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To contact us:

Western Pacific Surveillance and Response

World Health Organization
Office for the Western Pacific Region
United Nations Avenue
1000 Manila, Philippines
wpsar@who.int
<https://ojs.wpro.who.int/>

Development of monitoring and evaluation guidelines for Indonesia's national Early Warning Alert and Response System: aiming for a standardized and systematic assessment

Shingo Nishiki,^{a,*} Irma Gusmi Ratih,^{b,*} Nur Assyifa Daiyah Fillah,^a Rizki Dinar Winiar,^a Isamu Kuboki,^a Rendy Manuhutu,^b Lia Septiana,^b Eka Muhiriyah^b and Triya Novita Dinihari^b

Correspondence to Shingo Nishiki (email: snishiki@utopia.ocn.ne.jp)

Monitoring and evaluation (M&E) are essential for establishing and maintaining effective communicable disease surveillance and response systems, as well as for enhancing capacity.¹ Recent public health emergencies, particularly the COVID-19 pandemic, have underscored the importance of these advancements globally. In Indonesia, the Early Warning Alert and Response System (EWARS) was implemented in 2009 as a web-based syndromic surveillance platform for infectious diseases.² Like many other countries, Indonesia has faced challenges related to emerging and re-emerging infectious disease outbreaks.^{3,4} These experiences have exposed gaps in key surveillance areas, such as outbreak detection, laboratory diagnostics and control measure implementation, highlighting the need to strengthen national capacity.³⁻⁵ Moreover, the 2023 World Health Organization (WHO) *Joint external evaluation of the International Health Regulations (2005) core capacities of Indonesia* encouraged the Government to regularly assess its surveillance system to identify priority gaps and implement targeted interventions.⁶

In response, the Indonesian Ministry of Health (MOH) initiated efforts in 2024 to integrate EWARS into a standardized systematic M&E scheme for its national infectious disease surveillance system in collaboration with the WHO Representative Office for Indonesia and

the Japan International Cooperation Agency (JICA). This initiative aims to translate international standards into specific and practical operations for Indonesia, addressing local needs and contexts. This brief report outlines these efforts and offers insights for future development.

Indonesia's EWARS operates across four levels: national, provincial, district and subdistrict.^{2,7} At the subdistrict level, primary health-care centres serve as the main reporting units. The system monitors 24 diseases and syndromes through indicator-based surveillance (IBS). These diseases include acute diarrhoea; acute flaccid paralysis; acute jaundice syndrome; acute respiratory infections; animal bites; anthrax; avian influenza in humans; bloody diarrhoea/dysentery; chikungunya; cholera; COVID-19; dengue; diphtheria; hand-foot-mouth disease; influenza-like illness; leptospirosis; malaria; measles; meningitis/encephalitis; neonatal tetanus; non-neonatal tetanus; pertussis; pneumonia; and typhoid fever.^{2,8} The system provides weekly reports, and also incorporates event-based surveillance (EBS), which requires reporting of 20 disease events within 24 hours of detection.² Data are primarily transmitted from reporting units to the national server, which contains aggregated IBS case counts and individual EBS reports.^{2,9} When the IBS system detects an unusual pattern exceeding a predefined alert threshold, alerts are automatically generated for relevant agencies, prompting primary

^a Project for Strengthening Capacity for Early Warning and Response to Infectious Diseases, Japan International Cooperation Agency, Jakarta, Indonesia.

^b Directorate of Surveillance and Health Quarantine, Ministry of Health, Jakarta, Indonesia.

* These authors contributed equally to this work as shared first authors.

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response activities.^{2,9} Responses to EBS notifications are promptly triggered upon detection.

The M&E for EWARS has primarily focused on performance indicators such as report submission completeness and timeliness, the number of alerts and response rate.² Regular stakeholder meetings have been held at various levels to review and discuss these indicators. However, there remain concerns that these indicators do not always ensure the quality of surveillance, highlighting the need for new tools that enable systematic assessments and in-depth analysis beyond the scope of existing indicators.

The developed EWARS M&E scheme adopts an external cascade evaluation approach, whereby national authorities evaluate provincial activities, provinces assess districts, and districts review reporting units. This approach can ensure the generality, reproducibility and granularity of the assessment compared to self-assessment methods.¹⁰ Accordingly, three tailored guidelines were developed, aligned with the specific roles of each evaluation target. These guidelines comprise four key components: 1) assessment sheets; 2) assessment summary tables; 3) user manuals; and 4) preparation checklists. The assessment sheets include approximately 100–130 questions, comprising both closed- and open-ended questions, to evaluate the quality of EWARS qualitatively and quantitatively across eight domains (Box 1). These domains include facility equipment and environment, performance indicators, IBS, EBS, laboratory testing, data management, response activities, and information-sharing and communication, which are consistent with the WHO and EWARS guidelines.^{1,2} Each domain consists of several topics, each accompanied by multiple questions. In most cases, closed-ended questions with single- or multiple-choice answers are followed by open-ended questions that allow respondents to provide additional details, particularly in cases where they encounter challenges. The summary tables compile results from key closed-ended questions on a two- or three-point scale, alongside evaluator recommendations. The manuals assist interviewers and data-entry operators in accurately interpreting questions and formulating appropriate responses. The checklists specify the documents and data that respondents should prepare in advance. Additionally, widely accessible free online tools are used to streamline data management processes, including data collection and visualization. During

evaluations, data are entered into online forms in real time, with the results instantly visible on dashboards in various formats immediately after data entry.

Box 1. **Eight evaluation domains for Indonesia's national Early Warning Alert and Response System**

No.	Evaluation domain
1	Facility equipment and environment
2	Surveillance performance indicators
3	Indicator-based surveillance
4	Event-based surveillance
5	Laboratory testing and records
6	Data management and analysis
7	Response activities
8	Information-sharing and communication

The first trial was conducted in East Kalimantan Province in February 2025, involving site visits to provincial and district health offices and primary health-care centres to assess effectiveness and identify areas for improvement. Prior to fieldwork, stakeholders received online orientation on assessment procedures. During onsite evaluations, evaluators conducted interviews, entered data and prepared assessment summaries with support from MOH supervisors. Although each of the site visits initially lasted approximately 1–2 hours, the duration decreased with successive rounds. During the trial, online feedback questionnaires were distributed to the participants, and wrap-up workshops were held to facilitate the exchange of ideas between evaluators and respondents. This trial demonstrated that the M&E guidelines and tools functioned effectively, highlighting performance variations between facilities and identifying key challenges. Participants rated the guidelines as highly practical, but suggested modifications to questions for the sake of clarity and requested more time for preparation.

Following the trial, questions that caused interpretative or response challenges were extensively revised, and the user manuals and preparation checklists were refined accordingly. For instance, terms that could be interpreted differently by respondents, such as the requirements relating to training or to the conduct of analyses, necessitated the specification of criteria along with typical examples. To minimize any miscalculations

in questions requiring numerical responses, such as proportions, a formula was added to the questionnaire. Additionally, the quality of the pre-prepared data set was standardized, detailed breakdowns of the submitted data were specified, and target periods were clarified.

Using these updated materials, the second trial was conducted in Banten Province in May 2025. Based on lessons learned, a more precise pre-trial briefing was provided to subnational authorities, with extended preparation time. As a result, the second trial demonstrated shorter assessment times and improved guideline usability, indicating increased operational efficiency and greater feasibility of EWARS M&E activities. The guidelines were subsequently published with the necessary revisions in July 2025.¹¹

Overall, these trials were deemed successful, providing valuable insights for future implementation. First, the summary table offered multiple benefits, as it can be quickly generated by simply clicking checkboxes, with results calculated automatically. It serves as a convenient reference for review, facilitates timely feedback and functions as an evaluation certificate. Second, the effective use of online tools addresses constraints related to time, budget and human resources. Third, the use of free online tools supported efficient data collection and visualization. Additionally, dashboards facilitated data-driven communication among stakeholders, which is expected to enhance data-informed decision-making.¹² Also, periodic assessments with quantitative indicators derived from key questions are expected to enable the monitoring of progress in surveillance capacity over time. Furthermore, trial participants recommended conducting online M&E activities in parallel with in-person assessments in future implementations.

Finally, the trials underscored that evaluation is not merely about assessment but also about learning. Interactive exchanges fostered knowledge-sharing, benefiting both evaluators and respondents. Evaluators gained clearer insights into existing challenges and effective practices in field surveillance, while respondents enhanced their understanding of standard procedures. Highlighting these mutually beneficial outcomes and best practices can promote greater stakeholder engagement in M&E activities and drive improvements in surveillance

quality. Moreover, these findings suggest that similar approaches can be tailored to address the specific surveillance challenges faced in various low- and middle-income country settings, while promoting collaborative relationships and cultivating a culture of continuous improvement across different health-care sectors.

In conclusion, the initiative to establish a systematic M&E framework for EWARS in Indonesia began in 2024 with the development of guidelines and online tools through pilot activities. Although still in its early stages, this effort represents a significant step towards regular, large-scale implementation. Ultimately, this initiative has the potential to strengthen Indonesia's surveillance system and contribute to capacity-building in other countries by offering practical insights into structuring surveillance M&E systems.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Ethics statement

Formal ethical approval was not sought as research was not undertaken.

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Integrating hospital information systems into foodborne disease surveillance: retrospective assessment, Shenzhen, China, 2024–2025

Yuchen Xie,^{a,b} Yan Zhou^c and Zhou Wang^c

Correspondence to Zhou Wang (email: 147573499@qq.com)

In China, foodborne diseases require manual reporting with the surveillance network relying on sentinel hospitals as the foundational building blocks of case detection. However, within this framework, traditional manual reporting remains the main bottleneck, often due to heavy clinical workloads. Fu has asserted that automation is the key to solving this problem.¹ The transition from passive notification to active early warning requires the leveraging of big data technologies, specifically the automated mining of clinical records to identify potential outbreaks before manual reports are filed.¹ In 2024, the Shenzhen Center for Disease Control and Prevention completed the integration of a hospital information system (HIS) into the national surveillance network. A key feature of this digital upgrade is the automated extraction of diagnostic keywords (for example, “acute gastroenteritis” or “food poisoning”) directly from electronic medical records. Operating as a clinical decision support system, this mechanism triggers a pop-up prompt of auto-filled clinical data, enabling real-time detection of suspected cases by requiring clinicians simply to verify and submit the report, rather than manually completing separate reports. This brief report describes an evaluation of the performance of this new digital surveillance system (reporting volume) and user experience (satisfaction) 12 months post-integration.

METHODS

Study design and data collection

A retrospective assessment of Shenzhen's digital surveillance system for foodborne disease was performed, using a mixed-methods approach to ensure a comprehensive evaluation.

System audit (objective data)

De-identified reporting logs were extracted from 53 sentinel hospitals to compare case volumes and reporting timeliness between the manual phase (2024) and the digital integration phase (2025).

User survey (subjective data)

A structured questionnaire was distributed to 263 front-line staff. The instrument was developed based on the Beijing Model and adapted for the Shenzhen context.²

- Participants: targeted respondents included clinicians from key departments (for example, paediatrics, infectious diseases and emergency) and public health staff in prevention departments.

