%). The most common service providers evaluated in studies were doctors (n = 118, 31.8%), followed by Accredited Social Health Activists (ASHA) (n = 109, 29.4%) and allied health workers (n = 95, 25.6%). Personnel training was mostly for ASHA workers (n = 52; 29.7%) and primary care physicians (n = 38; 21.7%). Common outcomes investigated in the majority of the studies were quality of intervention (n = 113; 23.2%) and health indicators (n = 110; 22.6%). Other outcomes measured included quality of life, access indicators, cost-effectiveness, customer satisfaction, and social acceptability.

Overall, the largest barrier to telemedicine adoption identified in our review was technological issues (n = 163 studies, 26.9%), while the second most commonly observed barriers were social acceptability (n = 105 studies, 17.3%) and accessibility of telemedicine services (105 studies 17.3%). Other barriers identified were sustainability (n = 81 studies, 13.4%), cost (n = 63 studies, 10.4%), and literacy (n = 63 studies, 10.4%). A small percentage of studies identified gender (n = 15, 2.5%) and religious beliefs (n = 11, 1.8%) as barriers.

Table 2 provides a comprehensive overview of telemedicine in primary care within India, detailing the utilization of various digital tools across health issues, the spectrum of interventions across diseases, and the targeted outcomes. It also outlines the involvement of different healthcare providers, evaluates the WHO building blocks of intervention, and identifies barriers facing telemedicine implementation across various medical conditions. This table encapsulates the multifaceted approach of telemedicine, highlighting its impact on healthcare delivery and the challenges that need to be addressed for its broader adoption. Among

	Number of studies	Percentage
Where was the study designed?		
Primary care	36	9.3%
Tertiary care	279	71.9%
Not clear	31	8.0%
Not mentioned	42	10.8%
What were the study settings?		
Rural	247	57.0%
Semi-Urban	28	6.5%
Urban	104	24.0%
Not Clear	54	12.5%
What was the study design used?		
Cohort study	48	12.4%
RCT study	26	6.7%
Case-control study	9	2.3%
Pre-post intervention	22	5.6%
Qualitative study	51	13.1%
Quasi experimental	17	4.5%
Exploratory	60	15.5%
Cost analysis	15	3.8%
Cross-sectional	133	34.3%
Diagnostic study	7	1.8%
What m-tools were used for the intervention?		
Computer-based software	73	16.9%
Smart phone app	171	39.6%
Feature phone	103	23.8%
Wearable devices	15	3.5%
Mobile van	20	4.6%
Tablets	32	7.4%
Other	18	4.2%
Which domain does the Telemedicine intervention target?		
Client education and behavior	170	26.1%
Provider training and education	62	9.5%
Provider-to-provider communication	121	18.6%
Point-of-care diagnostics	49	7.5%
Electronic decision support	79	12.1%
Data collection and reporting	52	8.0%
Electronic health records and access	44	6.8%
Tele-follow up	74	11.4%
What WHO Building blocks of intervention in health care did the study measure?		
Service delivery	271	66.1%
Health workforce	58	14.1%
Health system information	48	11.7%
Medical products, vaccines, and technology	11	2.7%
Financing	9	2.2%
Leadership and governance	4	1.0%
Not applicable	9	2.2%
Who were the service providers involved?		
Primary care physicians	118	31.8%
Nurses	30	8.1%
ASHA workers	109	29.4%
Allied health workers	95	25.6%
Not mentioned/not clear	19	5.1%
If mentioned, who were the personnel trained?		
Primary care physicians	38	21.7%

(Table 1 continues on next page)

	Number of studies	Percentage
(Continued from previous page)		
Nurses	18	10.3%
ASHA workers	52	29.7%
Allied health workers	27	15.4%
Not mentioned/not clear	40	22.9%
What are the outcomes targeted by telemedicine interventions?		
Quality of life	25	5.1%
Health indicator	110	22.6%
Access indicator	62	12.7%
Quality of intervention	113	23.2%
Cost effectiveness	51	10.5%
Customer satisfaction	69	14.2%
Social acceptability	57	11.7%
What were the barriers to telemedicine?		
Accessibility	105	17.3%
Religious belief	11	1.8%
Social acceptability	105	17.3%
Gender	15	2.5%
Literacy	63	10.4%
Cost	63	10.4%
Sustainability	81	13.4%
Technology	163	26.9%

Note: The total number of studies are 388. Some studies include multiple settings, multiple m tools, different telemedicine intervention targets, and more than one WHO building block. Therefore, the total exceeds the sum of actual studies. Feature phones: A feature phone is a type of mobile phone that has more features than a standard cellphone but is not equivalent to a smartphone; ASHA workers: ASHA (Accredited Social Health Activist) workers are community health workers in India who act as link between the community and the public healthcare system.

Table 1: **The demographic attributes of studies related to telemedicine that were conducted in primary healthcare facilities from 2011 to 2021 (n = 388).**

the digital tools, smartapps were predominantly utilized in studies focusing on malnutrition and disease rehabilitation, accounting for 75% and 33.3% respectively. For infectious disorders, smartapps emerged as the most commonly used modality, comprising 48.8% of the studies, followed by computer-based software at 17.1%. Smartphone-based apps emerged as the primary tool for interventions targeting hypertension and cardiovascular diseases, with rates of 50% and 43.8% respectively. For psychiatry, both computer-based software and smartapps exhibited significant usage, representing 33.3% and 38.1% of the studies respectively.

