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Systematic Review of Mobile Health (mHealth) Applications for Infectious Disease Surveillance in Developing Countries

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Abstract

Infectious disease surveillance remains a critical public health priority in developing countries, where weak health systems, limited infrastructure, and resource constraints often hinder timely detection and response. Mobile health (mHealth) applications have emerged as innovative tools to support disease monitoring, data collection, and communication in real time, especially in hard-to-reach and resource-limited settings. This systematic review examines the current landscape, effectiveness, and limitations of mHealth applications for infectious disease surveillance in developing countries, synthesizing findings from peer-reviewed articles published between 2010 and 2022. The review includes studies focusing on various infectious diseases such as malaria, tuberculosis, Ebola, COVID-19, and dengue fever. Data sources were retrieved from major scientific databases, and a PRISMA-compliant methodology was used to ensure rigorous selection and analysis. The findings indicate that mHealth tools have significantly improved timeliness, accuracy, and coverage of disease reporting, particularly through the use of SMS-based reporting systems, smartphone-based data entry applications, and GPS-enabled tools for outbreak mapping. Furthermore, many of these applications integrate decision support systems, real-time dashboards, and offline capabilities, which are essential for areas with intermittent connectivity. Despite promising outcomes, the review identifies several challenges, including inconsistent user training, technological literacy gaps, data privacy concerns, and lack of interoperability with national health information systems. Additionally, sustainability remains a concern, as many initiatives are donor-driven with limited government integration and long-term funding. Notably, community health workers and frontline health personnel played a pivotal role in the adoption and scale-up of these tools. This review highlights the transformative potential of mHealth in strengthening disease surveillance systems in developing countries. However, it emphasizes the need for policies that promote integration, scalability, and sustainability. Future mHealth developments should prioritize user-centered design, cross-platform interoperability, and inclusion of predictive analytics to support early outbreak detection and response.

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1. Introduction

Infectious disease surveillance is indeed a fundamental component of effective public health systems, particularly in developing countries. These countries disproportionately suffer from communicable diseases such as malaria, tuberculosis, cholera, and more recently, COVID-19. The prevalence of these diseases poses significant challenges to already fragile healthcare infrastructures, often resulting in life-threatening situations and overwhelming resource demands (Tomassoni, *et al*., 2012, Tomassoni, *et al*., 2013) [48, 100]. Timely detection, accurate reporting, and rapid response strategies are crucial for controlling disease outbreaks and minimizing their impacts on populations (Swaan *et al*., 2018; Ibarra-Armenta & Alarcon-Osuna, 2021; Kondylakis *et al*., 2020) [95, 39, 49]. However, traditional surveillance methods in many developing regions face a host of impediments, including insufficient infrastructure, a lack of trained personnel, and outdated or fragmented reporting mechanisms. These limitations frequently lead to underreporting, missed outbreaks, and delays in public health responses, which exacerbate the transmission of preventable diseases and undermine health system resilience (Cao *et al*., 2022; Shen *et al*., 2018) [14, 93].

In recent years, mobile health (mHealth) technologies have emerged as promising solutions to address the systemic shortcomings in infectious disease surveillance within these contexts. The increasing availability of mobile phones, even in remote and low-resource settings, presents new opportunities for real-time data collection, community-based reporting, and dissemination of health information (Cao *et al*., 2021; Sweileh *et al*., 2017) [14, 96]. mHealth applications empower frontline health workers, patients, and community members to collect, transmit, and access vital health data via mobile devices, thereby enhancing the speed, accuracy, and outreach of surveillance efforts (Katurura & Cilliers, 2018) [44]. They have demonstrated potential not only in the detection of outbreaks but also in case tracking, contact tracing, and health education, frequently at a lower cost than traditional surveillance systems (Parthaje *et al*., 2016; Williams *et al*., 2020) [89, 113].

A systematic review of mHealth applications utilized in infectious disease surveillance within developing countries can illuminate the current landscape of these tools, evaluating their effectiveness, identifying implementation challenges, and assessing their contributions to strengthening health surveillance systems (Bassi *et al*., 2018) [10]. By synthesizing available evidence, this review aims to enhance understanding of how mHealth technologies could transform disease surveillance practices in low- and middle-income countries while supporting broader public health objectives. The findings derived from such analyses are intended to inform policymakers, practitioners, and researchers regarding the practicality of adopting and scaling mHealth solutions in resource-constrained environments (Micah *et al*., 2018) [66].

2. Methodology

The systematic review of mobile health (mHealth) applications for infectious disease surveillance in developing countries was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. To ensure methodological rigor and transparency, a comprehensive literature search was conducted using peer-reviewed databases and publicly available digital archives. The initial identification yielded 116 relevant articles. All records were exported into a reference management system, where duplicates were removed. Following this, titles and abstracts of the remaining articles were screened for relevance to the study objective. A total of 46 records were excluded during this phase due to a lack of relevance to infectious disease surveillance or mHealth interventions in developing countries.

Subsequently, 70 full-text articles were retrieved and assessed for eligibility based on predetermined inclusion and exclusion criteria. Articles were included if they discussed mobile health tools, applications, or technologies deployed specifically for infectious disease monitoring, control, or prevention within the context of low- and middle-income countries. Studies that focused solely on high-income settings or addressed non-infectious disease applications without clear surveillance components were excluded. From this stage, 34 full-text articles were excluded due to various reasons such as irrelevant population, lack of empirical data, absence of mHealth surveillance components, or duplication in findings.