^a Shenzhen Nanshan District Center for Disease Control and Prevention, Shenzhen, Guangdong, China.

^b Shenzhen Field Epidemiology Training Program, Shenzhen, Guangdong, China.

^c Shenzhen Center for Disease Control and Prevention, Shenzhen, Guangdong, China.

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Table 1. Evaluation of and satisfaction with the digital system for foodborne disease surveillance ($N = 263$), using the three dimensions of the Beijing Model,² Shenzhen, China, 2025

Dimension	Subdimension	Indicator (Level 3)	Mean Likert score ^a	Satisfaction rate ^b or median frequency
System construction	Efficiency	Login speed	4.59	242 (92.0)
		Ease of data entry	4.57	239 (90.9)
		Optimization of review process	4.61	242 (92.0)
		Reduction in data entry time	4.36	229 (87.1)
	Data management	Convenience of report management	4.45	234 (89.0)
		Convenience of data download	4.49	237 (90.1)
	Analysis	Utility of statistical analysis	4.38	231 (87.8)
	Permissions	Ease of user permission management	4.43	234 (89.0)
	Assistance	Completeness of logic checks	4.41	231 (87.8)
Reporting quality	Compatibility	Browser compatibility	4.50	237 (90.1)
	Stability	Mean frequency of system failures	2.03 ^c	2 times/year ^c
	Security	Data and permission security	4.59	237 (90.1)
	Timeliness utility	Reduction in reporting time	4.47	234 (89.0)
		Utilization for local risk assessment	4.30	234 (89.0)
Operational support	Personnel	Mean number of dedicated staff	4.05 ^c	3 persons ^c
	Knowledge	Awareness of case definition	4.57	239 (90.9)
		Awareness of reporting timeliness	4.58	242 (92.0)
	Training	Mean frequency of training	3.08 ^c	2 times/year ^c
		Satisfaction with training quality	4.58	242 (92.0)
	Hardware	Satisfaction with hardware/server	4.54	239 (90.9)
	Credibility	Authenticity of entered data	4.58	242 (92.0)

^a Scores range from 1 (strongly disagree) to 5 (strongly agree) that the system works well.

^b Values are n (%) unless otherwise indicated.

^c These values represent the mean of actual counts, not mean Likert scores.

- Questionnaire structure: the survey consisted of two sections. The first section collected information about seven demographic characteristics, including age, education and years of experience. The second section was a system evaluation, covering system construction, reporting quality and operational support.
 - Scoring: most items were rated on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) to gather data on whether the respondent thought that the system was working well. Three items recorded the number of dedicated staff and the frequency of system failure and annual training.
 - An evaluation framework was also included and is described below.
- The assessment applied the hierarchical indicator framework established in the Beijing Model,² which served as the structural basis for evaluating the sentinel hospitals. We applied the original weight coefficients derived from the model's Delphi consultations (authority coefficient ≥ 0.85) to calculate the final scores. Its three primary dimensions are defined here to clarify the metrics used in **Table 1**.
- System construction: focuses on technical efficiency, specifically measuring login speed, ease of data entry and system stability.

- ii. Reporting quality: evaluates data integrity, including data security, the timeliness of uploads and the completeness of logic checks.
- iii. Operational support: measures “soft” capacity, specifically personnel training frequency and staff knowledge of case definitions.

RESULTS

The total number of cases of foodborne disease reported in 2024 (pre-integration) was 4329, but after integration of the HIS into the surveillance network in 2025 (post-integration), the number of cases rose to 5403, a 24.8% increase (data not shown). Regarding system efficiency, the survey of 263 front-line staff revealed high satisfaction with the digital workflow. Specifically, 242 out of 263 respondents (92.0%) were satisfied with the login speed (mean score: 4.59/5), and 229/263 (87.1%) indicated that the automation effectively reduced data entry time (Table 1).

However, growth was uneven across districts. While Nanshan District recorded a 161% increase in the number of reports (rising from 427 to 1115), Pingshan District saw a 44% decline (dropping from 143 to 80) (data not shown). This disparity aligns with the survey findings across the different evaluation dimensions: while the overall mean score for the System Construction dimension was high (4.48/5), the Operational Support dimension revealed a critical weakness. Specifically, the mean frequency of training during the study period was only 3.08, which corresponds to an actual median frequency of just two training sessions per year (Table 1). This highlights a critical gap in personnel readiness.

DISCUSSION

Our data validate the interoperability dividend, that is, the immediate efficiency gain derived from automated data exchange. The 24.8% spike in case reports signals a structural transformation from passive notification to active capture. By automating the extraction of keywords for symptoms of foodborne diseases, the Shenzhen system has effectively lowered the physical barrier to reporting, supporting the finding that the electronic transfer of data reduces reporting lag.³ Unlike the struggles with manual entry observed in Jiangsu Province where the clinical workload often crowded out public health duties, Shenzhen’s automated approach has successfully embedded surveillance into the workflow of clinicians.⁴

Although technology is a force multiplier, it is not the solution to a complex problem. The contrast between Nanshan (a 161% increase in reporting) and Pingshan (a 44% decrease) suggests that surveillance performance is strictly limited by the availability of local resources, such as front-line clinicians to verify data and dedicated public health staff to provide regular training and oversight (for example, the review of the submitted records).⁵ Alternatively, the decrease in Pingshan might be due to the new system’s rigorous automatic rule that removes duplicate reports, which may have successfully filtered out false positives or duplicate entries that were previously over-counted during manual reporting.

This review identified a distinct mismatch between technology and capacity. While the mean score for indicators in System Construction was high (4.48/5), in the Operational Support dimension, mean training frequency was low at 3.08 (reflecting an actual median of two training sessions per year). This is a major weakness in the system. As Feng noted in their study of Ma’anshan City, the primary barrier to effective surveillance is often not the lack of willingness, but the lack of diagnostic clarity among front-line doctors.⁶ In Shenzhen, while doctors have the tool (the HIS interface), the low training frequency identified by our survey remains a critical bottleneck. In this “human-in-the-loop” system, busy clinicians lacking clear diagnostic criteria may dismiss automated prompts due to alert fatigue (causing underreporting) or hastily confirm them without verifying the prompt to clear the screen (causing misclassification). This mirrors experiences in Europe and the United States of America, highlighting that alert fatigue is a universal issue.⁷ Thus, a system’s true sensitivity remains heavily dependent on strict clinical workflow adherence and continuing user training.

Future strategies must pivot from infrastructure investment to prioritizing scenario-based training to bridge the gap between digital tools and front-line competence.

Limitations

This study has limitations because this retrospective assessment covers only the first year post-integration, and the findings rely on subjective user feedback and may not fully capture long-term trends. Additionally, while variations in reporting volumes between districts were observed, the study’s reliance on purely quantitative

data restricts our ability to completely explain these local differences, highlighting the need for future qualitative research.

Conclusions

Shenzhen's digital leap has effectively dismantled the reporting volume barrier, demonstrating that interoperability effectively mitigates the burden of manual reporting. However, the stark technology–capacity mismatch, evidenced by the critical lag in training frequency, remains the system's drawback. Future resilience relies on empowering the front-line sentinels rather than merely upgrading the IT infrastructure.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Ethics statement

This study was approved by the Ethics Committee of the Shenzhen Nanshan District Center for Disease Control and Prevention (protocol code 2026A002). The requirement

for informed consent was waived due to the retrospective nature of the study and the use of de-identified data.

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Emergency medical preparedness and response for mass gatherings: Papua New Guinea emergency medical team's experience during Pope Francis's 2024 visit

Ulysses Oli,^{a,b} Garry G Nou,^{a,c} Rose Hosea^{a,b} and Kelvin Konigala^{a,b}

Correspondence to Ulysses Oli (email: ulyssesoli123@gmail.com)

Problem: Papua New Guinea has hosted several mass gatherings in recent years. Yet, there is limited data on the involvement of emergency medical teams in these events, let alone in other low- and middle-income countries. Prior to Pope Francis's state visit in September 2024, the national emergency medical team (EMT) had not simulated its updated clinical patient flow systems.

Context: During Pope Francis's visit, an estimated 70 000 attendees gathered at the national stadium. Using Arbon's mass gathering model, the patient presentation rate was calculated to be 330 over 2 days, or 4.7 per 1000, posing a significant challenge to local health-care capacity.

Action: The National Department of Health mobilized its EMT to lead clinical operations in collaboration with the National St. John Ambulance service. Planning spanned 6 weeks and involved provincial partners.

Outcome: Over 2 days, 257 patients, or 3.7 per 1000, were managed using a hub-and-spoke model. First-aid stations operated by the St. John Ambulance service treated 200 patients for dehydration and headaches, while the Advanced Casualty Management Centre handled 57 cases of heat-related illnesses and chronic condition exacerbations.

Discussion: The deployment of the EMT showcased its capability and credibility, setting a national milestone and providing a feasible model for mass-gathering preparedness and response in low- and middle-income countries in the World Health Organization's Western Pacific Region. This report highlights not only the importance of multipartner collaboration in such preparedness, providing baseline data for low-resource settings, but also the scalability of rehabilitation services and the Interagency Integrated Triage Tool as frameworks for future deployments.

PROBLEM

Mass gatherings (MGs) can significantly strain the resources of host communities, increasing the risk of injuries, illnesses and catastrophic incidents.¹ MGs, including cultural, religious, political and sporting events, often lead to higher injury and illness rates among the attendees than in the general population.² Thorough planning is mandatory for risk mitigation and timely access to health care.² The principles of MG medical care include rapid patient access and triage, effective stabilization and transport of

critically ill or injured patients, and onsite management of minor injuries and illnesses.²

In Papua New Guinea (PNG), past events like the 15th Pacific Games (2015) and the 26th Asia-Pacific Economic Cooperation Summit (2018) demonstrated the importance of a multisector approach and an integrated emergency care system in managing such large-scale events.^{3,4} However, data on national emergency medical team (EMT) involvement in MGs, particularly in low- and middle-income countries (LMICs) in the Pacific, remain scarce.⁵ Most regional studies focus on disaster or

^a Papua New Guinea Emergency Medical Team, Port Moresby, Papua New Guinea.

^b Port Moresby General Hospital, Port Moresby, Papua New Guinea.

^c Department of Health, Port Moresby, Papua New Guinea.

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pandemic responses, with limited attention to MGs.⁶⁻¹⁰ Although the PNG EMT had achieved key milestones, including deployments during the COVID-19 surge, member training and procurement of an EMT cache, it had not deployed for an MG until the state visit of Pope Francis in 2024.^{7,8,11} This report highlights the first deployment of the PNG EMT for an MG, documenting the strengths, challenges and strategies for improving operational readiness in resource-limited settings.

CONTEXT

Pope Francis's state visit to PNG in September 2024 tested the country's emergency medical response capabilities. An estimated 70 000 attendees were expected at the Sir John Guise Stadium in Port Moresby for the primary event, a Holy Mass, with an additional gathering in West Sepik Province.¹² Due to the stadium's limited capacity of 35 000 people, events were dispersed across multiple venues to accommodate the crowd, increasing the complexity of medical planning, as first-aid stations and response teams needed to cover multiple sites.

