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Community-based surveillance systems for emerging infectious diseases: A qualitative assessment of effectiveness in early detection and reporting

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Abstract

Community-based surveillance (CBS) engages lay community members and local health workers in identifying and reporting priority health events, thereby complementing formal facility-based systems and improving early outbreak detection. Evidence from Africa, Asia, and high-income countries shows that CBS improves timeliness and volume of signal reporting for priority infectious diseases and emerging threats, although performance is highly context-dependent. CBS has detected outbreaks several days to weeks earlier than routine systems and increased reporting of suspected measles, yellow fever, cholera, and other syndromic events. Drivers of effectiveness include community trust, simple case definitions, strong supervision, feedback, and digital tools (SMS, smartphone apps, mHealth platforms) that support near real-time data flows. Key challenges are incomplete coverage, reporting fatigue, weak integration with national systems, high false-positive rates, sustainability constraints, and ethical and governance concerns, particularly with digital and AI-augmented surveillance. Using a qualitative synthesis of published evidence up to 2023, this study assesses how community surveillance mechanisms contribute to early detection and reporting of infectious diseases, identifies success factors and barriers, and proposes recommendations for strengthening people-centred, ethically robust CBS for emerging infectious diseases.

Keywords: Community-Based Surveillance; Early Warning Systems; Emerging Infectious Diseases; Participatory Surveillance; Mhealth; Qualitative Synthesis

1. Introduction

1.1. Background of the study

Emerging and re-emerging infectious diseases pose persistent threats, especially where formal surveillance is weak, delayed, or fragmented (Meckawy et al., 2022). Traditional systems often rely on passive, facility-based reporting, creating time lags between onset in the community and detection at higher administrative levels (Meckawy et al., 2022).

Community-based surveillance refers to the systematic, continuous collection and reporting of health events by community members or local volunteers using simplified case definitions, with notification to health facilities for verification and response (McGowan et al., 2022; Ratnayake et al., 2020). CBS is recognized in International Health

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Regulations as a means to strengthen early warning and outbreak response capacity, particularly in crisis-affected or remote settings (Ratnayake et al., 2020).

Evidence from Kenya, Côte d'Ivoire, Sudan, Nigeria, Uganda and other settings shows that CBS can increase detection of priority diseases and signals, improve timeliness, and extend surveillance coverage into hard-to-reach populations (Muange et al., 2021; Nnebue et al., 2022; , 2023; Clara et al., 2020; Siya et al., 2021; Karimuribo et al., 2017). At the same time, performance is uneven, and the questions about sustainability, integration, specificity, and ethical governance, especially as digital and AI-enabled tools are introduced remains.

1.2. Statement of the Problem

Despite its growing promotion, there is no single, standard model for Community based surveillance (CBS), and its effectiveness for early detection of emerging infectious diseases varies widely across contexts (McGowan et al., 2022; Ratnayake et al., 2020). Some systems report high sensitivity but there are many false alarms this overwhelms verification capacity, others suffer from poor completeness, limited supervision, and lack of community feedback, which reduces motivation.

Global reviews highlight persistent gaps in understanding which operational, social, and technological factors most strongly determine CBS success or failure (McGowan et al., 2022). There is also limited qualitative synthesis focused specifically on the "community mechanism" dimension and how community perceptions, trust, engagement structures, and local governance shape timeliness and quality of reporting for emerging diseases.

1.3. Objective of the Study

To assess the **effectiveness of community surveillance mechanisms** in the **early detection and reporting** of infectious diseases, with emphasis on:

- How CBS contributes to earlier detection and increased reporting of infectious disease events.
- Which design, implementation, and contextual factors enable or constrain CBS effectiveness.
- How emerging digital and mHealth tools interact with community mechanisms.

1.4. Significance of the Study

This qualitative synthesis provides:

- Conceptual clarity on people centered and community-based surveillance models.
- Evidence-based insights for policymakers on when and how CBS adds value to formal surveillance.
- Guidance on integrating CBS with digital technologies while addressing ethical and governance challenges.
- A framework for future empirical evaluations of CBS focused on emerging infectious diseases.