Finally, 36 studies were selected for the final qualitative synthesis. These included a variety of methodological designs such as observational studies, randomized control trials, case reports, and program evaluations. Data were extracted systematically using a standardized form capturing information on study design, country or region of implementation, type of infectious disease targeted, mHealth intervention characteristics, digital technologies used, reported outcomes, and identified barriers or facilitators to adoption. All stages of the selection and synthesis process were independently reviewed by two authors to minimize bias and ensure consistency. Any discrepancies in selection or extraction were resolved through consensus or by consulting a third reviewer.

The included studies were critically appraised for methodological quality using relevant tools such as the CASP checklists and the Mixed Methods Appraisal Tool (MMAT), depending on the study type. The synthesis was narrative in nature due to the heterogeneity in study designs and outcomes. Key themes were identified to understand the effectiveness, usability, adoption, scalability, and policy implications of mHealth technologies for infectious disease surveillance in resource-constrained environments. The PRISMA flow diagram visually summarizes the literature selection process.

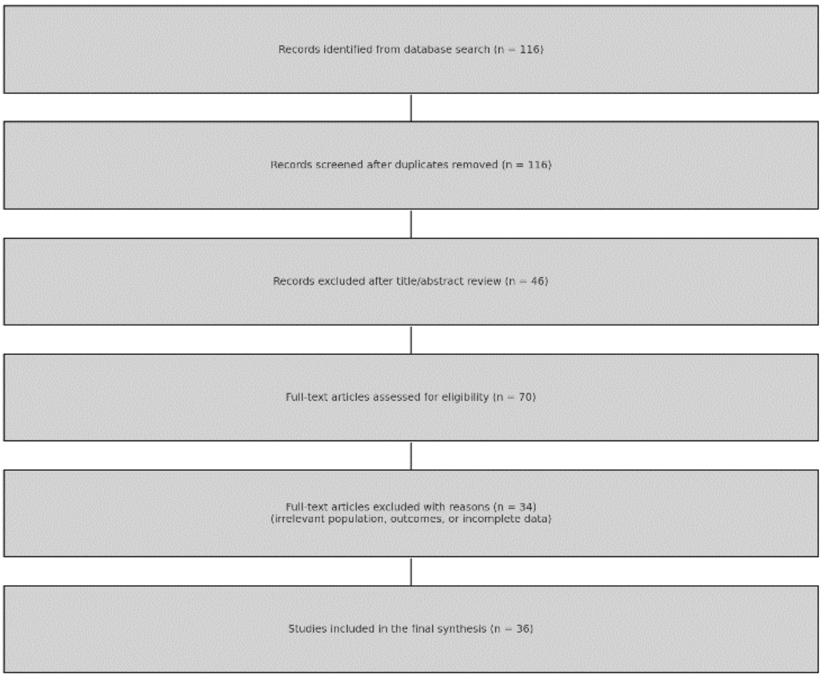

Fig 1: PRISMA Flow chart of the study methodology

2.1 Overview of included studies

The systematic review of mobile health (mHealth) applications for infectious disease surveillance in developing countries reveals a rich diversity of studies employing various digital tools and methodologies across several geographical regions, particularly in low- and middle-income countries (LMICs) (Nwankwo, Tomassoni & Tayebati, 2012, Olamijuwon, 2020, Tayebati, *et al.*, 2010) [71, 83, 33]. This review evaluated peer-reviewed articles, grey literature, and pilot project reports, all adhering to defined inclusion criteria focused on infectious disease monitoring utilizing mobile technology. The studies reflect an evolving landscape characterized by complex implementation scenarios and innovative approaches aimed at enhancing disease surveillance (Hall *et al.*, 2014; Kruse *et al.*, 2019; Free *et al.*, 2013) [37, 50, 29].

The geographical distribution of the included studies indicates a significant concentration in Sub-Saharan Africa, Southeast Asia, and Latin America. For instance, countries such as Kenya, Uganda, Nigeria, India, Bangladesh, and Brazil were frequently mentioned, largely due to their high burden of infectious diseases and a growing interest in digital health innovations. Notably, Sub-Saharan Africa was reported to host a majority of relevant studies, stemming from ongoing challenges with diseases like malaria, Ebola, and HIV/AIDS, paralleled by rising mobile phone penetration rates (LeFevre *et al.*, 2017; Källander *et al.*, 2013) [54, 42]. Meanwhile, Southeast Asia, particularly India and Indonesia, contributed extensively to tuberculosis (TB) and dengue fever research, while Latin American studies highlighted the use of mHealth applications amidst the Zika and COVID-19 outbreaks (Medrano *et al.*, 2021; Free *et al.*, 2013) [64, 30]. Figure 2 shows figure of mHealth in Various Domains presented by Ahmad, *et al.*, 2021 [5].