The MG presented several health risks, informed by prior regional and global experiences and World Health Organization (WHO) guidelines.^{1,5} Prolonged outdoor exposure posed risks of heat-related illnesses and dehydration, worsened by high temperatures and a lack of shade in the outdoor stadium. The high attendance raised concerns about the potential for a mass casualty incident, such as a crowd crush or structural failure, particularly given the stadium's capacity constraints, which necessitated crowd control measures and enhanced triage capacity.² These concerns were considered during risk assessments, prompting the use of a hub-and-spoke model and contingency plans for rapid escalation to nearby hospitals. Additionally, the large crowd size increased the risk of infectious disease transmission, such as respiratory illnesses, prompting public health measures such as mask distribution.

The PNG National Department of Health (NDOH) and its EMT worked closely with the National St. John Ambulance (NSJA) service, which was instrumental in developing a comprehensive preparedness plan in collaboration with other key partners. These partners included the country's top-tier public referral hospital, Port Moresby General Hospital (PMGH), as well as the National Capital District Provincial Health Authority

(NCDPHA) and the West Sepik Province Health Authority (WSPHA). External partners included the National Events Secretariat, the Ministry of Foreign Affairs, the PNG Defence Force and the West Sepik Provincial Emergency Operation Centre (WSPEOC). These partners played crucial roles in the operational framework. Internal partners included organizations directly involved in health care, such as PMGH and two provincial hospitals in the areas where the Pope's visit took place. These comprised Gerehu General Hospital under the authority of NCDPHA, and Vanimo General Hospital under WSPHA. External partners involved organizations in logistics, defence and emergency response, as well as government agencies responsible for national coordination and diplomacy, including the Ministry of Foreign Affairs and the National Events Secretariat. This multipartner approach addressed the identified risks and ensured a coordinated response across dispersed venues.

ACTION

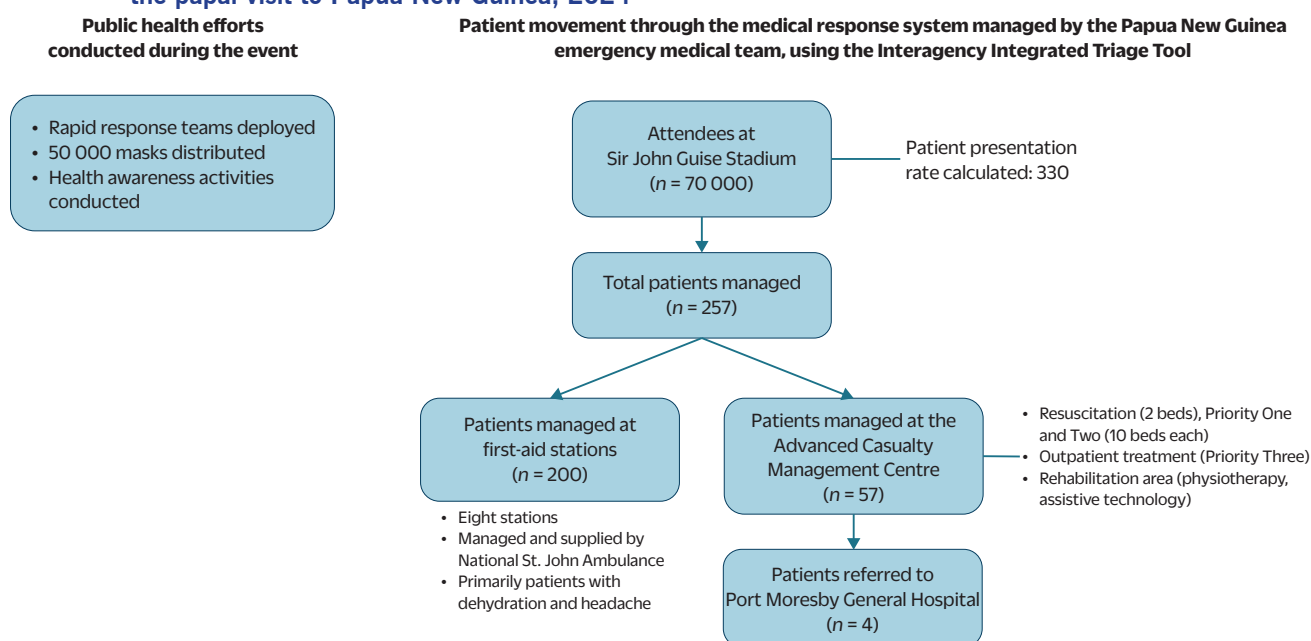
Overall planning and methods

The NDOH was the strategic lead, coordinating nationwide planning with various internal and external partners. Planning commenced in February 2024 and was divided into two phases.

In Phase 1, a multipartner, coordinated response was outlined in an overarching Health Operations Plan (Papal visit health operations plan. Port Moresby: National Department of Health, National St. John Ambulance, unpublished data, 2024) based on *Emergency response framework (ERF): internal WHO procedures*.¹³ NSJA was instrumental in the preparation efforts, representing health stakeholders in inter-agency meetings and contributing to pre-hospital care, logistics, critical care and aeromedical support. PMGH provided clinical, pharmaceutical and rehabilitation staff, most of whom were trained under the PNG EMT programme. NCDPHA oversaw the public health response, deploying rapid response teams. WSPHA and the WSPEOC supported NDOH during the Pope's visit to West Sepik Province, which is 946 km from Port Moresby. International EMTs were on standby for crisis-level surge capacity.

Phase 2 involved simulations and walkthroughs conducted with all response teams in the weeks leading up to the event. Arbon's mass gathering model, a

Fig. 1. Patient movement through the medical response system and concurrent public health activities during the papal visit to Papua New Guinea, 2024



predictive tool used to estimate patient presentation rate (PPR) based on crowd size, event characteristics and environmental factors, was applied to forecast service demand. This model estimated a PPR of 330 over 2 days, or 4.7 patients per 1000 attendees daily.¹⁴ This projection informed staffing, equipment allocation and clinical capacity planning and highlighted the potential strain on local health-care resources.²

Clinical planning for Type 1 EMT

The PNG EMT, a Type 1 EMT focused on outpatient care, planned for the calculated PPR of 330 over 2 days, providing onsite clinical and rehabilitation services using established patient pathways. EMT members used the Interagency Integrated Triage Tool (IITT)¹⁵ to improve patient flow and include rehabilitation for musculoskeletal injuries. NSJA supplied mobile medical kits, pharmaceuticals and first-aid teams at eight stations to address issues such as dehydration and headaches (Fig. 1).

Despite its role in providing outpatient care, the diverse skills of PNG EMT members, including those of emergency physicians, surgeons and senior non-specialist doctors, enabled the establishment of a temporary resuscitation and critical care bay within the Advanced

Casualty Management Centre (ACMC) – the primary onsite medical hub (Fig. 2). Equipped for advanced procedures like intubation, electrical cardioversion and defibrillation, it ensured readiness for critical cases. The small team required close collaboration with NSJA staff, who provided standby support to enhance critical care capacity.

NSJA coordinated contingency plans and arranged the transfer of patients: low-priority patients to Gerehu General Hospital and high-priority patients to PMGH. They also supported Pope Francis's trip to West Sepik Province with an aeromedical escort. Two-week pre-event simulations included scenario-based training on the IITT and patient flow, ensuring staff proficiency in triaging and transitions between first-aid stations and the ACMC.

Rehabilitation services were added to the clinical plan, with physiotherapists trained in acupuncture and assistive technology like wheelchairs and walking aids sent to the ACMC to address mobility needs. The plan was supported by a logistics system that ensured sufficient supplies of oral rehydration salts, pain relievers and rehabilitation equipment, tailored to resource limitations common in LMICs. This strategy enabled the PNG EMT to manage outpatients and standby for critical care during the papal visit.

Fig. 2. Layout of the Advanced Casualty Management Centre and its various stations during the papal visit to Papua New Guinea, 2024



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A: entrance to stadium; B: ambulance bay; C and D: triage area; E: Priority Three and rehabilitation area; F: Priority Two area; G: Priority One area; H: coordination and communication centre; I: pharmacy and inventory; J: resuscitation and critical care bay.

Setting

Patient flow was streamlined using a hub-and-spoke model, with first-aid stations passing patients to the ACMC (**Fig. 1**). Located in the north-west car park of the stadium where the Holy Mass was held (**Fig. 2**), the ACMC operated under a three-colour triage system based on the IITT.¹⁵ The system facilitated efficient patient flow and the integration of physical rehabilitation into the ACMC by categorizing patients into Priority One (immediate, life-threatening conditions requiring resuscitation), Priority Two (urgent conditions requiring early intervention) and Priority Three (non-urgent or minor conditions).¹⁵

The ACMC spanned 700 m² (14 × 50 m) with a 23-bed capacity, comprising:

- 2-bed resuscitation ward;
- 10-bed Priority One ward;
- 10-bed Priority Two ward; and
- 1-bed examination/rehabilitation area in the Priority Three ward.

Staff

The PNG EMT lead and the NSJA Chief Medical Officer headed operations as Health and Deputy Health

Commander, respectively. Their team included an incident manager, public health commander, logistics commander, and sector commanders for NCDPHA and WSPEOC.

The NSJA deployed 50 personnel, including emergency physicians, paramedics, ambulance officers, critical care nurses, pharmacists and logistics officers. PMGH contributed 17 staff members, 14 of whom were trained by the PNG EMT, including emergency doctors, nurses, physiotherapists, a critical care anaesthetist, an orthopaedic surgeon, a health extension officer, an anaesthetic scientific officer, a pharmacist, and logistics and data officers. A dedicated aeromedical team, consisting of a critical care anaesthetist and critical care nurse, provided escort services for Pope Francis to West Sepik Province.

Data collection

Members of the PNG EMT collected patient data on standardized paper-based triage forms based on the IITT. A designated logistics officer compiled data from the first-aid stations and the ACMC, which were aggregated daily into a centralized electronic log post-event, with supervisory cross-checks to ensure accuracy. This process enabled real-time tracking of patient presentations and outcomes, despite resource constraints typical in an LMIC setting.

Table 1. General characteristics of patients who visited the Advanced Casualty Management Centre for medical review during the papal visit in Papua New Guinea, 2024

Characteristic	Day 1	Day 2	Total
Subtotal	28	29	57
Sex			
Male	17 (61)	18 (62)	35 (61)
Female	11 (39)	11 (38)	22 (39)
Age range, years			
Median age	36	42	35
0–5	2 (7)	0 (0)	2 (4)
6–15	3 (11)	0 (0)	3 (5)
15–50	19 (68)	25 (86)	44 (77)
>50	4 (14)	4 (14)	8 (14)
Nationality			
Papua New Guinea	27 (96)	29 (100)	56 (98)
Expatriate	1 (4)	0 (0)	1 (2)

• Values are *n* (%) unless otherwise indicated.

OUTCOME

Patient care and results

The onsite first-aid stations and the ACMC aided in surge capacity, thus reducing the patient load in Port Moresby's resource-constrained hospitals. Patient care began at one of eight strategically placed first-aid stations inside the stadium. Patients requiring advanced care were redirected to the ACMC, where the IITT guided triage and treatment. Referrals for specialized care were directed to PMGH.