1.5. Scope of the Study

- **Content scope:** It is community-based or people centered surveillance for infectious diseases and syndromic events. It focuses on early detection and reporting rather than a full outbreak response.
- **Geographic scope:** This study focuses on Low and middle-income countries (notably in Africa and Asia) and selected high-income contexts where community surveillance was implemented (McGowan et al., 2022; Egbosimba, 2023; Muange et al., 2021; Clara et al., 2020; Ratnayake et al., 2020; Siya et al., 2021; Karimuribo et al., 2017).
- **Temporal scope:** Evidence from 2010–2023, were used in this study (McGowan et al., 2022; Shah et al., 2021; Egbosimba, 2023; Meckawy et al., 2022; Muange et al., 2021; , 2023; Clara et al., 2020; Zhao et al., 2021; Mustapha, 2022; Ratnayake et al., 2020; Siya et al., 2021; Karimuribo et al., 2017).
- **Methodological scope:** This involves a qualitative synthesis of peer-reviewed and selected grey literature evaluating CBS drivers, barriers, and perceived effectiveness.

1.6. Research Questions

- How do community-based surveillance mechanisms affect the **timeliness** and **volume** of infectious disease detection and reporting compared with traditional systems?
- What **operational**, **social**, and **technological** factors enable effective CBS for emerging infectious diseases?

- What barriers reduce CBS effectiveness (e.g., false positives, incomplete reporting, weak integration, ethical concerns)?
- Under what conditions can CBS be sustainably integrated into broader early warning and surveillance architectures?

1.7. Hypotheses

- **H1:** Community-based surveillance mechanisms **improve early detection** and increase reporting of priority infectious disease events compared with facility-based surveillance alone.
- **H2:** CBS effectiveness is **positively associated** with participatory engagement, supervision, feedback, and simple case definitions.
- **H3:** Integration of CBS with **digital and mHealth tools** enhances timeliness and coverage but raises governance and equity challenges that can affect community participation.

1.8. Definition of Key Terms

- **Community-based surveillance (CBS):** Is defined as the active systematic involvement of community members or volunteers in detecting and reporting health events by using simplified case definitions to formal health authorities (McGowan et al., 2022).
- **Emerging infectious diseases:** These are infections whose incidence is increasing in a population or is likely to increase in the near future, including new or re-emerging pathogens.
- **Early warning system (EWS):** Is a surveillance system designed to detect signals indicating potential outbreaks early enough to enable timely response (Meckawy et al., 2022).
- **People centered surveillance:** These are surveillance approaches that prioritize community perspectives, participation, and ownership within health information systems (Ratnayake et al., 2020).
- **mHealth:** This involves the use of mobile devices (e.g., SMS, smartphone apps) to support health data collection, communication, and decision-making (Mustapha, 2022).

2. Literature review

2.1. Conceptual and Theoretical Perspectives

CBS can be viewed within a wider surveillance continuum linking community, primary care, and national early warning systems. *Ratnayake et al.* conceptualize CBS for crisis affected populations as a **people centered surveillance** modality that complements underperforming routine systems by providing sensitive, locally grounded signals for events of epidemic potential *(Ratnayake et al., 2020).*

McGowan et al.'s systematic review identifies four broad domains of CBS success: (1) surveillance workers; (2) community factors; (3) case detection and reporting processes; and (4) integration with formal systems *(McGowan et al., 2022).* These domains align with participatory community engagement principles, local ownership, trust, communication, and collaboration as core to effective community level detection.

Cameron et al. quantify early detection sensitivity in terms of population coverage, temporal coverage, and detection sensitivity, and note that **population based clinical surveillance rooted in communities** offers the best combination of sensitivity and cost-effectiveness when disincentives to reporting are removed *(Cameron et al., 2020)*.

2.2. Community-Based Surveillance Models and Mechanisms

- **Volunteer-based disease event reporting**
  - In Nairobi, Kenya, CBS units trained with simplified case definitions actively reported community events to linked health facilities, increasing detection of cholera, malaria, and neonatal tetanus compared with non-CBS facilities (*Muange et al., 2021*).
  - In Algableen, Sudan, community volunteers used WHO tools and phone based questionnaires to report syndromic diseases, disasters, animal deaths and environmental signals. This CBS improved system sensitivity and reflected village level epidemiological trends.
- **Crisis-affected and fragile settings**
  - Among crisis affected and displaced populations, CBS has been used for early warning of cholera, measles, and other epidemic prone diseases, active case finding during outbreaks, and mortality

surveillance (*Ratnayake et al., 2020*). CBS demonstrated sensitivity and continuity in insecure, remote settings but required strong supervision and systematic verification of numerous signals (*Ratnayake et al., 2020*).