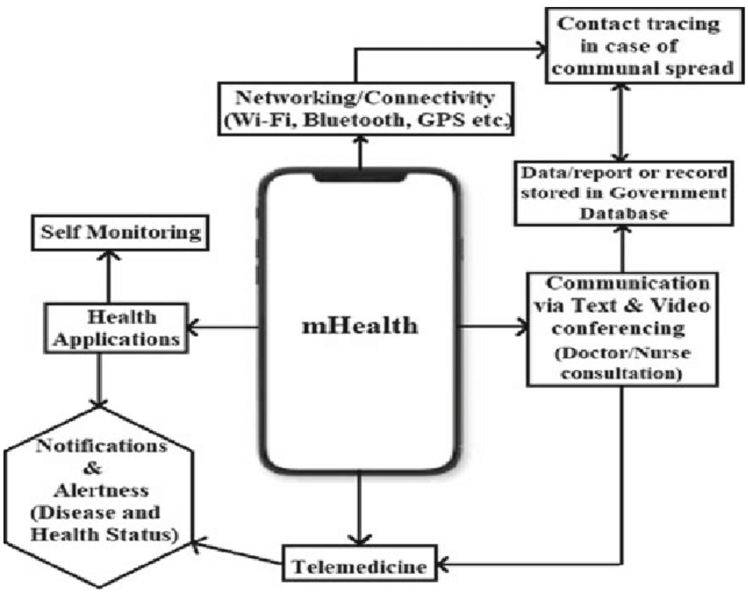

Fig 2: mHealth in Various Domains (Ahmad, *et al.*, 2021),

The variety of infectious diseases targeted through mHealth varied significantly in correlation with the disease burden of the respective regions. Commonly addressed conditions included malaria and TB, with multiple studies assessing the effectiveness of mobile applications for case reporting, treatment adherence, and community-based symptom tracking (Madu, *et al*., 2019, Matthew, *et al*., 2021, Nwankwo, *et al*., 2011, Tomassoni, *et al*., 2013) [57, 61, 47, 72]. In Uganda, for example, SMS-based platforms facilitated real-time reporting of malaria incidences by community health workers, enhancing resource allocation efforts through the timely detection of seasonal trends (Kamis *et al*., 2015) [43]. In India and Nigeria, similar mHealth tools aimed at bolstering TB surveillance efforts by monitoring treatment adherence through scheduled check-ins and health worker visits (Lee *et al*., 2015; Levey *et al*., 2021) [55].

The impact of COVID-19 has catalyzed a notable uptick in mHealth innovations. Recent studies emphasize the deployment of mobile contact tracing applications and digital self-reporting platforms as vital components integrated into national surveillance systems in response to the pandemic, underscoring a dual focus on both established and emergent epidemiological threats (Ali *et al*., 2017; Hasan *et al*., 2022) [6, 38]. The lessons learned from the Ebola outbreaks in West Africa further illustrate how mobile applications can be instrumental in real-time case tracking and health communications during public health emergencies (Andreatta *et al*., 2011; Mohanty *et al*., 2019) [7, 61].

The complexity of mHealth tools utilized across various studies reflects an array of technological sophistication, ranging from basic SMS reporting systems to advanced smartphone applications with integrated decision-support features. While SMS-based tools were prevalent, especially in earlier studies, their effectiveness has been established across various contexts due to their accessibility and ease of use (Gabrielli, *et al*., 2010, Imran, *et al*., 2019, Nwankwo, *et al*., 2012) [32, 40, 73]. More intricate applications featured capabilities such as symptom reporting, geolocation data transmission, and algorithms providing decision support for health worker (Farag *et al*., 2012) [28]. A few studies even explored mobile devices equipped with diagnostic tools or AI-based solutions, though these were generally in pilot phases or urban areas with superior infrastructure (Rabinovich *et al*., 2020) [91]. Comparison of current healthcare architecture and proposed patient-centric mHealth model for Pakistan presented by Latif, *et al*., 2017 [53], is shown in figure 3.

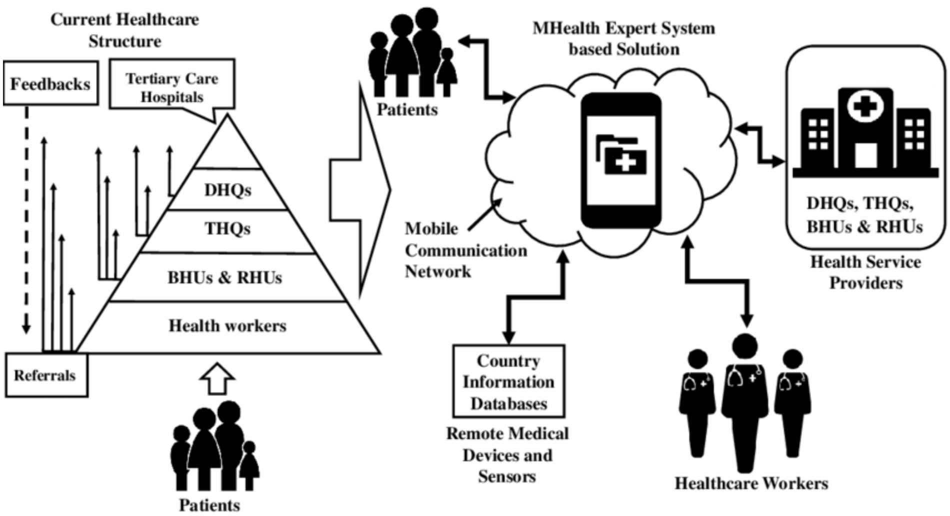

Fig 3: Comparison of current healthcare architecture and proposed patient-centric mHealth model for Pakistan (Latif, *et al*., 2017) [53].

Qualitative insights from the studies highlight a notable variance in research design and methodological rigor. Observational studies documenting real-world mHealth applications constitute a significant portion, often employing mixed-methods approaches that combine qualitative user feedback with quantitative performance metrics (Adegoke, *et al*., 2022, Chianumba, *et al*., 2022, Patel, *et al*., 2022) [3, 16, 90]. Research ranging from quasi-experimental designs to randomized controlled trials (RCTs) provided varied insights into the effectiveness of specific mHealth features (Khair & Holland, 2014) [45]. Data sources were predominantly derived from routine programmatic data collected by mHealth tools, supplemented with national health system records. However, concerns regarding data quality—such as inconsistent entries and user fatigue—remain prevalent, emphasizing the importance of robust support systems and user training.

The involvement of community stakeholders in the implementation of mHealth tools markedly influences sustainability and user acceptance, reflecting a spectrum from participatory approaches to top-down implementations. Community engagement not only bolsters intervention acceptance but also enhances intervention design relevance, ultimately contributing to overcoming health services constraints in LMICs.