Over the 2-day event, 257 patients, or 3.7 per 1000, received care. First-aid stations managed 200 cases with primarily dehydration and headaches. The ACMC treated 57 patients, comprising 11 Priority Two and 46 Priority Three patients. These included 35 males, 22 females, two children under 5 years and eight patients over 50 years (Table 1). Four patients required urgent referral to PMGH:

- a 6-month-old infant with acute febrile illness and signs of meningism;
- a 12-year-old boy with facial cellulitis;
- a 2-year-old male with acute bronchiolitis; and
- a 40-year-old male with clinical pneumonia.

The most common presentations at the ACMC were acute outpatient conditions (17 cases), exacerbations of

chronic illnesses (14 cases) and heat-related illnesses (12 cases). Additionally, 16 patients required physical rehabilitation services. They were managed onsite by experienced physiotherapists trained in acupuncture. Assistive technology, particularly wheelchairs and walking support, was provided to patients who required it.

Public health efforts complemented clinical care. The public health team distributed over 50 000 face masks and conducted health-awareness activities.

DISCUSSION

This deployment of the PNG EMT during Pope Francis's visit marked a significant milestone in its first-ever response to an MG event, setting a precedent for similar medical responses in PNG and the broader WHO Western Pacific Region. By effectively integrating rehabilitation services and using the IITT, this operation provides a valuable model for resource-limited settings facing such challenging situations.

Two key observations highlight the significance of this deployment:

- **Rehabilitation services:** Rehabilitation services played a critical role in managing musculoskeletal injuries, helping patients with mobility limitations recover and providing assistive technologies,

such as wheelchairs, during the deployment. This highlights the importance of integrating rehabilitation into MG planning that aligns with WHO's guidelines for comprehensive health care during such events.¹⁶

- IITT system: The IITT system facilitated efficient patient flow and prioritization of care, even in the context of disparate staff familiarity. Its structure streamlined onsite management, reinforcing the importance of standardized triage protocols in MGs, as supported by multiple studies.¹⁷

While this deployment was largely successful, several limitations should be considered. PNG EMT's first MG response lacked historical data for accurate caseload prediction. Arbon's model offered a framework, but it had not been validated locally, highlighting the need for context-specific data. Some staff's unfamiliarity with the IITT led to triage errors, such as the misclassification of some Priority Three patients as Priority Two, which caused delays and incomplete IITT form completion and reporting. Targeted remedial training, including IITT workshops and simulation drills with realistic MG conditions, could improve staff proficiency. Incorporating these into capacity-building programmes, possibly via WHO EMT guidelines, would enhance future MG readiness in LMICs. Finally, limited resources may necessitate partner collaborations.

Despite these limitations, the operation demonstrated notable strengths. The diverse clinical expertise of the team ensured comprehensive patient care, and the efficient referral process enabled seamless access to higher levels of care when necessary. Strong collaboration between the PNG EMT, NSJA and other partners was key to effective coordination and resource management, emphasizing the importance of interagency communication in successful MG preparedness and response.

The findings from this deployment are consistent with the expected trends in MG medical responses.^{2,14} The PPR was slightly lower than predicted by Arbon's model (3.7 vs 4.7 per 1000), potentially due to an underreporting by the satellite teams managing patients or due to timely public health awareness efforts. The prevalence of heat-related illnesses and the exacerbation of chronic conditions was consistent with expected presentations during MGs, particularly those involving prolonged sun exposure.

This experience highlights several opportunities for future research and improvement. The validation of Arbon's model for the PNG context is crucial in refining planning and resource allocation. Further research could focus on the influence of specific environmental factors, such as temperature, humidity and rainfall, on patient presentations during MGs in PNG. Additionally, valuable insights for optimizing future deployments could be gathered by evaluating the integration of rehabilitation services into MG medical teams and by collecting data on team members' feedback.

By addressing these areas and building on the lessons learned, PNG could enhance its capacity to deliver comprehensive health care during MGs, ensuring the safety and well-being of local communities and visitors.

Conclusions and recommendations

This report highlights the value of involving a national EMT in MG events and emphasizes the importance of multipartner collaboration in a low-resource setting. It establishes baseline data for MG medical response in PNG, which other similar settings in the WHO Western Pacific Region could utilize. Key findings include integrating rehabilitation services and using the IITT system, which is crucial for patient care. We recommend improving triage training, enhancing data collection and establishing pre-deployment training for MGs to address identified gaps. This clinical response model proved effective during the papal visit and could be adapted by EMTs in other low-resource settings.

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collaboration ensured seamless inter-agency coordination. The Sir John Guise Stadium authorities and city officials also deserve recognition for their indispensable logistical support and venue management.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Ethics statement

No ethical or special permissions were required for the submission of this report.

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Emergency medical team coordination management following the 2024 Vanuatu earthquake

Sharin Vile,^a Jimmy Obed,^a Pierre-Yves Beauchemin,^b Samuel Kemuel,^a Tatsuhiko Kubo,^{c,d} Erin E Noste,^{b,e} Chandra Gilmore,^b Philippe Guyant,^{f,g} Ryusuke Ikeda,^h Tomoaki Natsukawa,ⁱ Kaoru Harada,ⁱ Yuki Takamura,^c Hideshige Tanaka,^c Hirotaka Sugiyama^h and Sean T Casey^{b,c}

Correspondence to Sharin Vile (email: svile@vanuatu.gov.vu)

Problem: On 17 December 2024, a magnitude 7.3 earthquake struck the Pacific Island country of Vanuatu, affecting over 80 000 people and causing 14 deaths and 265 injuries. Facing limited specialist clinical capacity, increased patient load and strained facilities, Vanuatu's Ministry of Health requested support from emergency medical teams.

Context: Vanuatu, highly disaster-prone and geographically dispersed, has a health system constrained by limited human resources and recent cyclone-related damage. The country's national emergency medical team, the Vanuatu Medical Assistance Team, was established in 2017 and plays a central role in health emergency response in the country.

Action: Within 24 hours of the earthquake, the Vanuatu Medical Assistance Team was activated and established an Emergency Medical Team Coordination Cell within the national health emergency operations centre. National and international emergency medical teams from Australia, Fiji, Indonesia, Japan and New Zealand were deployed over the subsequent weeks and provided clinical, mental health and information management support. The World Health Organization's emergency medical team Minimum Data Set was implemented to monitor health trends and inform response actions.

Outcome: Eight national and international emergency medical teams deployed alongside local health services. Together, they reported more than 5500 consultations to the Emergency Medical Team Coordination Cell, and a specialized team provided mental health and psychosocial support to 521 people. Minimum Data Set analysis showed a rapid decline in trauma-related presentations and detected increases in influenza-like illness, guiding the transition from emergency to recovery.

Discussion: This response underscored the value of emergency medical teams following disasters, the importance of national leadership and coordination, and the significance of regional solidarity and partnerships. It also highlighted the importance of information management during emergencies and demonstrated potential innovations in this space.

PROBLEM

The Pacific Island nation of Vanuatu was struck by a magnitude 7.3 offshore earthquake on 17 December 2024, approximately 30 km west of the capital city of Port Vila (Fig. 1).¹ This disaster affected

over 80 000 people in and around Port Vila, leaving over 10 buildings destroyed and around 570 houses damaged; Vanuatu's national referral hospital, Vanuatu National Hospital (VNH), was also damaged.^{1,2} The earthquake caused 14 deaths and approximately 265 injuries, and displaced approximately 2435 individuals

^a Ministry of Health, Port Vila, Vanuatu.

^b World Health Organization Regional Office for the Western Pacific, Manila, Philippines.

^c Department of Public Health and Health Policy, Graduate School of Biomedical and Health Sciences, Hiroshima University, Hiroshima, Japan.

^d Department of Multi-Sectoral Preparedness & Strategic Coordination for Health Security, Center for Health Security, Graduate School of Medicine, Kyoto University, Kyoto, Japan.

^e Department of Emergency Medicine, University of California San Diego, San Diego, California, United States of America.

^f World Health Organization Division of Pacific Technical Support, Suva, Fiji.

^g World Health Organization Country Liaison Office, Port Vila, Vanuatu.

^h Secretariat of Japan Disaster Relief / Japan International Cooperation Agency, Tokyo, Japan.

ⁱ Yodogawa Christian Hospital, Osaka, Japan.

^j Seirei Mikatahara General Hospital, Hamamatsu, Shizuoka, Japan.

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across six evacuation centres and host families.^{1,2} With limited specialist clinical capacities and an overwhelmed and damaged hospital in the capital city, the Government of Vanuatu, through its Ministry of Health (MoH) and Ministry of Foreign Affairs, requested assistance from international emergency medical teams (EMTs).²

CONTEXT

Vanuatu, an archipelago of 83 islands (65 inhabited) in the South Pacific, is among the world's most disaster-prone nations due to its location along the Pacific Ring of Fire and within the South Pacific cyclone belt. Its population of 300 000 is spread across four archipelagos, covering over 663 000 km² of ocean territory.³ Vanuatu's geography makes the country highly vulnerable to natural hazards, including earthquakes, tsunamis, tropical cyclones, flooding and volcanic eruptions.⁴

Vanuatu is classified by the World Bank as a lower-middle income country, with life expectancy of 74.2 for females and 71.6 for males.³ The country faces a marked shortage of health professionals and capacity, with 0.17 physicians per 1000 people.⁵ Noncommunicable diseases (NCDs) account for up to 74% of all deaths, while common infectious diseases include leptospirosis, dengue and tuberculosis.⁶ Vanuatu's health system includes six hospitals (including two tertiary referral hospitals), 35 health centres, and approximately 290 aid posts and dispensaries.⁷ It faces significant workforce limitations, including shortages of specialist physicians and loss of health workers to overseas employment and retirement.⁷ At the time of the earthquake, Vanuatu had no orthopaedic surgeons, one psychiatrist and a significant shortage of nurses. The nursing school in Vanuatu has not been enrolling or graduating nurses since 2022 due to an internal audit conducted by the Vanuatu Qualification Authority to evaluate compliance and national standards. Beyond its chronic challenges, Vanuatu's health system was already recovering from multiple disasters in 2023, including back-to-back tropical cyclones.⁸ A 2025 Joint External Evaluation of Vanuatu's International Health Regulations (2005) core capacities confirmed significant gaps in health emergency response readiness, with both the ability to surge health workforce during public health events and health emergency logistics scoring at the lowest level (1 out of 5).⁹

Vanuatu's MoH established the Vanuatu Medical Assistance Team (VanMAT) in 2017 due to the persistent threat of disasters and outbreaks in the country.^{8,10} The establishment of VanMAT was accomplished with technical and operational support from the World Health Organization (WHO), and with funding and technical support from the Governments of Australia and New Zealand.^{10,11} VanMAT was established within Vanuatu's MoH, with coordination linkages to Vanuatu's National Disaster Management Office (NDMO). In peacetime, VanMAT maintains readiness through training and coordination with MoH, NDMO, WHO and regional partners. VanMAT's EMT Coordination Cell (EMTCC) serves as the national coordination mechanism for EMT deployment during health emergencies, responsible for receiving and processing offers of international assistance, tasking (assigning) EMTs to work in specific affected areas, and consolidating health data to guide response decisions.