The spectrum of telemedicine interventions across various diseases such as diabetes, hypertension, and cerebrovascular disorders, the focus primarily lies on client education and behavior. Cardiovascular disorders, dyslipidemia, and infectious diseases predominantly emphasize point-of-care diagnostics. In oncology, interventions are centered around point-of-care diagnostics and provider-to-provider communication. Malnutrition interventions primarily revolve around client education and behavior. Disease rehabilitation initiatives prioritize provider training, education, and provider-to-provider communication. Telemedicine interventions in maternal and child health and psychiatry span across multiple domains. Lastly, ophthalmology and other medical disease interventions are primarily focused on point-of-care diagnostics and client education and behavior respectively.

In terms of targeted outcomes of telemedicine interventions across different diseases conducted in primary care in India, the primary focus is to enhance health indicators, with 52.9% and 37.5% of studies targeting hypertension and cardiovascular diseases respectively. Improving quality of life is a key objective for dyslipidemia (50%) and disease rehabilitation (33.3%) interventions. Evaluating the quality of interventions is prominent in studies targeting cerebrovascular diseases (50%), while those addressing malnutrition aim to improve health access (75%). For infectious diseases, telemedicine interventions primarily assess the quality of intervention (26.6%), health indicators, customer satisfaction (19.5% each), and social acceptability (17.1%). In psychiatry, the focus is on health indicators (28.6%), quality of interventions, and customer satisfaction (26.2% each).

The breakdown of service providers involved in telemedicine studies across different medical conditions observed that physicians were the most common service providers in telemedicine studies on disease rehabilitation