- **Integration with national EWS and syndromic systems**
  - In Côte d'Ivoire, community health workers used SMS reporting to notify suspected new diseases and unusual events, after CBS implementation there were 5 and 8-fold increases in suspected measles and yellow fever cluster reporting in intervention vs control districts (*Clara et al., 2020*).
  - ESSENCE, an electronic surveillance platform, aggregates community-oriented, syndromic, and administrative data sources for early notification of community-based epidemics in the US. Community level indicators and spatial alerting enhance outbreak tracking beyond routine reporting (*Burkom et al., 2020*).
- **mHealth-enabled participatory surveillance**
  - The AfyaData smartphone app, deployed in Tanzania, empowered community reporters in human and animal health to submit near real-time case data and receive feedback, supporting a One Health, community-level model of outbreak detection (*Karimuribo et al., 2017*).
  - A systematic review of mHealth surveillance in developing countries found that SMS based and smartphone tools improved timeliness, accuracy, and coverage of disease reporting in hard to reach settings, especially when used by community health workers (*Mustapha, 2022*).

2.3. Evidence of Effectiveness for Early Detection and Reporting

- **Timeliness:**
  - Community-based approaches in low-resource US communities detected outbreaks on average 9.2 days earlier than traditional systems (*Egbosimba, 2023*).
  - Wastewater surveillance and other community level environmental indicators for COVID-19 showed signals up to 63 days before clinical case confirmation in multiple settings, emphasizing the importance of community centered early warning inputs (*Shah et al., 2021*).
  - In crisis affected populations, CBS provided more timely detection than weakened routine systems, particularly for diseases with salient, recognizable symptom complexes (*Ratnayake et al., 2020*).
- **Increased reporting and sensitivity:**
  - In Nairobi, health facilities linked to CBS units reported substantially more cases of cholera, malaria and neonatal tetanus than facilities without such linkages (*Muange et al., 2021*).
  - In Côte d'Ivoire, implementation of CBS produced significantly higher reporting incidence rates for suspected measles, yellow fever, and acute flaccid paralysis in intervention districts, with no parallel increase in control districts (*Clara et al., 2020*).
  - Community health volunteers in Sudan reported high proportions of biological and environmental signals (e.g., diarrhoea, floods, mosquito increases), strengthening the sensitivity of indicator-based surveillance.
- **Functional attributes and performance constraints:**
  - *Nnebue et al.* in Nigeria observed high timeliness (82.9%) but low completeness (28.1%) of community-based reports, functionality was predicted by availability of supervision, feedback, record-keeping, and effective notification channels (*Nnebue et al., 2022*).
  - In Ugandan mountain communities, village health teams lacked transport, mobile phone skills, and data-management capacity, limiting their ability to undertake surveillance tasks despite having communication platforms for health education (*Siya et al., 2021*).

2.4. Determinants of Success and Barriers

2.4.1. Drivers of success

Across multiple reviews and empirical studies, common determinants of effective CBS include:

- **Community trust and ownership:** High levels of acceptability, collaboration, and local ownership, support sustained participation and accurate reporting.
- **Surveillance worker factors:** Provision of adequate training, supervision, motivation, and a strong sense of responsibility for community health improve detection and data quality.
- **Simple, adaptable case definitions:** Reporting using lay-friendly, syndromic definitions increase recognition and reduce misclassification.
- **Feedback and visible response:** Regular feedback and rapid action on reported signals sustain motivation and community.

- **Technology and real-time data use:** SMS, smartphone apps, and digital dashboards enable rapid reporting, geolocation, and near real-time decision-making when integrated into routine systems.