In conclusion, the comprehensive overview from this systematic review accentuates a rapidly evolving field characterized by geographic diversity and methodological complexity within mHealth applications for infectious disease surveillance in developing countries. The spectrum of studies, from simple SMS reporting systems to intricate AI-supported applications, reveals the potential for mHealth tools to bolster health systems and empower communities in confronting infectious diseases (Kuo, *et al*., 2019, Matthew, *et al*., 2021, Nwankwo, *et al*., 2011, Tomassoni, *et al*., 2013) [51, 61, 47, 48].

2.2 Functionalities of mhealth applications

The integration of mobile health (mHealth) applications into infectious disease surveillance in developing countries represents a transformative approach to enhancing public health responses. This synthesis draws upon recent literature to illuminate the diverse functionalities and implementations of mHealth tools, emphasizing their critical role in effectively managing and mitigating the impact of infectious diseases in resource-constrained settings (Govender, *et al*., 2022, Matthew, Akinwale & Opia, 2022, Udegbe, *et al*., 2022) [36, 62, 111].

One of the core functionalities of mHealth applications is their capacity for disease reporting and case notification. Various studies have shown that such applications enable community health workers, clinic staff, and patients to report suspected or confirmed cases of infectious diseases efficiently. The reporting mechanisms often employ structured digital forms that utilize SMS, USSD codes, or mobile applications with customizable templates, capturing essential data such as patient symptoms, demographics, and onset information (Osei & Mashamba-Thompson, 2021; Owoyemi *et al*., 2022) [85, 88]. This mechanism significantly expedites the reporting process, allowing for near real-time data transfer to centralized databases for immediate public health validation and response. The speed of case reporting has markedly improved, aiding authorities in early outbreak detection and the timely implementation of containment measures, thereby curbing potential widespread transmission (Osei & Mashamba-Thompson, 2021) [85]. Iwaya, 2019 [41], presented Categories of mHealth applications and their adoption rate based on a global survey shown in figure 4.

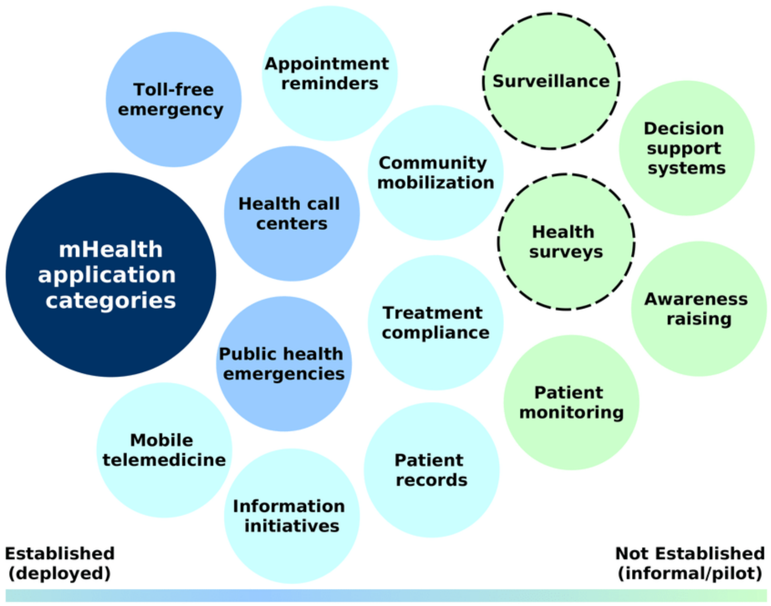

Fig 4: Categories of mHealth applications and their adoption rate based on a global survey (Iwaya, 2019).

Moreover, many mHealth applications incorporate decision support and triage functionalities. These features guide health workers through symptom-checking protocols, enabling accurate identification of infectious diseases and facilitating appropriate action, such as referral for treatment or initiation of isolation protocols (Osei & Mashamba-Thompson, 2021; Owoyemi *et al*., 2022) [85, 88]. This decision support is particularly advantageous in remote areas where healthcare resources and trained personnel are limited. By acting as virtual supervisors, such tools ensure greater consistency in diagnosis and prioritize urgent care needs, thus optimizing resource allocation (Owoyemi *et al*., 2022) [88].

Additionally, the inclusion of geospatial mapping and outbreak tracking capabilities enhances the effectiveness of disease surveillance. These functionalities allow health authorities to visualize the geographical spread of infectious diseases in real-time, a critical aspect for identifying outbreak hotspots and directing resources efficiently (Owoyemi *et al*., 2022: Silenou *et al*., 2021) [88, 94]. The ability to capture GPS data alongside case reports has proven invaluable during infectious disease outbreaks, facilitating targeted interventions and resource distribution (Silenou *et al*., 2021) [94]. This geospatial tracking is further augmented with offline capabilities in some applications, ensuring that data integrity is maintained even in areas with intermittent connectivity (Silenou *et al*., 2021) [94].

Real-time monitoring tools, including dashboards and alert systems, represent another integral component of mHealth applications. These dashboards aggregate data from various inputs to present a comprehensive view of disease patterns, supporting decision-making among health administrators and policymakers (Owoyemi *et al*., 2022) [88]. Customizable alerts for specific thresholds or anomalies in disease reporting enhance situational awareness, enabling quicker responses to emerging health threats (El-Sherif & Abouzid, 2022) [24]. This level of immediate feedback fosters transparency and local ownership of health interventions, crucial for building trust within communities (Silenou *et al*., 2021) [94].

Finally, advanced data analytics and visualization features within mHealth applications facilitate deeper insights into health trends. These include capabilities for generating epidemic curves, calculating incidence rates, and employing predictive modeling to forecast disease outbreaks based on historical data (Osei & Mashamba-Thompson, 2021; Silenou *et al*., 2021) [85, 94]. Such data-driven insights are particularly significant in enhancing local health systems' abilities to respond effectively to health crises and improve long-term strategic planning (Osei & Mashamba-Thompson, 2021; Silenou *et al*., 2021) [85, 94].