	CVD	CeVD	DM	Rehab	Dyslip	HTN	ID	Malnut	MCH	Onc	Ophth	Pysch	Others
What m-tools were used for the intervention?													
Smartapp (n = 207)	3.4	2.4	10.1	0.5	1.4	8.2	9.7	1.4	33.3	3.9	3.9	7.7	14.0
Computer-based tools (n = 110)	4.5	2.7	10.0	0.9	2.7	9.1	6.4	0.0	25.5	6.4	6.4	12.7	12.7
Feature phone (n = 83)	3.6	1.2	7.2	1.2	0.0	6.0	9.6	0.0	44.6	1.2	1.2	4.8	19.3
Mobile van (n = 25)	4.0	0.0	20.0	0.0	0.0	4.0	0.0	0.0	20.0	20.0	20.0	8.0	4.0
Wearable devices (n = 5)	0.0	0.0	20.0	0.0	0.0	0.0	20.0	0.0	40.0	0.0	0.0	0.0	20.0
Others (n = 113)	1.8	0.9	9.7	0.9	1.8	4.4	10.6	1.8	27.4	9.7	9.7	8.8	12.4
Which domain does the Telemedicine intervention target?													
Client education and behavior (n = 222)	4.1	2.7	13.1	0.0	3.2	9.9	10.8	1.4	26.6	2.7	2.7	5.9	17.1
Point-of-care diagnostics (n = 164)	4.3	1.2	12.2	0.0	1.8	7.9	4.9	0.0	28.7	11.0	11.0	10.4	6.7
Electronic decision support (n = 100)	3.0	3.0	14.0	0.0	1.0	9.0	9.0	0.0	32.0	4.0	4.0	13.0	8.0
Tele-follow up (n = 90)	4.4	2.2	16.7	1.1	1.1	7.8	12.2	0.0	31.1	2.2	2.2	13.3	5.6
Provider training and education (n = 83)	4.8	3.6	3.6	2.4	2.4	4.8	9.6	0.0	32.5	2.4	2.4	12.0	19.3
Data collection and reporting (n = 76)	5.3	1.3	14.5	0.0	0.0	11.8	14.5	1.3	22.4	3.9	3.9	6.6	14.5
Provider to Provider communication (n = 63)	1.6	1.6	7.9	3.2	0.0	6.3	6.3	0.0	25.4	7.9	7.9	22.2	9.5
Electronic health records and access (n = 61)	4.9	0.0	16.4	1.6	1.6	9.8	6.6	0.0	27.9	4.9	4.9	9.8	11.5
What are the outcomes targeted by telemedicine interventions?													
Quality of life (n = 36)	5.6	5.6	5.6	2.8	22.2	5.6	5.6	0.0	22.2	0.0	0.0	19.4	5.6
Social acceptability (n = 68)	2.9	0.0	7.4	2.9	2.9	5.9	10.3	0.0	38.2	1.5	1.5	13.2	13.2
Cost-effectiveness (n = 71)	2.8	1.4	7.0	2.8	0.0	1.4	5.6	0.0	29.6	14.1	14.1	9.9	11.3
Access to healthcare (n = 74)	4.1	2.7	8.1	0.0	0.0	4.1	8.1	0.0	39.2	4.1	4.1	9.5	16.2
Customer satisfaction (n = 85)	4.7	2.4	9.4	1.2	1.2	4.7	9.4	0.0	35.3	4.7	4.7	12.9	9.4
Quality of intervention (n = 131)	4.6	3.8	9.2	0.0	3.1	7.6	11.5	0.8	36.6	0.8	0.8	8.4	13.0
Health indicator (n = 153)	3.9	1.3	18.3	0.0	2.6	11.8	5.2	2.0	19.0	5.9	5.9	7.8	16.3
Which healthcare service providers were involved in telemedicine interventions?													
Physician (n = 175)	5.1	3.4	11.4	1.1	2.9	8.0	6.9	0.0	28.6	5.7	5.7	12.6	8.6
ASHA worker (n = 75)	5.3	2.7	8.0	0.0	2.7	12.0	5.3	1.3	30.7	0.0	0.0	9.3	22.7
Nurse (n = 61)	6.6	3.3	16.4	1.6	3.3	13.1	9.8	0.0	26.2	3.3	3.3	8.2	4.9
Allied health worker (n = 51)	0.0	0.0	13.7	0.0	0.0	0.0	2.0	0.0	33.3	15.7	15.7	3.9	15.7
Not mentioned (n = 28)	10.7	0.0	10.7	0.0	0.0	10.7	21.4	0.0	35.7	3.6	3.6	0.0	3.6
Not clear (n = 17)	0.0	0.0	5.9	0.0	0.0	0.0	0.0	0.0	58.8	5.9	5.9	11.8	11.8
Which WHO Building blocks of intervention in health care did the study measure?													
Service delivery (n = 376)	3.7	2.7	10.4	0.3	1.9	7.4	7.7	0.5	31.4	6.1	6.1	9.0	12.8
Health system information (n = 75)	9.3	5.3	12.0	0.0	1.3	10.7	12.0	1.3	28.0	4.0	4.0	2.7	9.3
Health workforce (n = 72)	4.2	4.2	4.2	2.8	1.4	2.8	8.3	0.0	37.5	4.2	4.2	12.5	13.9
Financing (n = 13)	0.0	0.0	7.7	0.0	0.0	0.0	7.7	0.0	46.2	7.7	7.7	7.7	15.4
Medical products, vaccines and technology (n = 12)	0.0	8.3	0.0	8.3	0.0	0.0	16.7	0.0	33.3	8.3	8.3	8.3	8.3
Leadership and Governance (n = 3)	0.0	33.3	0.0	0.0	0.0	0.0	33.3	0.0	33.3	0.0	0.0	0.0	0.0
What were the barriers to telemedicine?													
Religious beliefs (n = 11)	0.0	0.0	9.1	0.0	0.0	0.0	0.0	0.0	63.6	0.0	0.0	18.2	9.1
Gender (n = 16)	0.0	0.0	6.3	0.0	0.0	6.3	0.0	0.0	43.8	0.0	0.0	18.8	25.0
Cost (n = 74)	1.4	1.4	9.5	0.0	0.0	2.7	4.1	0.0	31.1	12.2	12.2	12.2	13.5
Literacy (n = 80)	5.0	2.5	10.0	0.0	1.3	6.3	5.0	0.0	36.3	3.8	3.8	10.0	16.3
Sustainability (n = 94)	4.3	3.2	9.6	0.0	1.1	7.4	3.2	0.0	34.0	5.3	5.3	10.6	16.0
Accessibility (n = 122)	4.9	1.6	9.0	0.0	1.6	4.9	7.4	0.8	33.6	5.7	5.7	13.1	11.5
Social acceptability (n = 131)	3.1	3.8	9.9	0.0	1.5	6.1	7.6	0.8	32.1	4.6	4.6	13.0	13.0
Technology (n = 188)	0.5	2.7	6.4	0.5	2.1	5.9	6.4	0.0	38.3	5.3	5.3	10.6	16.0

Note: CVD: Cardiovascular Diseases; CeVD: Cerebrovascular Diseases; DM: Diabetes Mellitus; Rehab: Disease Rehabilitation; Dyslip: Dyslipidemia; HTN: Hypertension; ID: Infectious Diseases; Malnut: Malnutrition; MCH: Maternal and Child Health; Onc: Oncology; Ophth: Ophthalmological Conditions; Psych: Psychiatric Conditions.

Table 2: **Overview of telemedicine tools, intervention domains, and outcomes across health conditions.**

(66.7%), cerebrovascular disease (60%), cardiovascular diseases (56.3%), and psychiatry (52.4%). Nurses were the second most common service providers in telemedicine studies on disease rehabilitation (33.3%), cardiovascular diseases (25%), and hypertension (23.5%). ASHA workers were the service providers in hypertension (26.5%) cardiovascular diseases and malnutrition (25% each). Allied health workers were also used as service providers in oncology and ophthalmology (29.6% each).

For the various WHO building blocks of intervention, almost all studies evaluated the service delivery building block, while health workforce and health system information were the next most commonly evaluated WHO building blocks. Leadership and governance and financing were the least commonly studied while there were a few studies on medical products, vaccines, and technologies, mainly in disease rehabilitation and cerebrovascular diseases.