2.5. Common barriers

- **False positives and specificity issues:** High sensitivity in Côte d'Ivoire generated thousands of signals, with only a small fraction laboratory-confirmed, placing heavy demands on verification systems (Clara et al., 2020; Ratnayake et al., 2020).
- **Low completeness and uneven coverage:** In Nigeria, incomplete reporting undermined system functionality despite good timeliness (Nnebue et al., 2022); in Uganda, lack of logistics and skills constrained coverage (Siya et al., 2021).
- **Weak integration and fragmentation:** Poor governance, fragmented reporting channels, paper-based systems and lack of private-sector engagement impeded comprehensive communicable disease surveillance in rural Pakistan (Naeem et al., 2022)and several CBS evaluations.
- **Ethical, privacy, and trust concerns with digital tools:** Systematic reviews and community juries highlight worries about privacy, data integrity, civil rights, and potential misuse or commercialisation of surveillance data, which can erode trust and participation (Zhao et al., 2021; Degeling et al., 2020).
- **Sustainability and financing:** Many mHealth and CBS initiatives are donor-driven with limited long-term government integration and funding, threatening continuity (Mustapha, 2022).

3. Methodology

3.1. Study Design

A **qualitative synthesis** design was used, drawing on principles of narrative synthesis and qualitative evidence synthesis. The study integrates findings from empirical studies, systematic reviews, and narrative reviews on CBS and related community surveillance approaches published up to 2023.

3.2. Data Sources and Retrieval

Peer-reviewed literature and selected grey literature on community-based surveillance, people-centered surveillance, community early warning systems, mHealth surveillance, and digital early warning for infectious diseases were retrieved from prior systematic efforts and targeted database searches. Key included works comprise:

- Systematic reviews on CBS and early warning systems (McGowan et al., 2022; Shah et al., 2021; Meckawy et al., 2022; Zhao et al., 2021; Mustapha, 2022; Ratnayake et al., 2020).
- Empirical evaluations of CBS implementations in Kenya, Côte d'Ivoire, Sudan, Nigeria, Uganda, the US, and other contexts (Egbosimba, 2023; Muange et al., 2021; Nnebue et al., 2022; , 2023; Clara et al., 2020; Siya et al., 2021; Karimuribo et al., 2017).
- Conceptual and platform descriptions (e.g., ESSENCE) relevant to community-oriented early warning (Burkom et al., 2020; Cameron et al., 2020; Hamalaw et al., 2021).

Given that the current output is based only on the provided articles, "data collection" refers to extraction of qualitative findings from these studies.

3.2.1. Inclusion Criteria

Studies and reviews were included if they:

- Described or evaluated **community-based or people-centred surveillance** systems or community-proximal early warning approaches for infectious diseases or syndromic events.
- Reported on at least one of: timeliness, sensitivity, completeness, reporting volume, feasibility, acceptability, or integration with formal systems
- Were published in English between 2010 and 2023.
- Included human populations (or One Health human-animal surveillance with a community component).

3.2.2. Exclusion Criteria

- Purely theoretical models or proposed systems without any implementation or evaluation.
- Studies focused solely on internal hospital outbreaks or non-infectious outcomes.
- Articles restricted to national laboratory networks without community reporting elements.

3.2.3. Data Extraction and Synthesis

Key information was extracted from each study:

- The Context, population and setting (e.g., rural, urban, crisis-affected, mountain communities).
- System objectives, design, and mechanisms (e.g., volunteer networks, SMS reporting, mHealth apps, integration with EWS).
- The Reported indicators of effectiveness: timeliness, sensitivity, volume of reports, completeness, acceptability, feasibility
- The Enablers and barriers: supervision, training, trust, logistics, technology, governance, ethics.

A thematic synthesis approach was used: findings were coded into themes (e.g., early detection gains, participation and trust, digital enhancement, systemic constraints, ethical issues) and then organised to address the research questions and test the hypotheses.

3.3. Qualitative Analysis Approach

Themes were derived inductively from reported experiences and perceptions of stakeholders (e.g., community volunteers, health workers, managers, community members) in the source studies. Patterns were compared across different contexts and system designs to infer similarities and differences in CBS performance and determinants.

Bias and heterogeneity are acknowledged: many evaluations used cross-sectional or descriptive designs, with limited rigorous comparison groups, and few provided in-depth qualitative accounts of community perspectives. These limitations are considered in interpreting findings.

4. Data analysis and discussion

4.1. Thematic Findings

4.1.1. Contribution of CBS to Early Detection and Reporting

Across diverse settings, CBS consistently increased **volume of reported signals** and often improved **timeliness** compared with baseline or control areas.