VanMAT is one of many national and international EMTs in WHO's Western Pacific Region, established based on the principles and standards detailed in WHO's *Classification and minimum standards for emergency medical teams*.^{10,12} EMTs provide clinical care and public health assistance to populations affected by disasters, outbreaks and other health emergencies. VanMAT, like other national EMTs in the South Pacific, was designed by adopting and adapting global EMT standards to Vanuatu's unique island context and high vulnerability to natural hazards.⁸ EMTs have been established across the Western Pacific Region, with 16 teams classified (quality-assured) by WHO and peer EMTs by the end of 2024 (of 53 globally).¹⁰

ACTION

Following the 17 December 2024 earthquake, Vanuatu's MoH and partners immediately undertook damage and needs assessments at VNH and other health centres.^{1,2} Power and telecommunications were disrupted across Port Vila, with early coordination relying on Starlink satellite connectivity, in-person EMTCC situation updates and bilateral partner channels. Given the uncertainty over the structural integrity of health facilities, a lack of specialist capacity in Vanuatu, and the large number of injured and displaced people, Vanuatu's MoH requested

Fig. 1. Map of Vanuatu showing the epicentre of the magnitude 7.3 earthquake of 17 December 2024, with provincial boundaries and regional context (inset)



support from international EMTs in the Western Pacific Region.

On 18 December, VanMAT leadership within the MoH established an EMTCC. On the same day, the Australian Medical Assistance Team (AUSMAT) and New Zealand Medical Assistance Team (NZMAT) deployed forward teams as part of larger support provided by the Governments of Australia and New Zealand.¹³ The NZMAT forward team demobilized a few days later, while AUSMAT deployed a second rotation of 13 team members, focusing support on VNH.

Additional teams, including VanMAT's clinical team, were activated in the 10 days after the earthquake to provide specialized support to the response. On 21 December, following an online meeting between Vanuatu's MoH and the Secretariat of the Japan Disaster Relief Team (JDR)/Japan International Cooperation Agency (JICA), JICA initiated remote support for information management (IM) for Vanuatu's EMTCC, with team members providing in-person IM support from 26 December, applying WHO's EMT Minimum Data Set (MDS).¹⁴ On 27 December, the Pasifika Medical Association Medical Assistance Team (PACMAT) arrived in Port Vila, deploying as a specialized care team with a focus on mental health and psychosocial support (MHPSS).¹⁵ The Indonesia EMT arrived on the same day to establish an outpatient field clinic at Vanuatu's NCD Hub. The Fiji Emergency Medical Assistance Team (FEMAT) deployed a 12-member team from 5 to 17 January 2025. FEMAT's response focused on supporting Vanuatu's NCD Hub, providing outpatient care and supporting haemodialysis at VNH along with AUSMAT.

While some EMTs deployed quickly, others arrived approximately 2 weeks after the earthquake, by which time acute cases related to the earthquake had already been managed. However, Vanuatu's fragile and understaffed health system required surge support throughout the response and recovery periods.

OUTCOME

VanMAT was activated immediately after the earthquake and led the clinical response, with the overarching health response coordinated by the MoH, supporting the deployment of eight national and international EMTs. From December 2024 to February 2025, more than

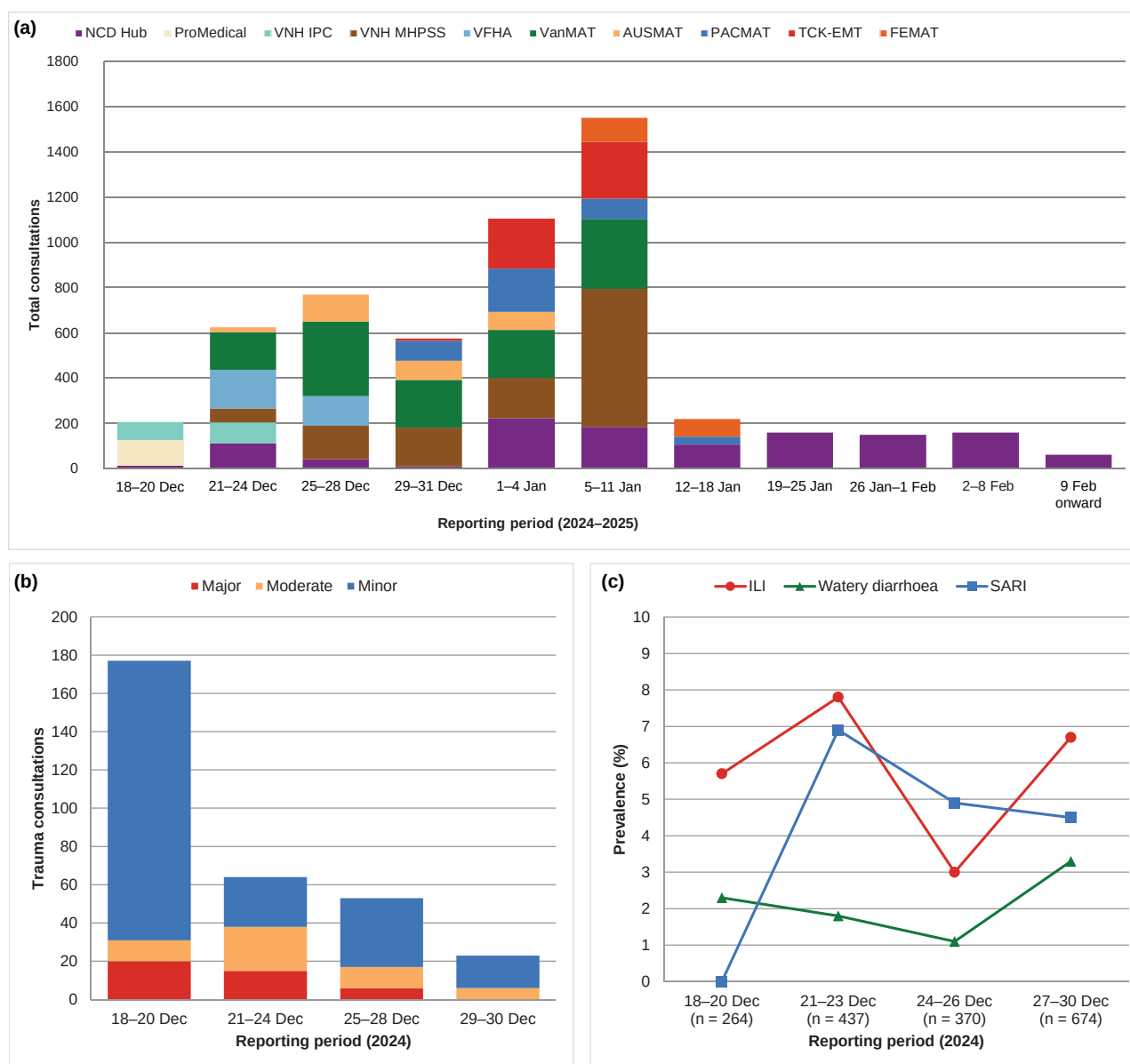
5500 consultations were reported to the EMTCC through the MDS by EMTs and participating local health facilities (Fig. 2). An MHPSS EMT was also deployed and provided care for 521 individuals, all of whose presentations were directly linked to the earthquake.¹⁵ Data collection and information management were supported by JICA, applying the WHO MDS.¹⁴

EMTs provided a wide range of services, including clinical support at VNH, NCD Hub and community locations around Port Vila, as well as rehabilitation, orthopaedic care and MHPSS. In particular, teams contributed specialists who were not readily available in-country, such as orthopaedic surgeons, rehabilitation professionals and mental health specialists.¹³

The MoH initiated daily reporting using the EMT MDS just 1 day after the disaster. A version of the MDS was also developed specifically for MHPSS services, adapted from the Japanese national EMT daily MHPSS reporting template. These tools enabled monitoring of disease trends and supported transition planning. Collaborative analysis of MDS data by the EMTCC and JICA IM team showed that trauma-related consultations declined sharply over the first weeks of the response, indicating a transition from acute emergency to recovery. MDS syndromic surveillance, cross-referenced with the national early warning, alert and response system, detected increases in influenza-like illness presentations following the earthquake, enabling early public health action. The MDS was also extended beyond EMTs for use by local health facilities, a novel approach that broadened the scope of routine health data collection during the response.

Despite strong coordination and data reporting mechanisms, challenges emerged in the operational aspects of the response. Based on observations from the VanMAT coordinator and WHO logistics expert, pre-positioned emergency supplies were not properly stored or inventoried, limiting the ability to rapidly deploy VanMAT's logistics cache when needed, and VanMAT satellite communication systems were not activated during early blackout periods. Most EMTs deployed outside of their formal WHO classification typologies. For example, AUSMAT (a Type 2 EMT) deployed as a Specialized Care Team to VNH, and PACMAT (pursuing Type 1 Mobile classification) deployed to provide both outpatient care and specialized MHPSS services.^{13,15}

Fig. 2. EMT Minimum Data Set summary, Vanuatu earthquake response, December 2024–February 2025: (a) weekly consultations reported to the EMTCC by EMTs and participating local health facilities, by reporting entity; (b) trauma consultations by severity; and (c) infectious disease prevalence among reported cases



AUSMAT: Australian Medical Assistance Team; EMT: emergency medical team; EMTCC: emergency medical team coordination cell; FEMAT: Fiji Emergency Medical Assistance Team; ILI: influenza-like illness; IPC: infection prevention and control; MHPSS: mental health and psychosocial support; NCD: noncommunicable disease; PACMAT: Pasifika Medical Association Medical Assistance Team; ProMedical: private ambulance and emergency medical service, Vanuatu; SARI: severe acute respiratory infection; TCK: Tenaga Cadangan Kesehatan (Indonesia's health emergency reserve workforce); VanMAT: Vanuatu Medical Assistance Team; VFHA: Vanuatu Family Health Association; VNH: Vanuatu National Hospital.

In panel (a), reporting periods before 5 January are shorter than the subsequent 7-day periods, so consultation counts are not directly comparable across periods.

While the Vanuatu MoH coordinated most EMT engagement through the EMTCC, some offers of assistance, both accepted and declined, were managed bilaterally or through diplomatic channels, occasionally

outside of EMTCC processes. While the MoH engaged EMTs directly to request their support, offers of assistance were also received by at least two other teams, which were respectfully declined based on an MoH determination

that needs were sufficiently addressed, and applying a preference for local teams with whom Vanuatu had existing relationships and for those pursuing WHO EMT classification (Table 1).

DISCUSSION

The Vanuatu earthquake response demonstrated that nationally led coordination, underpinned by structured data collection through the EMT MDS, is central to mobilizing surge clinical capacity and managing the transition from emergency to recovery. Investment in national coordination mechanisms and systematic IM enabled a small island developing state to direct international assistance while maintaining national ownership.