The barriers to telemedicine varied for different health conditions. The major common barriers include accessibility, religious beliefs, social acceptability, gender, literacy, cost, sustainability, and technology. Overall, technology appears to be the most significant barrier to telemedicine, with a range of 6.3%–50% across diseases. Other barriers vary across diseases, but social acceptability, cost, and accessibility are common barriers for several diseases. For instance, social acceptability is a barrier for 50% of cerebrovascular diseases and 40.5% of psychiatry cases. The cost was not a barrier to disease rehabilitation but was relevant for oncology and ophthalmology. Accessibility was a barrier for psychiatry, cardiovascular diseases, and oncology. Literacy was an important barrier to cardiovascular and cerebrovascular diseases. Gender, and religious beliefs, appear to be less of a barrier for telemedicine in most studies, with less than 10% of studies identifying them as a barrier.

Discussion

This review of telemedicine in primary care in India sought to address four pivotal inquiries concerning telemedicine's role in improving outcomes in primary care within the Indian healthcare system. The first was to identify inadequacies and gaps in existing evidence in telemedicine research in primary healthcare in India. Despite recognizing telemedicine's potential to revolutionize primary healthcare delivery, the current evidence base displayed several deficiencies. Notably, there is a scarcity of high-quality, actionable research on telemedicine interventions, which impedes the ability to draw definitive conclusions regarding their effectiveness. Challenges such as lack of standardization in telemedicine usage, heterogeneity in interventions, small sample sizes, and selection bias among participants further exacerbate these limitations. Additionally, there is a notable absence of cost-effectiveness studies across various disease conditions and outcomes in primary care, which hinders scalability and sustainability. The discernible influence of leadership practices and governance structures on the quality of care delivered through telemedicine, as well as their impact on access, equity, and affordability, is evident. Despite 376 studies evaluating service delivery, only three studies have examined leadership and governance aspects. Leadership holds pivotal significance in shaping implementation and success, playing a central role in driving transformative change. Governance structures are instrumental in ensuring accountability, regulation, and ethical considerations in telemedicine service delivery and must be tailored to address the specific needs and challenges of primary care telemedicine in India. To address these inadequacies, there is a pressing need for more rigorous research methodologies, standardized protocols, and increased focus on cost-effectiveness analyses as well as studies examining leadership and governance.

Technological advancements have greatly improved telecardiology practices, allowing for remote monitoring, diagnosis, and management of heart conditions with wearable ECG monitors and smartphone apps.[9–12] These tools enable continuous cardiac health tracking, seamless data transmission to healthcare providers, and prompt feedback, reducing the need for regular hospital visits for heart disease patients.[13] While telecardiology has advanced in India, technical barriers persist for other diseases like diabetes or chronic respiratory conditions, presenting significant challenges.[3,14] These include a lack of specialized remote monitoring tools for accurate disease-specific indicators and the absence of comprehensive platforms for complex health data analysis. Additionally, deploying telemedicine for these conditions is hindered by varying levels of digital infrastructure robustness and technological proficiency among patients and healthcare providers in India.[3] Addressing these challenges requires concerted efforts to develop and validate telemedicine technologies tailored to specific diseases, alongside initiatives to enhance digital literacy among stakeholders and strengthen telemedicine infrastructure.[14] These steps will broaden telemedicine's reach and effectiveness across various diseases, ensuring equitable access to high-quality healthcare services regardless of condition or geographic location.[7]

The second inquiry focused on identifying barriers to implementing telemedicine in primary healthcare in India, revealing several obstacles. These include technological challenges, accessibility issues, social acceptability concerns, cost constraints, and sustainability considerations.[15] Technological hurdles encompass inadequate internet connectivity, interoperability issues between telemedicine platforms, and gaps in digital literacy.[16] Social acceptability poses a significant barrier, driven by cultural norms, language differences, and a

preference for in-person consultations, especially in rural areas. Financial limitations and the lack of sustainable funding models also hinder broader adoption and research into telemedicine solutions. Additionally, the absence of smartphones or computers for many patients further limits access to telemedicine services. As reliance on digital platforms for healthcare grows, concerns about patient data security and breaches intensify, necessitating robust cybersecurity measures. Gender differences and patients' religious beliefs can influence healthcare-seeking behavior and preferences for accessing healthcare services, impacting the successful implementation of telemedicine in primary care.[17] India's linguistic diversity with 22 major languages and several hundred dialects presents communication challenges, which can be addressed by involving local consultants to ensure comfortable conversations. Fragmented regulations and the absence of comprehensive digital health policies impede uniform deployment and scaling of digital health solutions. While cost evaluations exist for specific diseases, further investigation is needed for others.[9,18] Social and cultural factors, language barriers, and patient preferences for face-to-face consultations affect the social acceptability of telemedicine, particularly in rural areas.[17,19,20] Long-term planning and funding are lacking in many telemedicine studies, emphasizing the need for sustainable approaches like the 'Tuver' project in Gujarat.[21] Addressing these technological barriers is crucial for optimizing the reach and effectiveness of telemedicine services in India, ensuring equitable access to digital health innovations for all population segments.