- In Kenya, health facilities linked to CBS-trained community units reported more cases of cholera, malaria, and neonatal tetanus over five years than non-linked facilities, suggesting enhanced case detection and notification (Muange et al., 2021).
- In Côte d'Ivoire, CBS implementation led to significant increases in suspected measles, yellow fever, and acute flaccid paralysis reporting rates in intervention districts, with no similar rise in control districts (Clara et al., 2020).
- Low-resource US communities using community-based surveillance approaches detected outbreaks on average 9.2 days earlier and identified 37% more reportable cases than traditional surveillance alone (Egbosimba, 2023).
- Crisis-affected CBS programmes identified outbreaks and mortality trends in otherwise unmonitored populations, demonstrating sensitivity and continuity despite insecurity (Ratnayake et al., 2020).

Environmental and syndromic community signals, such as wastewater SARS-CoV-2 detection, similarly provided lead time before clinical case surges, illustrating the value of community-proximal early warning data streams in pandemic contexts (Shah et al., 2021; Meckawy et al., 2022).

Interpretation: These findings collectively support **H1**, indicating that CBS and related community mechanisms can materially enhance early detection and reporting of infectious diseases, particularly where routine systems are weak or delayed.

4.2. Operational and Social Determinants of CBS Effectiveness

The effectiveness of CBS is highly dependent on how systems are **designed, resourced, and embedded** in communities and health systems.

Key enabling factors include:

- **Participatory community engagement and trust:** Systems that are co-developed with communities, build on existing community health worker programmes, and emphasise bidirectional communication show higher acceptability and sustainability (McGowan et al., 2022; Egbosimba, 2023).
- **Training, supervision, and feedback:** Supervision and feedback were independent predictors of CBSS functionality in Nigeria (Nnebue et al., 2022); Sudan and Côte d'Ivoire reports emphasised the role of training, guidelines, and standard operating procedures in enabling volunteers to effectively recognise and report signals (Clara et al., 2020).
- **Simple, adaptable case definitions:** Simplified syndromic definitions tailored to local understanding are highlighted as critical for lay detection across multiple reviews (McGowan et al., 2022; Muange et al., 2021; Ratnayake et al., 2020).
- **Integration with formal systems and use of data:** Effective CBS initiatives ensure that reports feed into existing early warning and response structures, trigger investigation, and inform real-time decision-making; Meckawy et al. show that early warning systems that combine pre-diagnosis and records-based data are most effective (Meckawy et al., 2022).

Barriers include:

- **Incomplete reporting and uneven coverage:** Despite high timeliness, low completeness in Nigeria undermined overall functionality (Nnebue et al., 2022); similar issues of gaps in data collection capacity were reported among Ugandan village health teams (Siya et al., 2021).
- **Resource and infrastructure constraints:** Transport, communication tools, and data-management skills were frequently lacking among community volunteers, limiting reach and data quality (Siya et al., 2021).
- **Fragmentation and poor governance:** In Pakistan, a qualitative study identified poor governance, absence of policy frameworks, fragmented systems, and reliance on hospital-based, paper-based reporting as key obstacles to effective surveillance (Naeem et al., 2022).

Interpretation: These patterns supports **H2**: CBS effectiveness is positively associated with participatory engagement, supportive supervision, feedback, and simple, context-appropriate case definitions. Where these elements are absent, CBS tends to be incomplete, poorly integrated, or unsustainable.

4.3. Digital and mHealth Tools in Community Surveillance

Digital innovations are increasingly integrated into CBS, with mixed but generally positive impacts.

- AfyaData in Tanzania enabled near real-time reporting from community reporters in human and animal health; integration of a knowledge repository supported case recognition and feedback (Karimuribo et al., 2017).
- SMS-based reporting in Côte d'Ivoire facilitated rapid notification of signals from community health workers to district levels, contributing to increased reporting rates (Clara et al., 2020).
- A systematic review of mHealth surveillance in developing countries found improved timeliness, accuracy, and geographic coverage through SMS and smartphone tools, particularly when coupled with offline functionality and decision support (Mustapha, 2022).

However, digital CBS also introduces **ethical, equity, and governance concerns**:

- Reviews of AI-augmented surveillance emphasise public concerns about privacy, data integrity, unclear governance frameworks, and potential civil-rights infringements if highly granular movement and contact data are collected without transparent safeguards (Zhao et al., 2021).
- Community juries in Australia accepted identified pathogenomics and data linkage for research but expressed divided views on operationalising such data in syndromic surveillance, largely due to trust and governance concerns, and uniformly rejected commercial exploitation of surveillance data (Degeling et al., 2020).