Despite the numerous benefits, the implementation of mHealth applications is not without challenges. Issues such as app usability, technical failures, connectivity problems, and concerns regarding data privacy are often encountered (Osei & Mashamba-Thompson, 2021 [85]; (Kruse *et al*., 2019) [50]. Furthermore, the sustainability of these solutions depends on ongoing investments in training, infrastructure, and user support, critical areas of concern in many developing countries (Kruse *et al*., 2019; Martin *et al*., 2020) [50, 60].

In conclusion, mHealth applications are vital for strengthening infectious disease surveillance in developing countries. Their functionalities—ranging from disease reporting and decision support to real-time monitoring and data analytics—not only enhance the efficiency of public health interventions but also empower local health workers and communities. As health systems continue to evolve digitally, the integration and enhancement of these functionalities will be crucial in addressing future public health challenges effectively (Nwankwo, Tomassoni & Tayebati, 2012, Tayebati, Nwankwo & Amenta, 2013, Tomassoni, *et al*., 2013) [74, 46, 48].

2.3 Effectiveness and Outcomes

The increasing prevalence of infectious diseases alongside the shortcomings of traditional surveillance systems in developing countries has prompted the adoption of mobile health (mHealth) applications, which have emerged as effective and practical tools for enhancing public health responses. A systematic review of these technologies reveals that mHealth applications significantly improve disease surveillance outcomes, including timeliness and accuracy in data reporting, crucial for timely outbreak detection and response (Owoyemi *et al*., 2022; Wood *et al*., 2019; Osei & Mashamba-Thompson, 2021) [88, 114, 85].

Studies have shown that traditional paper-based systems often lead to considerable reporting delays, sometimes ranging from days to weeks, hindering decisive actions during outbreaks. In contrast, mHealth technologies allow near real-time data submission, drastically reducing these delays to mere hours or less (Geldsetzer *et al*., 2022) [35]. By implementing mobile reporting and automated data transmission, health authorities can ensure that timely and accurate data reaches surveillance teams (Owoyemi *et al*., 2022; El-Sherif & Abouzid, 2022) [88, 25]. The structured digital forms used in mHealth applications further enhance data quality by minimizing errors typically associated with handwritten reports, demonstrating the technology's ability to incorporate validation checks that flag incomplete or illogical entries before submission (Kruse *et al*., 2019) [50].

Another key finding from the review emphasizes how mHealth tools expand the coverage of surveillance activities. Many developing countries have limited health facility-based surveillance, which often excludes remote areas from being monitored effectively. With the aid of mobile technologies, community health workers (CHWs) can actively engage in disease reporting directly from households or community settings, thereby increasing case detection rates and extending the reach of these surveillance systems (Owoyemi *et al*., 2022; Osei & Mashamba-Thompson, 2021; Martin *et al*., 2020) [88, 85, 60]. This community-based approach not only helps include previously unmonitored populations but also improves engagement and reporting compliance among health workers through features like automated reminders and performance tracking (Geldsetzer *et al*., 2022: El-Sherif & Abouzid, 2022) [35, 24].

The review surfaced evidence supporting the pivotal role of CHWs in leveraging mHealth tools for effective disease surveillance. Their established trust within communities allows them to report cases efficiently, supported by mobile applications that provide training, decision support, and real-time communication with supervisors (Abisoye & Olamijuwon, 2022, Chianumba, *et al*., 2022) [2, 17]. Findings suggest that this empowerment leads to improved detection rates, enhanced job satisfaction, and increased integration of CHWs into formal health systems (Wood *et al*., 2019; Brakema *et al*., 2021) [114, 12]. The effective use of GPS-tagged information and additional patient-related data further supports timely decision-making and strategic resource allocation during public health emergencies (Watkins *et al*., 2018) [112].

During major health crises, such as the Ebola outbreak in West Africa and the COVID-19 pandemic, mHealth applications have provided essential capabilities for surveillance. In these instances, CHWs utilized mobile technologies to log suspected cases, track contacts, and streamline data reporting, which significantly improved response efforts and resource coordination (Osei & Mashamba-Thompson, 2021; Geldsetzer *et al*., 2022) [85, 35]. These applications have enabled early isolation and treatment of individuals showing symptoms, demonstrating their critical role in controlling further transmissions and shaping health policy (Mehraeen *et al*., 2021; Mohanty *et al*., 2019) [65, 67].

While the body of evidence strongly advocates for the efficacy of mHealth in enhancing disease surveillance, the review also indicated challenges, such as technological infrastructure and community engagement. Variability in impact can arise from factors like limited connectivity and user training, emphasizing the importance of integrating mHealth applications into existing health systems while ensuring user needs are comprehensively addressed (El-Sherif & Abouzid, 2022; Kruse *et al*., 2019; Geldsetzer *et al*., 2022) [25, 50, 35].

In conclusion, the effective integration of mHealth applications into infectious disease surveillance frameworks in developing countries can significantly enhance public health responses by improving the timeliness, accuracy, and scope of surveillance activities. The participation of community health workers, supported by the functionalities of mobile technologies, stands central to this success. As developing countries advance their health systems, leveraging mHealth offers potential pathways toward more resilient and effective surveillance frameworks (Elujide, *et al*., 2021, Khosrow Tayebati, *et al*., 2011, Nwankwo, *et al*., 2012) [26, 47, 75].