The third objective was to scrutinize the strengths, weaknesses, opportunities, and threats of telemedicine research in primary healthcare in India. Telemedicine services for primary care in India have the strength of providing patients residing in remote and rural areas, easy access to quality and affordable healthcare, reducing travel and work loss costs, and have the potential to improve patient outcomes through earlier diagnosis and guideline-based treatment. One of the most important success stories in India was the Imtecho project in Gujarat which reduced infant mortality by 16% using ASHA workers.[22] Other key success stories include improved uptake of immunization among children in Haryana,[23] safer maternal health practices in Mumbai[24] and Bihar,[25] better diabetic control in Chennai, Mumbai, and higher diagnosis of diabetic retinopathy.[26] Remote diagnostic facilities can be set up with telemedicine for various diseases and with several messaging services, can increase patient engagement for better outcomes such as improved adherence to antiretroviral and anti-tubercular treatment and improved prevention practices of HIV transmission from mother to child and greater reduction in cardiovascular risk factors.[12] The Nielsen Bharat 2.0 Internet Study[27] unveils critical data, showing that while rural India surpasses urban areas in the number of internet users with 352 million individuals online, a significant 60% of the rural populace remains offline. This contrast suggests substantial potential for expanding digital access. Urban areas, despite a 59% internet penetration rate accounting for 294 million users, still face challenges in bridging the digital gap. The overall internet user base in India reached 646 million as of December 2021, with rural growth rates (45%) surpassing urban rates (28%) since 2019. Remarkably, female internet usage has surged by 61% in the past two years, outpacing male growth rates and indicating a shift towards gender parity online. Daily internet access is nearly universal among users, with mobile phones dominating as the primary access point across all demographics. Weaknesses in the current research evidence include limitations in generalizability, reliance on self-reported data, lack of long-term follow-up, and absence of cost-effectiveness analyses. Many studies focus on specific geographic areas or populations, which may hinder the applicability of their findings to other contexts.[15,19,28–30] Reliance on self-reported data introduces the possibility of biases or inaccuracies.[9,25,31] Short follow-up periods in some studies may not capture the long-term effects of telemedicine interventions.[22,31,32] Moreover, the absence of cost-effectiveness analyses limits the scalability and sustainability of telemedicine services.[19,23,33] Telehealth holds the potential to bridge the primary care gap by offering remote access to healthcare services, particularly in regions facing shortages of healthcare professionals. However, it can aggravate disparities among specific populations. For instance, research indicates that groups disproportionately affected by COVID-19 also encountered increased challenges in accessing telehealth.[34] Furthermore, factors such as older age, female sex, ethnicity, non-English language preference by the patient, and lower household income were associated with reduced utilization of video for telemedicine visits.[35,36] These findings suggest that the expansion of telehealth during the COVID-19 pandemic did not significantly alter pre-existing disparities in access to primary care. Health systems should implement evidence-based strategies to deliver care equitably, including representative provider networks, targeted and empowering outreach efforts, co-development of culturally and linguistically appropriate tools and technologies, and the provision of enabling resources and services. Significant opportunities for the expansion of telemedicine services exist: the increasing spread of cell phones and internet connectivity has made telemedicine more accessible, particularly for remote and rural populations.[37] Furthermore, investments from both the government and private sector need to be scaled up to seize these opportunities and overcome the challenges of healthcare access and affordability in India. Threats remain: the absence of reimbursement and payment systems may jeopardize the long-term viability of

telemedicine services, particularly for low-income patients.[38] In the lack of established protocols and norms, service quality and patient outcomes may vary. Depending on their region or healthcare practitioner, patients may receive varying intensity of diagnostic services and treatment. In response to the COVID-19 pandemic, health insurance companies have recently made significant policy changes to include telemedicine consultations for reimbursement.[39] However, these policies are still in their infancy and require further development to ensure their effectiveness and sustainability over time. Patients may be concerned about the lack of data privacy and security protocols, which may limit their use.[22,40]

Finally, we aimed to examine the diseases and outcomes targeted in telemedicine research in primary healthcare in India that have a potential impact on public health and we identified maternal and child health, psychiatric diseases, diabetes, infectious diseases, and hypertension emerge as predominant focus areas that have been evaluated. The telemedicine interventions primarily encompass patient education, behavior modification, point-of-care diagnosis, and telefollow-ups, and observed a positive impact on public health outcomes. Several telemedicine research projects have been successful in improving outcomes in primary care in India in child health,[17,19,22–25,30] diabetes mellitus[26,31–33,41] psychiatric conditions,[31,42] and infectious diseases.[18,28,40,43,44] Successful interventions include the Kilkari program for maternal education,[45] the m-MITRA project for improving infant care,[24] and various telemedicine interventions for child health to improve immunization uptake, child nutrition, and development using various communication channels.[17,19,20,22–25,29,30,43] Telemedicine interventions (Chunampet Rural Diabetes Preventive Project) have successfully improved diabetes control and reduced healthcare burden.[32,33,41,46] Programs like mWellcare improved drug adherence,[31,47] while mPower, mWellcare cluster RCT,[31] and TETRA[48] enhanced clinical decision support systems. Telepsychiatry interventions, such as SCARF[49] and CHAMP programs[50] improved mental healthcare access in rural areas. Telemedicine has improved the diagnosis and treatment of tuberculosis (LearnTB)[51] and HIV[18,40,44] including early HIV diagnosis in infants, and prevention of mother-to-child transmission.[20,23–25,30,43] One of the glaring drawbacks was the lack of telemedicine services for respiratory diseases in India. Poseidon study,[52] observed that respiratory conditions are the most common reason (>50%) for seeking primary care services. However, there is a need for more robust research methodologies and cost-effectiveness analyses to further validate the impact of telemedicine interventions on public health in India.