VanMAT's national EMT activation demonstrated the importance of this national health emergency response capability. Vanuatu scaled up the EMTCC immediately following the earthquake, enabling national authorities to issue bilateral requests for assistance, receive classified EMTs, and gather and analyse data and information from the day after the earthquake through the departure of the last international EMT. Through the EMTCC, the MoH consolidated requests for surge health workforce and tasked EMTs based on needs and available resources, drawing on the MDS to match specialized skills to locations.

EMTs responded quickly to the Government's call for assistance, mostly through bilateral arrangements. Evidence suggested that EMTs effectively supported response actions, particularly through deployment of clinicians with specialties that are typically not available in Vanuatu. This response highlights the utility of a connected regional EMT network, with broader implications for global preparedness through sharing operational data and lessons across borders.¹⁰

The proportion of clinical consultations directly related to the earthquake quickly decreased, according to MDS data submitted to the EMTCC, guiding the transition from emergency to recovery. The MDS was used for reporting by both EMTs and local health facilities, suggesting the potential for broader application in future health emergency responses. This expansion of the EMT MDS within the existing local health system following the disaster could suggest an opportunity for future use in similar contexts.

Determining the number and types of EMTs needed is often a challenging task because information is often imperfect. The complexity of managing offers of international support, particularly when channelled through bilateral mechanisms, reinforces the importance of clear national coordination structures and broad awareness of EMT coordination processes. However, in Vanuatu, regional solidarity and pre-existing relationships were evident throughout the response and directly facilitated coordination. For example, PACMAT had previously worked with Vanuatu's mental health services, AUSMAT had deployed to Vanuatu in previous emergencies, and EMTCC leadership had participated in AUSMAT-led training. These relationships enabled rapid tasking and reduced the burden of orientation during international deployments. However, the deployment of EMTs outside of their WHO classified typology, while practical, raises questions about how classification frameworks reflect real-world deployment needs. This warrants further discussion within the global EMT community, the WHO EMT Secretariat and the EMT Strategic Advisory Group. Many EMTs expend significant resources to achieve WHO classification, yet the roles they fulfil may differ from their classified typology. Acknowledging this need for flexibility, while maintaining core EMT principles and minimum standards, may better serve affected populations.

Integrating information and data management from the early stages of a health emergency response can improve data quality and help decision-makers understand the situation more clearly.¹⁴ In this event, early remote collaboration with the JDR Secretariat/JICA followed by in-person technical support provided more consistent EMT and response data. An important aspect of IM during this response was collating and interpreting local health facility data alongside EMT reporting. While EMTs contribute to health emergency response, local health providers are the primary responders. Documenting EMT action provides insights into certain elements of the response but may not reflect broader health impacts, including reductions in morbidity, mortality and pressures on resource-limited health systems. Information generated through the EMTCC was shared through WHO EMT coordination mechanisms, reinforcing the value of standardized reporting for cross-border learning.

This study has several limitations. As a descriptive account of a single emergency response, findings may not be generalizable. The analysis relies on aggregated MDS data, which do not capture the full clinical detail of

Table 1. **EMTs and health emergency surge personnel^a deployed in response to the Vanuatu earthquake, 2024–2025**

EMT	Deployment period	Deployment location	Team composition (function)	Team composition (gender)
VanMAT^b	22 December 2024–9 January 2025	Vanuatu National Hospital	4 registered nurses 1 midwife 1 driver	4 females, 2 males
AUSMAT (Alpha rotation)	18 December 2024–6 January 2025	Vanuatu National Hospital	2 nurses 1 midwife 2 medical officers 1 logistician	2 females, 4 males
AUSMAT (Bravo rotation)	23 December 2024–6 January 2025	Vanuatu National Hospital	3 logisticians 1 clinical team lead 1 general medicine specialist 1 physiotherapist 1 wound care nurse 2 scrub/scout nurses 1 biomedical engineer 1 recovery room & general nurse 1 occupational therapist 1 general surgeon	6 females, 7 males
NZMAT	18–22 December 2024	Ministry of Health/ Vanuatu National Hospital	1 mission lead 1 doctor 1 logistician	3 males
JDR/JICA (information management support)	21 December 2024–18 January 2025	EMTCC (in-country and remote support)	1 operations manager 1 team leader 1 coordinator 1 deputy coordinator 5 information management	2 females, 7 males (3 remote, 6 onsite)
UNFPA (midwives)	25 December 2024–22 March 2025	Vanuatu National Hospital and Vanuatu Family Health Association Mobile team	4 midwives	4 females
PACMAT (MHPSS specialized care team)	27 December 2024–17 January 2025	Specialized care team	1 team lead 1 logistician 2 psychiatrists 2 mental health nurses 2 registered nurses 1 medical officer	2 females, 7 males
Indonesia EMT	27 December 2024–10 January 2025	Type 1 Mobile (NCD Hub and outreach with Shefa health team)	5 nurses 3 general practitioners 1 pharmacist 1 logistics and administration 1 emergency specialist 1 internist specialist 1 orthopaedic 1 anaesthesia specialist 1 surgical specialist	15 males
FEMAT	5–17 January 2025	Type 1 Mobile (NCD Hub)	1 team lead 1 clinical lead 1 logistics lead 1 nursing lead 3 nurses (paediatric, emergency and haemodialysis) 1 midwife 1 carpenter 1 electrician 1 biomedical technician 1 data officer	7 females, 5 males

AUSMAT: Australian Medical Assistance Team; EMT: emergency medical team; EMTCC: emergency medical team coordination cell; FEMAT: Fiji Emergency Medical Assistance Team; JDR: Japan Disaster Relief; JICA: Japan International Cooperation Agency; MHPSS: mental health and psychosocial support; NCD: noncommunicable disease; NZMAT: New Zealand Medical Assistance Team; PACMAT: Pasifika Medical Association Medical Assistance Team; UNFPA: United Nations Population Fund; VanMAT: Vanuatu Medical Assistance Team.

^a A nongovernmental organization, Respond Global, also provided support to Shefa Province, but was not considered an EMT in this response.

^b VanMAT, Vanuatu's national EMT, was formally deployed through the EMTCC. VanMAT leadership in Port Vila established the EMTCC on 18 December 2024; the VanMAT clinical team arrived in Port Vila on 22 December 2024.

individual patient encounters. The study does not include outcome measures such as mortality or morbidity reduction attributable to EMT interventions. Future research should strive to link EMT operational data with health outcome indicators to strengthen the evidence base.

This response offers lessons for Pacific Island countries and areas on national leadership, coordination, data-driven decision-making and partnerships. It also contributes to the broader global EMT knowledge base through three innovations in data and information management: the extension of MDS reporting to local health facilities beyond EMTs, the adaptation of a Japanese MHPSS reporting template for Pacific use, and the initiation of remote IM support prior to in-country deployment, as well as the practical deployment of national, classified and non-classified teams in a sudden-onset emergency setting.

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Conflicts of interest

STC is an associate editor of the *Western Pacific Surveillance and Response* journal. He recused himself from all editorial decisions related to this manuscript. The remaining authors have no conflicts of interest to declare.

Ethics approval

This manuscript describes a public health emergency response using aggregated, de-identified programme data. No individual patient data were collected or analysed for this manuscript. Ethics approval was not required. The Vanuatu MoH gave approval to develop this manuscript.

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Data availability

The EMT MDS data referenced in this manuscript are held by the Vanuatu MoH and the EMTCC. Aggregated data are presented in the manuscript. Requests for additional data should be directed to the corresponding author.

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Humour-driven risk communication and community engagement to mitigate dengue: Lao People's Democratic Republic, 2024

Visith Khamlusa,^a Vilakone Phangkhambhak,^a William Seal,^b Outhikone Souphome In,^b Rachel Lorimer,^b Patrice Suyot^c and Lieke Visser^d

Correspondence to Lieke Visser (email: visserl@who.int)

Problem: In early 2024, the Lao People's Democratic Republic experienced a surge in dengue cases approaching levels of its 2013 epidemic, underscoring the persistent threat of dengue during the monsoon season. Although awareness of preventive behaviours is high, inconsistent adoption has limited their effectiveness.

Context: In response, the Ministry of Health, in collaboration with the World Health Organization, implemented an innovative, humour-driven risk communication and community engagement (RCCE) campaign targeting individuals who perceived dengue as a routine health concern.

Action: To capture attention and increase message retention, the April to September campaign employed an actor dressed as a giant mosquito who deliberately and humorously interrupted daily activities. The strategy used pre-tested materials, a strong social media presence, and television and radio to promote mosquito control, symptom recognition and timely medical care for severe dengue. The impact was assessed through nationwide phone and online surveys and social media analytics.

Outcome: The campaign reached almost 2.9 million unique users (68.2% of whom were using the country's most popular social media platform), generating more than 27 million content views and 86 342 interactions. Post-campaign surveys indicated a sharp rise in public concern about dengue (from 21% [42/200] to 56% [224/400], indicating they were "very concerned") and high awareness of key messages, with 81% (324/400) stating they would seek immediate care for severe symptoms. The humour-based approach was rated as appealing or very appealing by 76% (304/400) of respondents, with 90% (360/400) reporting increased likelihood of preventive action.

Discussion: These findings demonstrate that culturally relevant, humour-based RCCE, integrated across digital and traditional media, may be effective in enhancing awareness and shifting perceptions.

PROBLEM

In early 2024, the Lao People's Democratic Republic experienced a sharp increase in reported dengue virus cases, reaching levels comparable to the country's major 2013 outbreak, which recorded 44 171 cases and 95 deaths.¹ This surge highlighted the persistent and serious threat dengue poses to public health in the country and its population of 7.78 million, especially during the tropical monsoon season from June to September, when environmental conditions, such as

increased rainfall, create favourable habitats for mosquito breeding and enhance virus transmission.^{2,3}

Although awareness of preventive measures, such as eliminating mosquito breeding sites and protecting against mosquito bites, is relatively high and has been a focus for previous promotions undertaken by the Ministry of Health and provincial and district authorities, survey data suggest these practices are not consistently adopted across communities.⁴ This gap between knowledge and actual behaviour hampers efforts to reduce mosquito

^a Ministry of Health, Vientiane, Lao People's Democratic Republic.

^b World Health Organization Representative Office for the Lao People's Democratic Republic, Vientiane, Lao People's Democratic Republic.

^c United Nations Foundation, Washington, DC, United States of America.

^d World Health Organization Regional Office for the Western Pacific, Manila, Philippines.