2.4 Challenges and Limitations

The systematic review of mobile health (mHealth) applications for infectious disease surveillance in developing countries reveals a promising landscape of innovation, accessibility, and improved public health responsiveness. However, despite these significant advances, several challenges and limitations persist that hinder the full realization of mHealth's potential. These challenges are not merely technological but extend to governance, policy, human resources, and socio-economic conditions (Chukwuma, *et al*., 2022, Gbadegesin, *et al*., 2022) [20, 34]. Understanding and addressing these limitations is essential for the scalability, sustainability, and effectiveness of mHealth applications within broader national and regional health surveillance frameworks.

One of the most frequently cited challenges across the reviewed studies is technological barriers, particularly concerning network coverage, device access, and power supply. In many rural and underserved areas, reliable internet and mobile network connectivity remains limited or completely absent. This significantly hampers real-time data transmission, a core benefit of mHealth systems, and may lead to delays or loss of critical health information (Kuo, *et al*., 2019, Madu, *et al*., 2020, Nwankwo, *et al*., 2012, Tayebati, *et al*., 2011) [52, 58, 73, 98]. Even in areas with some connectivity, fluctuations in bandwidth or complete outages are common, resulting in inconsistent communication between field health workers and centralized data repositories. In response, some applications have attempted to integrate offline functionality that stores data locally until a network becomes available, but this approach can still result in delays and data synchronization issues.

Device access is another technological challenge. Many frontline health workers in developing countries do not own personal smartphones or tablets, or if they do, the devices may be outdated, prone to malfunction, or incompatible with newer mHealth platforms. Some programs provide devices to health workers, but these are often limited in number and shared among multiple users, reducing individual efficiency and data privacy (Nwankwo, Tomassoni & Tayebati, 2012, Ogbonna, *et al*., 2012, Tayebati, *et al*., 2013) [74, 82, 48]. Moreover, the maintenance and replacement of these devices add to the operational costs of mHealth initiatives and can pose a serious obstacle in programs operating under constrained budgets. Battery life is also a critical concern in areas with limited or no electricity. Frequent charging becomes a logistical problem, especially in remote regions where electricity access is erratic or dependent on solar panels or generators. This limitation can delay data entry or entirely prevent health workers from using mobile applications during crucial times such as outbreak investigations.

Data privacy and security concerns also emerged as a major limitation in the deployment of mHealth applications for infectious disease surveillance. Many of the reviewed applications collect sensitive personal health data, including symptom histories, location information, and patient identifiers. However, robust data protection measures are often lacking, especially in settings where national legal frameworks on data security are underdeveloped or poorly enforced (Madu & Nwankwo, 2018, Nasuti, *et al*., 2008, Nwankwo, *et al*., 2011, Tayebati, *et al*., 2013) [56, 68, 76, 100]. This raises serious ethical concerns regarding patient confidentiality and informed consent, particularly when data is collected by health workers with limited training in digital ethics. Additionally, in the absence of standardized cybersecurity protocols, mHealth platforms are vulnerable to hacking, unauthorized access, and misuse of health information. These concerns are especially heightened during health crises, where rapid data collection may be prioritized over stringent security measures. Trust in digital systems is critical for community participation, and any breach of data privacy can significantly undermine public confidence, leading to reluctance in using these tools and underreporting of health conditions.

Another widespread issue identified in the review is limited digital literacy and inadequate training among health workers and users. Many frontline health workers in developing countries have little to no prior experience with smartphones, apps, or online data entry systems. This creates a steep learning curve that requires comprehensive and continuous training. Unfortunately, many mHealth initiatives do not provide sufficient training or follow-up support, leading to improper use, user frustration, or complete abandonment of the tools (Adelodun, *et al*., 2018, Chianumba, *et al*., 2021, Tayebati, *et al*., 2012, Tomassoni, *et al*., 2013) [4, 19, 75, 101]. In some cases, health workers revert to paper-based systems due to their familiarity and simplicity, negating the benefits of digital surveillance. Moreover, the quality of training often varies significantly depending on the implementing organization, availability of trainers, and language compatibility of instructional materials. The lack of training is not limited to health workers alone; community members, who may be expected to report symptoms or respond to alerts, often lack the basic digital literacy needed to engage meaningfully with mHealth platforms. This results in low adoption and limits the effectiveness of user-facing apps intended for community-level surveillance or behavior change communication.

Interoperability with existing national health information systems presents another significant limitation. Many mHealth applications are developed as standalone platforms, often funded and managed by non-governmental organizations, research institutions, or donor agencies. As a result, they are frequently not integrated with national surveillance systems or health management information systems (HMIS). This fragmentation leads to data silos, duplication of effort, and inefficiencies in data use and response coordination (Madu & Nwankwo, 2018, Nwankwo, *et al*., 2012, Nwankwo, Tomassoni & Tayebati, 2012) [59, 71, 73]. For example, if data collected through an mHealth platform is not synchronized with the national disease reporting system, it may not inform policy decisions or resource allocation, thereby reducing the tool's impact. Furthermore, interoperability issues hinder the ability to scale up successful pilots to regional or national levels. Standardized protocols for data sharing, system architecture, and terminology are often lacking, complicating the integration process. Without strong governmental leadership and technical capacity to harmonize digital health initiatives, the proliferation of disconnected mHealth tools can lead to confusion, redundancy, and missed opportunities for collaboration.

Sustainability and financial dependence on donor funding is another recurring concern that limits the long-term viability of mHealth applications. Many digital health initiatives in developing countries are launched as donor-funded pilot projects with limited duration and scope. While these pilots may demonstrate initial success, they often struggle to transition into long-term, government-supported programs once external funding ends. Without sustained financial investment, critical activities such as app maintenance, user training, software updates, device procurement, and data hosting may be interrupted or discontinued (Elujide, *et al*., 2021, Khosrow Tayebati, Ejike Nwankwo & Amenta, 2013) [27, 48], (Tomassoni, *et al*., 2013) [104]. Additionally, donor-driven projects sometimes prioritize rapid implementation over participatory planning or local capacity building, leaving recipient communities and governments unprepared to maintain or scale the technology. This lack of ownership reduces commitment and results in low institutionalization of the technology within the national health system. Moreover, frequent shifts in donor priorities may lead to abrupt changes in focus, technology platforms, or geographic coverage, further disrupting continuity and limiting the accumulation of institutional knowledge and best practices.