Ensuring data security and privacy is crucial for safeguarding health-related information shared between patients and medical practitioners. While existing legislation like India's Information Technology Act of 2000 (IT Act), the Intermediaries Guidelines of 2011, and the Data Protection Rules of 2011 make attempts to address these concerns, they lack specific standards for data security and protection in the context of telemedicine. With the proliferation of digital healthcare technologies, the Ministry of Health and Family Welfare (MoHFW) proposed the National Digital Health Authority (NeHA) to oversee the development of India's Integrated Health Information System (IHIS), a significant step towards digital health governance.[53] The introduction of the Digital Personal Data Protection Act, 2023 (DPDP Act) aims to regulate personal data handling, reinforcing privacy measures and establishing a data governance framework, signaling a pivotal move towards digitalization in India's healthcare sector. India's healthcare regulatory framework, comprising the IT Act, SPDI Rules, and the National Digital Health Mission (NDHM), promotes a unified digital health ecosystem. This ecosystem emphasizes interoperability among digital health systems and adheres to the Health Data Management Policy issued by the MoHFW. The DPDP Act underlines accountability for entities handling personal data, emphasizing privacy and data protection in digital health. Ongoing digital health initiatives by the MoHFW demonstrate a comprehensive approach to e-health, including the proposal of NeHA in 2015 and the launch of the National Health Policy (NHP)[54] in 2017. The NDHM,[55] launched in 2020, aims for a citizen-centric healthcare system, supported by the National Digital Health Blueprint (NDHB)[56] of 2019, outlining a structured digital health framework for efficient and standardized healthcare services nationwide.

In March 2020, India released its inaugural Telemedicine Practice Guidelines, jointly developed by the National Medical Council of India and NITI Aayog.[57] These guidelines establish the official framework for telemedicine practice, outlining protocols for patient–doctor interactions, prescriptions, and technology usage. They mandate that doctors maintain the same standard of care in teleconsultations as in-person visits, while also requiring patients to provide accurate information to medical professionals.

In 2020, India introduced the Health Data Management Policy to regulate health data collection and storage, emphasizing consent and privacy safeguards. A revised policy emerged in 2022, addressing concerns by creating the Ayushman Bharat Digital Account (ABHA)[58] for data localization and non-consensual data processing. Additionally, the government established an Integrated Health Information Platform to integrate Electronic Health Records (EHRs) nationwide, enhancing interoperability.[59] The proposed Digital Information Security in Healthcare Act (DISHA)[60] aimed to give individuals control over their digital health data