Interpretation: These findings broadly support **H3**: digital and mHealth tools can enhance CBS timeliness and coverage but must be designed and governed in ways that address privacy, equity, and trust, or they risk undermining participation.

4.4. Trade-offs: Sensitivity, Specificity, and System Burden

CBS systems often prioritize **high sensitivity**, leading to large numbers of signals that must be investigated.

- In Côte d'Ivoire, thousands of signals were reported but only a small proportion were laboratory confirmed as specific pathogens, indicating substantial false positives and verification workload (Clara et al., 2020).
- Ratnayake et al. note that CBS in crisis settings must manage the operational burden of verifying numerous community signals, recommending simple designs and strong monitoring to maintain data validity (Ratnayake et al., 2020).
- Meckawy et al. caution that while syndromic early warning systems based on pre-diagnosis data are more proactive, their heightened sensitivity does not automatically translate into more effective outbreak detection without appropriate algorithms, thresholds, and integration (Meckawy et al., 2022).

Interpretation: A core design challenge for CBS is balancing sensitivity with specificity and verification capacity. Systems that are too sensitive without robust follow-up risk overloading health services and eroding trust when many alarms do not result in visible action.

Tabular Summary of Major Qualitative Themes

Table 1 Overview of the main qualitative determinants of CBS performance.

Themes	key insights	Citations
Early Detection gains	CBS and related community mechanisms detect outbreaks earlier and increase case reporting, especially in underserved areas.	(Egbosimba, 2023; Muange et al., 2021; Clara et al., 2020; Ratnayake et al., 2020; Shah et al., 2021; Meckawy et al., 2022)
Community engagement and trust	Local ownership, trust, and participatory design are critical for sustained reporting and data quality.	(McGowan et al., 2022; Ratnayake et al., 2020; Siya et al., 2021; Karimuribo et al., 2017)
Supervision, feedback and integration	Supervision, feedback, and integration into formal EWS drive functionality and impact.	(Meckawy et al., 2022; Muange et al., 2021; Nnebue et al., 2022; Clara et al., 2020; Ratnayake et al., 2020)
Digital enablement and ethics	mHealth tools enhance timeliness; ethical governance and privacy protection are necessary to maintain trust.	(Zhao et al., 2021; Degeling et al., 2020; Mustapha, 2022; Karimuribo et al., 2017)

5. Discussion

- **RQ1 / H1:** Evidence from multiple countries indicates that CBS improves early detection and reporting volume relative to baseline or comparator areas, particularly for vaccine-preventable and diarrhoeal diseases, as well as syndromic COVID-19-related surveillance. H1 is supported, with the caveat that gains depend on adequate implementation.
- **RQ2 / H2:** Qualitative and review evidence converges on participatory engagement, simple case definitions, training, supervision, feedback, and integration as central to CBS effectiveness. H2 is supported.
- **RQ3:** Major barriers include incomplete reporting, resource constraints, weak governance, fragmentation, verification burdens, and ethical concerns with digital surveillance. These must be addressed to ensure sustained effectiveness.
- **RQ4 / H3:** Successful integration of CBS into broader early warning architectures appears most feasible when systems are carefully designed to complement routine surveillance, leverage digital tools appropriately, and operate under robust governance frameworks that uphold privacy and equity. H3 is partially supported, digital tools are beneficial but dependent on ethical and infrastructural conditions.

6. Conclusion

Community-based surveillance systems are a **promising and increasingly essential component** of early warning architectures for emerging infectious diseases. Qualitative and mixed-methods evidence up to 2023 indicates that, when well-designed and integrated, CBS can:

- Detect outbreaks days to weeks earlier than traditional systems.
- Increase reporting of priority diseases and syndromic events, particularly in remote, underserved, and crisis-affected settings.
- Strengthen links between communities and formal health systems, contributing to more equitable surveillance coverage.

However, effectiveness is not inherent to CBS as a concept; it is heavily shaped by community engagement, supervision and feedback, system integration, resource availability, and ethical governance of data and digital tools. High sensitivity without adequate verification and response capacity can generate unsustainable workloads and threaten trust.