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populations and control disease spread. Given dengue's recurring outbreaks, sustaining preventive actions over time is crucial to minimizing future surges.⁵

Effective dengue control requires broad and consistent adoption of critical behaviours, including removing standing water, using personal protective measures and promptly seeking medical care when severe symptoms appear; delays in seeking treatment contribute to dengue fatalities in the country.⁶ Timely treatment at designated hospitals is essential to prevent severe illness and fatalities. Without ongoing behavioural change supported by community engagement to address these gaps, the country remains vulnerable to repeated outbreaks that strain health-care resources and negatively affect socioeconomic conditions.⁷

CONTEXT

Dengue fever is a mosquito-borne, viral disease endemic to the Lao People's Democratic Republic, regularly causing outbreaks.¹ The primary vector responsible for transmission is the *Aedes aegypti* mosquito, which thrives in tropical and subtropical environments. The country's tropical monsoon climate, marked by distinct wet and dry seasons, creates optimal conditions for mosquito breeding, particularly during the rainy season from June to September.³ During this period, increased rainfall results in the widespread accumulation of stagnant water, forming abundant mosquito habitats and elevating the risk of dengue transmission.^{2,3}

Dengue infections can range from mild febrile illness to severe dengue haemorrhagic fever, which can be fatal without proper treatment.³ Several ongoing challenges contribute to the persistent transmission of dengue in the country, including inconsistent community adoption of preventive behaviours and difficulties sustaining effective vector control programmes. Rapid urbanization, population growth and inadequate sanitation further facilitate mosquito breeding and disease transmission.⁵ Climate change is also expected to worsen the situation.¹

The country has historically experienced cyclical dengue outbreaks every few years, with major epidemics reported in 2013 and 2019.⁷ These recurrent surges place considerable strain on the country's public health resources and underscore the need to strengthen prevention and response efforts. As a result, the Ministry of Health, in

collaboration with the World Health Organization (WHO) and other partners, has prioritized the enhancement of surveillance systems and case management to reduce fatalities, expanding public education initiatives and implementing innovative strategies to reduce dengue transmission and its overall impact across the nation.¹

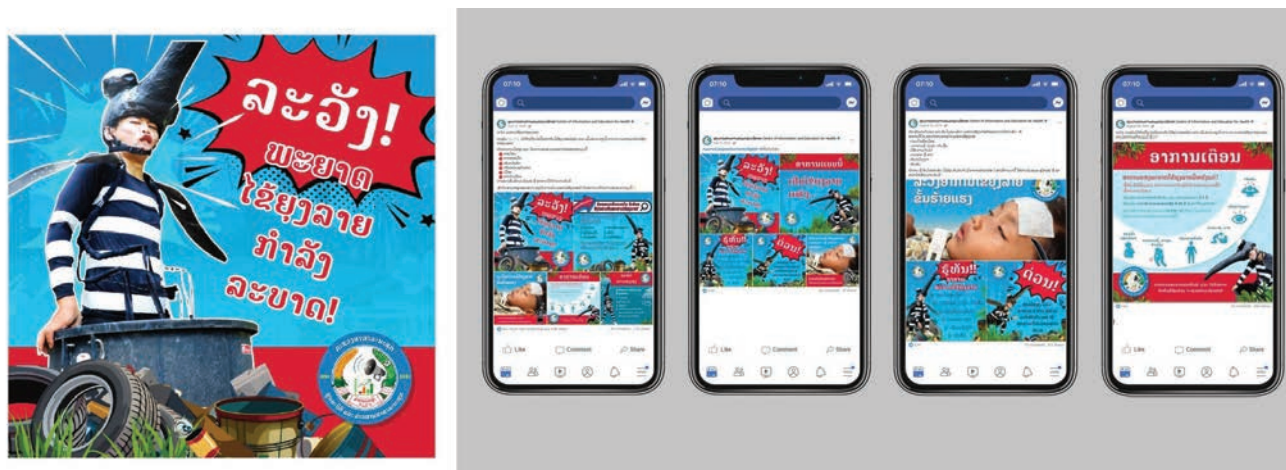
ACTION

In early 2024, to enhance dengue mitigation efforts amid a surge of cases, a humour-driven communication campaign was developed by the Ministry of Health's Center for Health Strategic Initiatives (CHSI), with technical and financial support from WHO. The strategy particularly targeted the 55% of the population (4.25 million) who use Facebook, the country's most popular digital platform, while also engaging traditional media and implementing village outreach to include other groups. Central to the campaign was an actor dressed as a mosquito who was portrayed as deliberately and humorously bothersome to people trying to go about their daily activities (Fig. 1 and 2). These striking visuals were designed to capture attention and engage social media audiences, and drew on tropes that had been well received during previous campaigns in the country. Conducted from April to September 2024, the campaign specifically targeted individuals who were indifferent to dengue or saw it as a routine health concern (Fig. 1 and 2).

Humour was chosen as the primary tool because, although it requires cultural context and alignment, it effectively draws attention and encourages active listening and information retention.⁸ When people laugh, they become more receptive, enabling important health messages to be communicated in a positive, approachable and non-intimidating way.⁸ Additionally, leveraging humour through social media was identified by local practitioners as the most cost-effective approach, offering wide reach at relatively low expense.

Incorporating behavioural insights was central to shaping the campaign materials to achieve the greatest possible impact. Public engagement with the humour-based campaign was assessed using a mixed-methods approach to capture both reach and audience response. A nationwide phone survey of 500 respondents was conducted in October 2024 to gather representative insights from diverse geographical and demographic

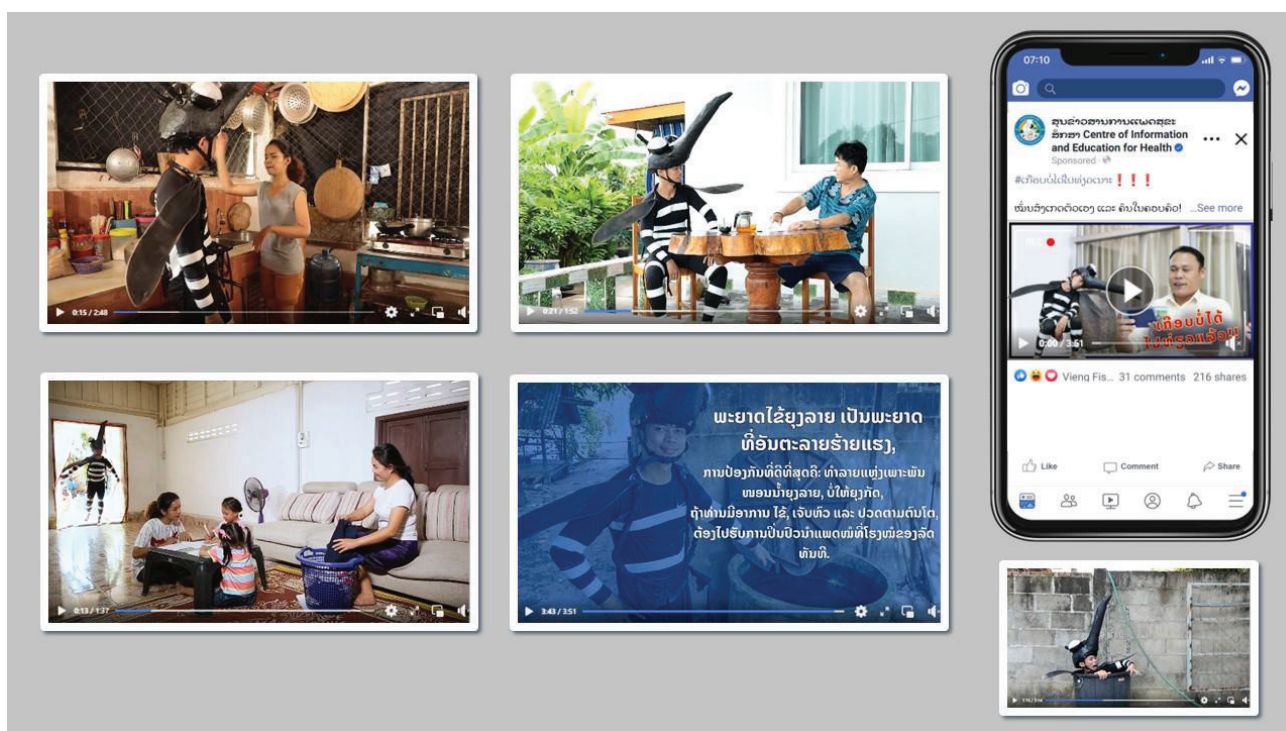
Fig. 1. Humour-based images used in the dengue awareness campaign, Lao People's Democratic Republic, April–September 2024



"Be careful! Dengue is spreading!" The dengue awareness campaign used a human-sized giant mosquito, strategically designed to use humour to engage audiences.

Source: materials created by Chongkham Phonekeo, Information, Education and Communication Materials Artist, WHO Representative Office for the Lao People's Democratic Republic/Center for Health Strategic Initiatives, Ministry of Health, Lao People's Democratic Republic.

Fig. 2. Humour-based videos used in the dengue awareness campaign, Lao People's Democratic Republic, 2024



The human-sized mosquito in the dengue awareness campaign was designed to capture attention, provoke reflection and engage audiences who often perceived dengue as a routine health concern.

Source: materials created by Chongkham Phonekeo, Information, Education and Communication Materials Artist, WHO Representative Office for the Lao People's Democratic Republic/Center for Health Strategic Initiatives, Ministry of Health, Lao People's Democratic Republic.

groups. In addition, three nationwide online surveys, each with 1000 respondents, were implemented at key intervals before the campaign launch (July 2023), immediately after its conclusion (September 2024) and during a follow-up phase (October 2024), to track changes in awareness, perceptions and intended behaviours over time. Complementing these surveys, comprehensive social media analytics were employed to quantify content reach, audience interactions and engagement patterns across Facebook.

Campaign materials were pre-tested to ensure resonance with the target audience, including with remote and rural communities. Promotion focused heavily on social media, emphasizing key messages such as mosquito control, symptom recognition and timely referral for severe dengue cases. Complementing digital outreach, the CHSI engaged with traditional media channels, including television and radio, to provide regular advice, warnings, updates on dengue case counts and other relevant information.

Recognizing that mass media cannot reach every community in the country, the CHSI and WHO undertook community focus group discussions and observational sessions around households in representative communities to identify factors that were successful in encouraging effective behavioural change, such as encouraging more involvement by village authorities and proactive outreach by health centre staff, and related behavioural insights, for potential integration into future outreach (Fig. 3).

OUTCOME

The dengue awareness campaign yielded strong results on social media engagement, public awareness and behavioural intent. Continually updating campaign materials throughout the dengue season proved highly effective in maintaining audience interest. In addition, it provided a strong foundation for informing communication strategies and content development for 2025, with revised and updated materials in use at the time of this publication.

On social media, the campaign achieved extensive reach and engagement. Content was viewed approximately 27 million times by almost 2.9 million unique users (reaching 68.2% of the country's 4.25 million Facebook users),⁹ generating more than 86 342 comments, likes

and shares. Video content was particularly successful, receiving more than 4.6 million views of at least 15 seconds, including 804 148 long-form views exceeding 60 seconds. These metrics demonstrate the campaign's ability to capture and sustain public attention across multiple platforms.

Survey data further underscore the campaign's impact on public perception and awareness. The October 2024 national phone survey revealed that after the campaign, respondents ranked dengue as the country's most urgent health concern. Similarly, online surveys showed a significant increase in public concern, with the proportion of individuals who reported being "very concerned" about dengue rising from 21% (42/200) before the campaign to 56% (224/400) afterwards.