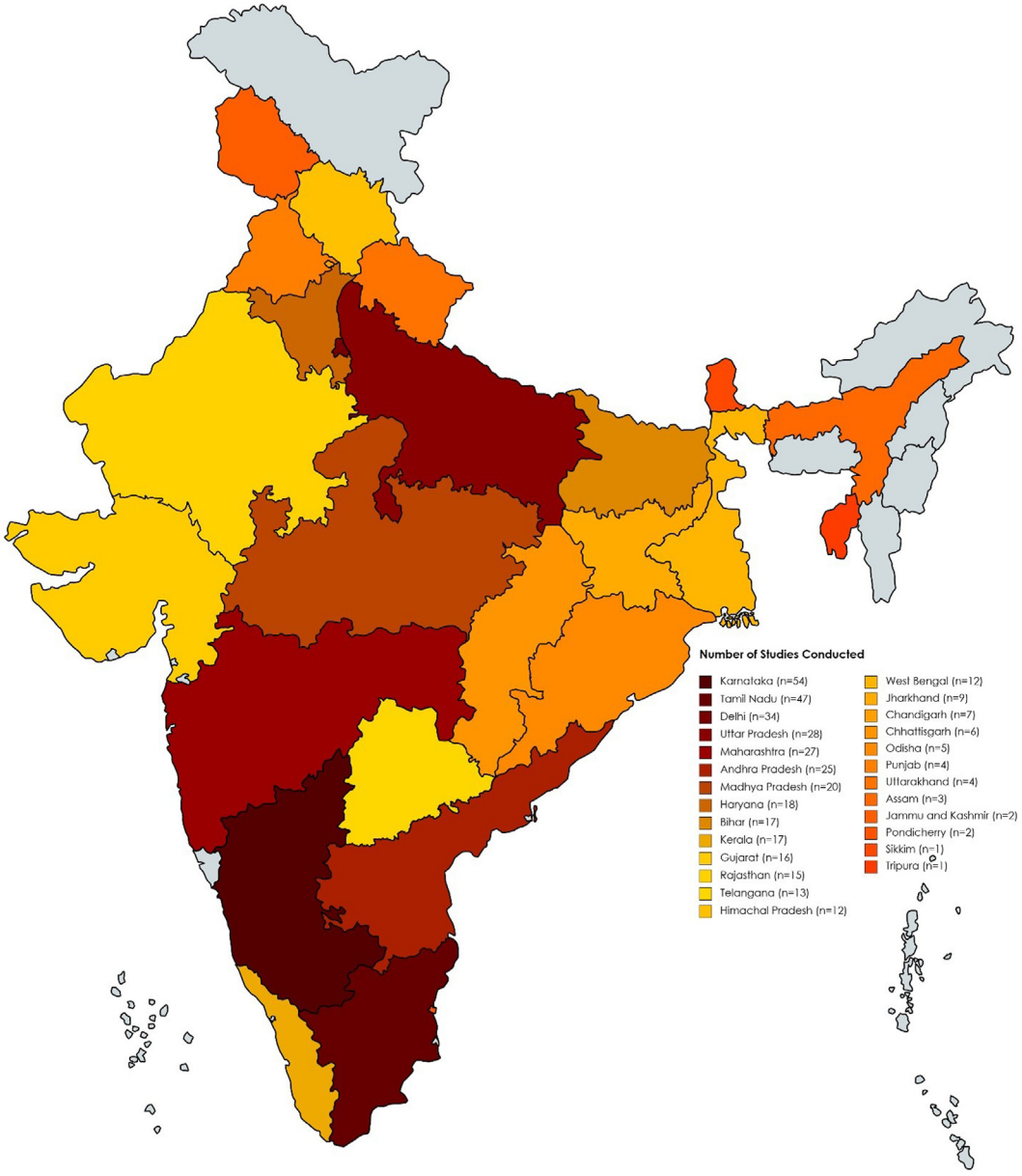

Fig. 1: A summary of the locations where research focused on telemedicine was carried out in primary healthcare facilities from 2011 to 2021 (n = 388). Note: The total number of studies are 388. Some studies include multiple study sites. Therefore, the total exceeds the sum of actual studies. In some studies, the study sites were not clear (n = 66).

and support secure data exchange. However, it was replaced by the Personal Data Protection Bill (PDP Bill) in Parliament, which aimed to enhance privacy and regulate data handling. Facing scrutiny over consent issues and government access to data, it was withdrawn in 2022. Subsequently, the draft Digital Personal Data Protection Bill (DPDP Bill)[61] was released, aiming for a comprehensive data protection framework. Approved in 2023, it raised concerns over privacy violations, data processing harms, and lacked rights for data portability.[62] Additionally, its criteria for international data transfer and short, renewable terms for Data Protection Board members might impact its independence. This evolving legal landscape underscores the need for clear, enforceable standards to ensure data privacy, security, and patient rights in India's digital healthcare ecosystem.

India's healthcare landscape, diverse in resource availability, cultural contexts, and technological infrastructure, is profoundly shaped by leadership practices

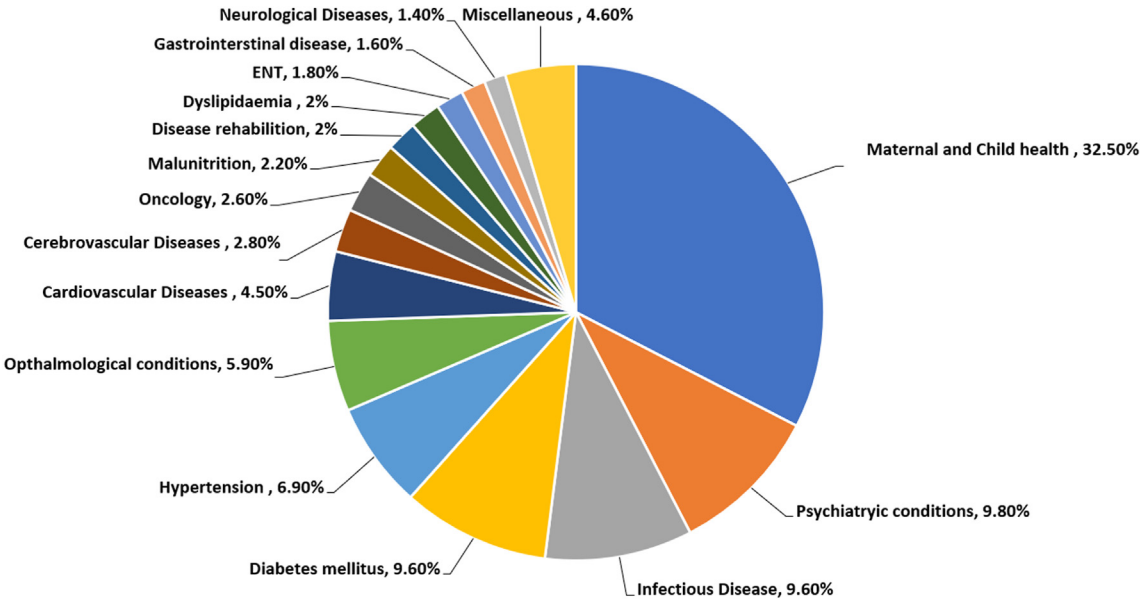

Fig. 2: Different healthcare conditions that were studied utilizing telemedicine in primary care settings in India from 2011 to 2021 (n = 388). Note: Miscellaneous (4.60%) include chronic kidney disease (0.80%); Dermatological Conditions (0.80%); Rheumatology (0.60%); Trauma (0.60%); Hematological Diseases (0.60%); Palliative Care (0.40%); Dentistry (0.40%); Endocrine Disorders (0.40%).