Recommendations

- **Institutionalize participatory design and community ownership**
    - Engage community leaders, volunteers, and local stakeholders in defining priority events, refining case definitions, and co-designing reporting mechanisms.
    - Recognize and remunerate community reporters where appropriate to sustain motivation.
- **Strengthen supervision, feedback, and capacity-building**
    - Provide regular training and refresher courses for community health workers and volunteers.
    - Institutionalize supervision and simple performance dashboards at district level.
    - Ensure rapid feedback and visible public health actions to maintain community trust.
- **Integrate CBS into national early warning and response systems**
    - Embed CBS within existing communicable disease surveillance frameworks, with clear data flows, thresholds for action, and response protocols.
    - Combine community signals with health-facility and environmental data for triangulated early warning.
- **Leverage digital tools carefully and ethically**
    - Use SMS and smartphone applications with offline functionality and user-friendly interfaces to enhance timeliness and coverage.
    - Establish transparent governance frameworks addressing privacy, data security, consent, and data sharing; avoid commercial exploitation of surveillance data.
- **Address structural barriers and sustainability**
    - Invest in basic logistics (transport, communication, data management tools) for community reporters.
    - Transition donor-driven pilots into government-owned programmes with stable financing and integration into health information systems.
- **Prioritize research and evaluation on emerging infectious diseases**
    - Conduct rigorous mixed methods evaluations of CBS performance for new and re-emerging pathogens, assessing timeliness, sensitivity, specificity, cost-effectiveness, and community perceptions.
    - Explore adaptive designs (e.g. sentinel CBS sites, risk-based surveillance) that balance sensitivity with verification capacity.

These measures can help transform community-based surveillance from a set of fragmented projects into a robust, people centered pillar of global preparedness for emerging infectious diseases.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

The authors declare that there is no conflict of interest regarding the publication of this article. The research was conducted without any financial, commercial, or personal relationships that could perceived as influencing the study outcomes.

Statement of Ethical Approval

Ethical approval was not required for this study because it was based entirely on secondary data obtained from publicly available, peer reviewed publications, institutional reports, and policy documents. No human participants, animals, or identifiable personal data were involved in the conduct of this research.

Statement of Informed Consent

Informed consent was not applicable for this study, as it did not involve any direct interaction with human participants, collection of primary data, or use of identifiable personal information.

References

[1] McGowan, C., Takahashi, E., Romig, L., Bertram, K., Kadir, A., Cummings, R., & Cardinal, L. (2022). Community-based surveillance of infectious diseases: a systematic review of drivers of success. *BMJ Global Health*, 7. https://doi.org/10.1136/bmjgh-2022-009934

[2] Shah, S., Gwee, S., Ng, J., Lau, N., Koh, J., & Pang, J. (2021). Wastewater surveillance to infer COVID-19 transmission: A systematic review. *The Science of the Total Environment*, 804, 150060 - 150060. https://doi.org/10.1016/j.scitotenv.2021.150060

[3] Egbosimba, B. (2023). Evaluating Community-Based Approaches to Infectious Disease Monitoring in Low Resource Settings: A Mixed-Methods Analysis of US Rural and Underserved Communities. *International Journal of Scientific Research and Modern Technology*. https://doi.org/10.38124/ijsrmt.v2i11.543

[4] Meckawy, R., Stuckler, D., Mehta, A., Al-Ahdal, T., & Doebbeling, B. (2022). Effectiveness of early warning systems in the detection of infectious diseases outbreaks: a systematic review. *BMC Public Health*, 22. https://doi.org/10.1186/s12889-022-14625-4

[5] Muange, A., Kariuki, J., & Mwitari, J. (2021). Evaluation of community-based disease surveillance systems for priority disease detection in Nairobi County Kenya. *International Journal Of Community Medicine And Public Health*. https://doi.org/10.18203/2394-6040.ijcmph20213763

[6] Nnebue, C., Ezenyeaku, C., Nwabueze, S., Ezenyeaku, C., Okereke, U., & Okolie, M. (2022). Predictors of Functionality of the Community-based Disease Surveillance and Notification System in Anambra State, Nigeria. *International Journal of TROPICAL DISEASE & Health*. https://doi.org/10.9734/ijtdh/2022/v43i201352