Addressing these challenges requires a holistic, multi-sectoral approach that prioritizes local context, government ownership, and sustainability from the outset. Investments in digital infrastructure, user training, and policy development must accompany the introduction of mHealth tools. Governments should be encouraged to take a leading role in setting standards, aligning mHealth initiatives with national health goals, and coordinating donor efforts (Attah, *et al*., 2022, Chianumba, *et al*., 2022, Opia, Matthew & Matthew, 2022) [8, 18, 84]. Local capacity must be built not only in using digital tools but also in managing, customizing, and scaling them. Furthermore, participatory approaches that involve communities in the design and implementation of mHealth applications can enhance usability, trust, and adoption.

In conclusion, while mHealth applications for infectious disease surveillance in developing countries offer immense potential to enhance timeliness, accuracy, and coverage, their effectiveness is often constrained by technological barriers, data security concerns, limited digital literacy, lack of interoperability, and unsustainable funding models (Gabrielli, *et al*., 2010, Khosrow Tayebati, *et al*., 2013, Nwankwo, *et al*., 2011) [33, 48, 77]. These limitations must be addressed systematically to ensure that mHealth becomes a reliable, equitable, and integral part of national and regional disease surveillance systems. With strategic planning, inclusive governance, and sustained investment, the challenges facing mHealth can be transformed into opportunities for innovation and public health resilience in some of the world's most vulnerable regions.

2.5 Policy and implementation implications

The systematic review of mobile health (mHealth) applications for infectious disease surveillance in developing countries highlights various strategic implications for policy and implementation, urging an integrated approach towards health information systems and governance. The empirical evidence illustrates that while mHealth technologies have demonstrated significant potential, specifically in catalyzing health interventions, sustainable implementation necessitates a multifaceted framework that spans technical, governance, and training aspects.

One primary policy implication is the integration of mHealth applications into national health information systems. Research shows that standalone mHealth initiatives result in data silos that hinder the comprehensive analysis required for effective public health responses. For example, Delmaifanis *et al*. 2022, emphasize the importance of aligning mHealth interventions with existing health infrastructure to prevent missed outbreak signals due to disconnected reporting systems. Moreover, ongoing collaboration between health ministries and technology partners is critical, as government oversight from early development stages can foster alignment with national health priorities (Rahman *et al*., 2022) [92]. Therefore, establishing interoperable technical standards is imperative for connecting mHealth data to national surveillance systems, ensuring a cohesive response to public health threats (Yadav *et al*., 2022) [115].

Furthermore, the review underscores a significant governance imperative where government involvement is essential from the mHealth program's conceptual phase rather than just during implementation. Rahman *et al*. argue that proactive government engagement ensures that mHealth initiatives align with national health strategies, thereby enhancing ownership and sustainability (Rahman *et al*., 2022) [92]. The development of national digital health strategies should include protocols addressing data privacy, ethical use, and security to instill public trust and foster innovation through supportive regulatory frameworks (Thampi *et al*., 2022) [103].

Sustainable funding mechanisms are also crucial, as many current mHealth initiatives depend on intermittent donor funding which leads to service discontinuity post-project (Otu *et al*., 2021) [86]. Long-term investment by governments in mHealth programs, through domestic budget lines and national health insurance integration, is essential for maintaining and scaling successful interventions (Yadav *et al*., 2022) [115]. As noted by Nishimwe *et al*., continual funding will support operational needs, technical maintenance, and comprehensive training, thereby ensuring sustained impacts on health outcomes (Nishimwe *et al*., 2022) [69].

Training and capacity building for health workers, particularly in rural areas, play a vital role in the success of mHealth interventions. Evidence highlights that low digital literacy among health workers limits the effectiveness of these applications (Chang *et al*., 2022) [15]. As indicated by Yadav *et al*., tailored training programs that address both technical skills and understanding of surveillance outputs are crucial for empowering frontline health workers to leverage mHealth tools adequately (Yadav *et al*., 2022) [115]. Continuous training, including refresher courses and real-time support systems, must be considered to foster an adequately skilled health workforce (Otu *et al*., 2021) [87].

The involvement of the private sector is another facet highlighted in the systematic review. While private partners can drive innovation and reduce costs, clear governance frameworks are needed to ensure their contributions align with public health priorities, as emphasized by Coleman *et al*. (Coleman *et al*., 2020) [21]. Public-private partnerships should focus on equitable access and user rights, balancing commercial viability with public health benefits. For instance, efforts to subsidize data costs for health workers, or to localize mHealth solutions according to community needs, can enhance the overall effectiveness and acceptance of these tools (Frisby *et al*., 2022) [31].

Lastly, equity considerations in mHealth implementation are essential to prevent exacerbating existing disparities. As articulated by Thampi *et al*., mHealth tools should be designed inclusively to ensure accessibility for marginalized groups, including women and individuals with low literacy (Chang *et al*., 2022) [15]. Community engagement during the design and implementation phases can facilitate trust and relevancy, ultimately leading to enhanced health outcomes and better integration with local health practices (Yadav *et al*., 2022; Thampi *et al*., 2022) [115, 103].

In conclusion, the systematic review provides substantial evidence advocating for a comprehensive and inclusive approach in integrating mHealth applications for infectious disease surveillance within developing countries. Addressing technical integration, governance, funding sustainability, training, and equity can create a robust mHealth framework that significantly enhances public health infrastructures and capacities.