and telemedicine adoption.[63–65] Effective leadership and governance structures are pivotal in ensuring quality telemedicine services, impacting access, equity, and affordability. However, challenges arise due to inadequate leadership preparedness, including a limited understanding of digital health leadership and literacy barriers among political leaders. This leads to hesitancy in adopting new digital health initiatives.[3,5,66–68] Navigating these complexities requires fostering innovation and ensuring accountability in governance structures.[69] Tailored governance is essential to address telemedicine's unique needs, such as overcoming infrastructure limitations and cultural barriers. Additionally, addressing social acceptability and sustainability issues is crucial for maximizing telemedicine's potential across diverse population segments. Leaders must prioritize education, cross-sector collaboration, and culturally sensitive policies. Overcoming leadership challenges necessitates addressing digital literacy and cultural diversity.[34] Effective leadership and governance are essential for telemedicine's success in advancing healthcare in India and ensuring equitable access to quality care. Fostered through informed, adaptable, and inclusive leadership, India can harness digital health services' full potential to improve healthcare outcomes nationwide.

Conclusion

In conclusion, digital healthcare in India holds the promise of enhancing access to quality care, particularly for marginalized groups. Nonetheless, this potential is contingent upon overcoming significant legal, ethical, and structural hurdles.[68] The importance of digital literacy among healthcare professionals and the need for supportive infrastructure is crucial for effectively implementing digital health solutions. The COVID-19 pandemic underscored the urgency of establishing reliable telemedicine services, yet data protection and broader health sector investments, akin to those seen in countries like Malaysia, remain essential for success in India. Ethical issues, especially around informed consent, are paramount in ensuring digital healthcare serves those with limited access to quality care without exploiting vulnerable populations.[68] A robust data protection and informed consent framework is vital for upholding individuals' rights within digital health initiatives.[68] A rights-based health framework emphasizing informed consent, data control, and explicit access to healthcare rights is necessary. This approach should also consider the unique socio-cultural dynamics within India, including caste and indigenous community intersections, applying the five dimensions of healthcare access to ensure equitable digital health interventions.[68] Addressing these challenges requires a multifaceted approach, including rigorous research to fill evidence gaps, particularly in cost-effectiveness, leadership, and the impact of telemedicine across diverse conditions and regions. Success will depend on the concerted efforts of clinicians to adapt and policymakers to enhance infrastructure, promote digital literacy, and develop evidence-based policies, driving a comprehensive

Search strategy

We searched online databases PubMed, Scopus, TRIP, Google Scholar, India Kanoon, and Cochrane database. There was a manual search of grey literature in the English language for online news articles and government documents. The time for the review was from 2011 to 2021. An initial screening search was performed on 17 July 2021 to identify available evidence, while a detailed search was conducted on 13 December 2021. We used key search terms related to Telemedicine, India, primary healthcare, healthcare access, quality, cost, facilitators, and barriers for telemedicine and combined them with Boolean operators (Supplementary file: Supplementary Table S1). We included only original research studies conducted in India, which assessed various aspects of telemedicine within a primary care setting, studies strategized and supervised by investigators in tertiary care but implemented in primary care settings. Additionally, the studies had to be published in English. On the other hand, studies that did not meet these inclusion criteria were excluded from the review. The complete data extraction form with all the variables and definitions collected has been attached (Supplementary file: Data form and Supplementary Table S2). Geographically, the majority of studies were from Karnataka (n = 54, 13.9%), followed by Tamil Nādu (n = 47, 12.1%), Delhi (34, 8.8%), Uttar Pradesh (28, 7.2%) and Maharashtra (27, 7.0%). Other states, including Andhra Pradesh, Madhya Pradesh, Haryana, Bihar, and Kerala, contribute significantly to the research landscape. Smaller but noteworthy contributions come from Gujarat, Rajasthan, Telangana, and various other regions (Fig. 1). An increase in the number of studies from the year 2011–2021 was observed, with the highest number of studies in 2020 (n = 74).

healthcare transformation that can serve as a benchmark for global digital healthcare innovation.

Contributors

The study was conceptualized and designed by and AP, SJ, AGJ, OJ, TDS, and PAM. AP, TG, MBK, SJ, VJC, OJ, TDS and PAM designed the search strategy. AP, TG, MBK, SJ, MKU, RP, AN, UP, EI and VJC, conducted the searches, retrieved articles, and screened the full text of potentially relevant articles. AP, TG, MBK, SJ, MKU, RP, AN, UP, EI, AGJ, VJC and PAM were responsible for the data analysis. AP, MKU, and PAM wrote the first draft of the manuscript. AGJ, OJ, TDS, and PAM provided critical comments on drafts of the manuscript. AP and MKU produced all figures. TDS and PAM supervised the review. All authors contributed to data interpretation, writing of the manuscript, and have approved the final submitted version of the manuscript. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. All authors had full access to the data in this study and had final responsibility for the decision to submit for publication.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lansea.2024.100431.

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