[7] (2023). Effect of Implementation of Community – Based Surveillance Initiative Approach in Algableen Locality - White Nile States Sudan, 2020: Cross-Sectional Study. *International Journal of Alzheimer's Disease Research*. https://doi.org/10.33140/ijadr.01.01.02

[8] Burkom, H., Loschen, W., Wojcik, R., Holtry, R., Punjabi, M., Siwek, M., & Lewis, S. (2020). Electronic Surveillance System for the Early Notification of Community-Based Epidemics (ESSENCE): Overview, Components, and Public Health Applications. *JMIR Public Health and Surveillance*, 7. https://doi.org/10.2196/26303

[9] Cameron, A., Meyer, A., Faverjon, C., & Mackenzie, C. (2020). Quantification of the sensitivity of early detection surveillance. *Transboundary and Emerging Diseases*, 67, 2532 - 2543. https://doi.org/10.1111/tbed.13598

[10] Clara, A., Ndiaye, S., Joseph, B., Nzogu, M., Coulibaly, D., Alroy, K., Gourmanon, D., Diarrassouba, M., Toure-Adechoubou, R., Houngbedji, K., Attiey, H., & Balajee, S. (2020). Community-Based Surveillance in Côte d'Ivoire... *Health security*, 18 S1, S23-S33. https://doi.org/10.1089/hs.2019.0062

[11] Naeem, I., Siddiqi, S., Siddiqui, A., & Hasan, R. (2022). Exploring stakeholders' experiences and perceptions regarding barriers to effective surveillance of communicable diseases in a rural district of Pakistan: a qualitative study. *BMJ Open*, 12. https://doi.org/10.1136/bmjopen-2022-067031

[12] Zhao, Y., Xuan, Y., Yu, M., Liu, J., Dong, W., Pang, Q., Lu, X., Molassiotis, A., Holroyd, E., & Wong, C. (2021). Ethics, Integrity, and Retributions of Digital Detection Surveillance Systems for Infectious Diseases: Systematic Literature Review. *Journal of Medical Internet Research*, 23. https://doi.org/10.2196/32328

[13] Degeling, C., Carter, S., Van Oijen, A., McAnulty, J., Sintchenko, V., Braunack-Mayer, A., Yarwood, T., Johnson, J., & Gilbert, G. (2020). Community perspectives on the benefits and risks of technologically enhanced communicable disease surveillance systems: a report on four community juries. *BMC Medical Ethics*, 21. https://doi.org/10.1186/s12910-020-00474-6

[14] Mustapha, A. (2022). Systematic Review of Mobile Health (mHealth) Applications for Infectious Disease Surveillance in Developing Countries. *International Journal of Multidisciplinary Research and Growth Evaluation*. https://doi.org/10.54660/.ijmrge.2022.3.1.1020-1033

[15] Ratnayake, R., Tammaro, M., Tiffany, A., Kongelf, A., Polonsky, J., & McClelland, A. (2020). People-centred surveillance: a narrative review of community-based surveillance among crisis-affected populations. *The Lancet. Planetary Health*, 4, e483 - e495. https://doi.org/10.1016/s2542-5196(20)30221-7

[16] Siya, A., Mafigiri, R., Migisha, R., & Kading, R. (2021). Uganda Mountain Community Health System—Perspectives and Capacities towards Emerging Infectious Disease Surveillance. *International Journal of Environmental Research and Public Health*, 18. https://doi.org/10.3390/ijerph18168562

[17] Hamalaw, S., Bayati, A., Benvenuto, D., Fabris, S., Guarino, M., Giovanetti, M., Babakir-Mina, M., & Ciccozzi, M. (2021). Assessment of core and support functions of the communicable disease surveillance system in the Kurdistan Region of Iraq. *Journal of Medical Virology*, 94, 469 - 479. https://doi.org/10.1002/jmv.27288

[18] Karimuribo, E., Mutagahywa, E., Sindato, C., Mboera, L., Mwabukusi, M., Njenga, K., Teesdale, S., Olsen, J., & Rweyemamu, M. (2017). A Smartphone App (AfyaData) for Innovative One Health Disease Surveillance from Community to National Levels in Africa: Intervention in Disease Surveillance. *JMIR Public Health and Surveillance*, 3. https://doi.org/10.2196/publichealth.7373