2.6 Future Directions

The systematic review of mobile health (mHealth) applications for infectious disease surveillance in developing countries reveals the transformative potential of digital tools in reshaping health systems within low-resource settings. Research highlights the growing integration of mHealth applications in public health infrastructure, particularly in addressing transmission pathways, managing outbreaks, and enhancing data collection through real-time reporting and monitoring systems (Zhao *et al*., 2021; Owoyemi *et al*., 2022) [116, 88]. Despite these advancements, there remains an urgent need for continuous innovation, better integration, and a comprehensive long-term vision that transcends the current reactive measures employed by many existing mHealth systems (Abad *et al*., 2021) [1].

Future directions in the realm of mHealth must encompass predictive analytics, particularly through the incorporation of artificial intelligence (AI) technologies. AI enables the processing of vast amounts of health data and environmental parameters to forecast potential outbreaks before they occur, thereby enhancing the capacity for proactive public health interventions (Owoyemi *et al*., 2022; Abad *et al*., 2021) [88, 1]. For example, machine learning algorithms, when applied in settings prone to diseases like malaria and cholera, can facilitate early warning systems that empower health authorities to execute timely interventions, including public health campaigns and resource allocation (Owoyemi *et al*., 2022) [88]. Moreover, the integration of AI into mHealth applications equipped for community health workers can aid in clinical decision-making, thereby improving diagnostic accuracy in areas with constrained healthcare access.

Equally significant is the role of blockchain technology in enhancing the integrity and security of health data. In low-income settings, issues of data integrity, privacy, and trust remain pronounced due to weak regulatory frameworks. Blockchain offers a robust framework to ensure secure data transactions, allowing health data gathered through mHealth applications to be encrypted and stored in distributed ledgers. This feature not only safeguards against unauthorized access but also fosters transparency and trust among users, particularly in communities wary of centralized data systems. Furthermore, blockchain technology can streamline the verification of health worker activities and the traceability of essential medical supplies, critical for maintaining effective response frameworks during outbreaks.

The design of mHealth applications must reflect user-centered and inclusive design principles, ensuring accessibility and engagement from a diverse range of users. Past mHealth initiatives often failed to consider local contexts, resulting in applications that were suboptimal for user needs (Eberle *et al*., 2021; Bossman *et al*., 2022) [23, 11]. To rectify this, participatory co-design methodologies—including community members and frontline health workers in the innovation process—should be adopted. Inclusive design approaches must address the needs of diverse populations, particularly marginalized groups such as individuals with disabilities and those with low literacy rates. Integrating supportive features like multilingual interfaces and offline functionality can further enhance accessibility to mHealth interventions (Eberle *et al*., 2021; Bossman *et al*., 2022) [23, 11].

Additionally, strong standardization and scalability of mHealth applications are paramount to overcoming common obstacles such as data fragmentation and interoperability challenges (DeFulio *et al*., 2021) [22]. Without standardized frameworks for data formats and functionalities, the effective comparison and sharing of surveillance results across different regions become severely hampered. Collaborations among governments and international health organizations to establish and enforce uniform digital health standards will be crucial in realizing cohesive mHealth applications (Abad *et al*., 2021; DeFulio *et al*., 2021) [1, 22]. Furthermore, scalability should be considered from the inception of mHealth initiatives, incorporating flexible architectural designs that can accommodate expansion and adaptation as needed (DeFulio *et al*., 2021) [22].

In conclusion, the evolving landscape of mHealth applications for infectious disease surveillance in developing countries is promising, with significant potential for enhancing public health resilience through improved predictive capabilities, secure data management, inclusive design, and standardized practices. The synergy of these elements is crucial not only for the advancement of health systems but also for achieving equity in health access across vulnerable populations. Future mHealth initiatives must align technological advancements with policy frameworks and community engagement to ensure their sustainability, effectiveness, and ethical considerations as they adapt to emerging global health challenges.

3. Conclusion

The systematic review of mobile health (mHealth) applications for infectious disease surveillance in developing countries reveals a growing body of evidence supporting the transformative potential of digital tools in strengthening public health systems. Key findings indicate that mHealth applications have significantly improved the timeliness, accuracy, and reach of disease surveillance, particularly in low-resource settings where traditional systems are often fragmented or underperforming. These tools have empowered frontline health workers, enhanced community engagement, and enabled real-time reporting and response during outbreaks of diseases such as malaria, tuberculosis, Ebola, and COVID-19. While the technological functionalities—ranging from case notification and decision support to GPS mapping and data visualization—have yielded measurable improvements, the effectiveness of these tools is closely tied to the involvement of local stakeholders, training, and alignment with national health systems.

mHealth has emerged as a critical component of global health resilience, particularly in regions vulnerable to epidemic-prone diseases and health system disruptions. Its ability to facilitate early detection, support rapid response, and ensure continuity of care even in remote and underserved communities makes it an essential strategy in pandemic preparedness and public health equity. Moreover, the adaptability of mHealth platforms allows them to evolve with changing epidemiological needs and technological advancements, including artificial intelligence, blockchain, and predictive analytics. As such, mHealth serves not only as a surveillance mechanism but also as a catalyst for broader health system innovation and resilience.

To fully realize the promise of mHealth, there is a pressing need for sustainable, integrated digital health solutions that are embedded within national policies and supported by long-term funding, inclusive training, and robust public-private partnerships. Governments must lead the way in establishing standards, ensuring interoperability, protecting data privacy, and scaling proven tools to reach all segments of the population. As the global health community continues to confront complex and evolving health threats, mHealth must be recognized not as a temporary innovation but as a foundational element of modern, equitable, and responsive public health systems.

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