The campaign also effectively delivered key public health messages and encouraged preventive behaviours. Awareness of critical messaging was high, with 81% (324/400) of respondents indicating they would immediately visit a hospital or health centre if they suspected severe dengue symptoms. Additionally, the humorous giant mosquito theme resonated strongly with audiences: 76% (304/400) of respondents rated the campaign as appealing or very appealing, and 90% (360/400) reported that it increased their likelihood of taking action to prevent dengue transmission. Together, these outcomes demonstrate the campaign's success in enhancing both people's awareness of and motivation to engage in protective behaviours against dengue.

The humour-driven risk communication and community engagement (RCCE) campaign was one part of a multicomponent dengue reduction campaign implemented by authorities that included high-level political engagement, vector control activities and enhanced case management. Importantly, epidemiological data showed a significantly flattened curve of dengue case numbers in 2024, although attributing this change to any one or all parts of the government's dengue response is not possible with the data currently available.

DISCUSSION

The sharp rise in dengue cases in the Lao People's Democratic Republic in early 2024, which reached levels comparable to the major 2013 outbreak, highlights the ongoing challenge dengue poses as a significant public

Fig. 3. WHO teams visiting communities to better understand knowledge, attitudes and behaviours around vector control, Lao People's Democratic Republic, 2024



Photo: World Health Organization Representative Office for the Lao People's Democratic Republic.

health threat. Despite relatively widespread awareness of preventive measures, their inconsistent practice has contributed to sustained dengue transmission. This gap between knowledge and action emphasizes the urgent need for strategies that effectively motivate behavioural change. These challenges reflect broader trends in endemic regions where environmental factors, such as the tropical monsoon climate and rapid urbanization, create ideal conditions for mosquito breeding and increased disease transmission.¹⁻⁵

The dengue awareness campaign centred on a humorous giant mosquito and demonstrated the potential of developing innovative communication strategies to engage populations who may be indifferent to or disengaged from dengue prevention. Given the level of indifference to dengue among the intended audience, the use of humour, based on tropes that had been effectively deployed in the country previously, resonated culturally as the campaign reflected everyday life but in comedic ways. Thus, it effectively captured public attention,

enhanced message retention and conveyed important health information in a non-threatening manner. This approach aligns with behavioural science insights showing that positive emotional engagement increases receptivity and encourages protective actions.^{8,10} It highlights that humour must be both culturally and contextually aligned to resonate with people, while emphasizing the need for a considered approach to avoid the risk of audience backlash and to ensure that official advice does not undermine the seriousness of the issue.

The campaign's implementation across multiple platforms including social media, television and radio ensured broad reach and accessibility across diverse demographic groups. Impressive social media metrics, with more than 27 million views and nearly 3 million unique users, combined with strongly positive survey responses, indicated successful public engagement. Notably, the marked increase in public concern about dengue following the campaign signalled an important shift in risk perception, a key driver of protective behaviour.

Furthermore, the campaign successfully translated increased awareness into intentions to adopt preventive measures. A high proportion of respondents indicated that they would promptly seek medical care for severe dengue symptoms, and that the giant mosquito character had strongly resonated with them. Most of the participants rated the campaign as appealing and reported an increased likelihood that they would engage in mosquito control activities. These results suggest enhanced community readiness to address dengue risk effectively, and were reflected by the continuation and expansion of the campaign in 2025. However, additional research is necessary to determine whether there was long-term behavioural change and to confirm whether intention translated into action. (There was limited scope to assess the long-term effects of the 2024 campaign due to the emergency nature of the outbreak.)

Similarly, sustaining behavioural change in endemic settings requires ongoing public engagement. While the survey results were highly positive, with both phone and online survey data aligning, online data were self-reported and sourced from social media users, potentially creating a slight bias towards over-reporting the impact, and highlighting a broader challenge to RCCE in the country's context. While more than 55% of the population uses Facebook, enabling rapid interaction with compelling content, modern mass communication tools, including TV and radio, remain inaccessible for a substantial proportion of the population, including ethnic minorities living in remote areas. Thus, costly, dedicated outreach in local languages and dialects is required, despite limited resources. The seasonal and recurrent nature of dengue outbreaks calls for the continual monitoring and adaptation of communication strategies to maintain vigilance and prevent message fatigue. Future efforts could benefit from localized messaging tailored to specific communities, expanded outreach efforts and enhanced prioritization of dengue by officials beyond the health sector.

The resolution of structural challenges is critical in complementing communication initiatives, such as through the improvement of health-care access, clinical management approaches and vector control infrastructure. Ensuring that these efforts are addressed in line with the national dengue strategy, under its comprehensive dengue control framework, will equip the country to reduce the disease burden sustainably.

This humour-centred communication campaign provided valuable insights into effective public health messaging in a resource-limited setting where dengue is endemic. By leveraging behavioural insights and combining digital tools with traditional media, the campaign not only raised awareness but also positively influenced public attitudes and behavioural intentions towards dengue prevention. These findings support ongoing innovation and investment in culturally relevant, evidence-based communication strategies as vital elements of successful dengue control programmes.

Conflicts of interest

The authors have no conflicts of interest to declare.

Ethics statement

This study was submitted to the WHO Regional Office for the Western Pacific Ethics Review Committee and was exempt from full ethical review (unique ID number: 2024.5.PHL.1.CPI).

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Connecting the region during crisis: a Community of Practice response to the MV Hondius hantavirus outbreak

Jeyanthini Sathasivam,^{a,b} Wenyajing Zhang,^a Sarika Patel,^a Thilaka Chinnayah^a and Gina Samaan^a

Correspondence to Jeyanthini Sathasivam (email: j.sathasivam@who.int)

Just 10 days after a cluster of passengers with severe respiratory illness aboard a cruise ship was reported to the World Health Organization (WHO),¹ the Asia Pacific Health Security Action Framework Community of Practice (CoP)² mobilized to address emerging information and coordination needs during a fast-evolving public health event. Although the MV Hondius hantavirus outbreak did not primarily occur within the WHO Western Pacific Region, Member States recognized the potential implications of onboard contacts who had already been repatriated or were awaiting repatriation to their respective countries. In response to the urgent need for timely information-sharing and front-line preparedness, a 1-hour technical webinar was convened on 12 May 2026, drawing 2332 participants. The webinar presented a WHO situation update, along with Singapore's experience and insights on quarantine-related activities. Importantly, the session served as a platform for rapid operational updates, allowing Member States and partners to learn, engage and communicate operational needs from countries and partners through the established CoP mechanism.

The webinar drew a diverse, multidisciplinary audience, reflecting broad regional and cross-sectoral engagement in hantavirus preparedness and response, as well as collective commitment towards strengthening regional readiness and response capacity. Attendees included epidemiologists, surveillance officers, clinicians, nurses, laboratory professionals, researchers and public health programme managers. Attendees also included professionals from One Health sectors, including animal

health, environmental health and agriculture, as well as local government officers, community health workers, port health authorities, and communication and media personnel. Interest from regional and international public health networks, particularly within the Western Pacific Region, was clearly evident.

Questions raised during the webinar reflected the wide-ranging concerns and information needs of participants as they respond to the evolving hantavirus event. Discussions focused on epidemiological parameters, including symptoms, incubation periods, infectiousness and analyses of fatal cases. Participants also sought information on medical countermeasures, including treatment options and vaccine development, as well as public health measures such as quarantine, contact tracing and repatriation procedures. Significant attention was given to laboratory diagnostics, surveillance systems, environmental prevention and One Health coordination. Concerns surrounding misinformation, transmission dynamics, climate-related influences, and infection prevention during travel and cruise operations further highlighted the complexity of preparedness and response efforts across sectors and countries (**Fig. 1**).

To gauge organizational preparedness, a rapid poll was conducted during the webinar. Of the 712 respondents, nearly half (49%) reported that their institutions were actively scaling up response activities, signalling heightened readiness across the region. The poll further revealed participants' need for timely updates, technical guidance and continuous information-sharing,

^a WHO Health Emergencies Programme, World Health Organization Regional Office for the Western Pacific, Manila, Philippines.

^b Fellow of Epidemic Intelligence Programme, Ministry of Health, Putrajaya, Malaysia.

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Fig. 1. Participant representation ($N = 2332$) and questions raised during the webinar, 12 May 2026

AUS: Australia; JPN: Japan; NEZ: New Zealand; PoE: points of entry; PHL: Philippines; SGP: Singapore; WP: Western Pacific.

Non-WP countries and areas: Åland Islands, Canada, Germany, Guatemala, Iceland, Ireland, Italy, Kuwait, Lebanon, Oman, Pakistan, Portugal, Qatar, Saint Kitts and Nevis, Saudi Arabia, Somalia, South Africa, Sudan, Suriname, Tanzania, Trinidad and Tobago, Uganda, United Arab Emirates, United States of America, Yemen, Zambia.

underscoring the importance of knowledge exchange and collaborative support in strengthening hantavirus preparedness and response.

The diversity of participants and the depth of engagement reflected substantial regional interest in hantavirus preparedness. This collective momentum underscores the critical importance of timely educational initiatives and sustained capacity-building to strengthen readiness for emerging infectious disease threats. By listening to and understanding Member States' concerns, the region is better positioned to anticipate challenges, coordinate across sectors and respond efficiently to future emergent events, demonstrating that preparedness is not only a shared responsibility but also a cornerstone of resilience.

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Grammarly was used to improve the language of the manuscript, and ChatGPT was used to generate the infographic based on the authors' data. The authors reviewed and verified all outputs and take responsibility for the integrity of the final content.

Conflicts of interest

TC is an associate editor, and GS is the executive editor of *Western Pacific Surveillance and Response*. They were not involved in the editorial decision to publish this article.

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Ethics statement

Ethics approval was not required, as no research was undertaken for the purposes of this report.

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Hepatitis B knowledge, attitudes and practices among health-care workers in Vanuatu, 2024

Leila Bell,^{a,b} Kaylene Kalmos,^c Annie Taissets,^c Florita Toa,^c Sereana Natuman,^{c,d} Mark Stoové,^{a,b} Margaret Hellard,^{a,b,e,f} Nicole Allard^{g,h} and Caroline van Gemert^a

Correspondence to Leila Bell (leila.bell@burnet.edu.au)

Objective: The prevalence of chronic hepatitis B in Vanuatu is high, at approximately 9%. While immunization has been available for infants since 1989, subsets of the adult population remain susceptible, including health-care workers. Prior to a planned roll-out of hepatitis B vaccination for health-care workers, we conducted a knowledge, attitudes and practices survey to inform education programmes aimed at promoting vaccine uptake.

Methods: Clinical and non-clinical health-care professionals at risk of occupational exposure to hepatitis B were invited to complete an online survey from April to June 2024. The survey sought information on hepatitis B knowledge (10 questions), attitudes (6 questions) and clinical practices (3 questions), as well as participant demographics. Participant knowledge scores were calculated and potential associations with demographic factors explored using Fisher's exact test.

Results: Most of the 50 respondents were female (73%) and worked in either hospitals or the Ministry of Health (82%). Knowledge was high, with a median score of 9 (range: 3–10); 21 participants scored 100%. The proportion of incorrect responses was highest for questions related to treatment availability and transmission risks. We found no evidence of associations between demographic factors and knowledge scores. Most participants believed that hepatitis B vaccines were useful (88%) and prevention and control measures would protect them from infection (96%).

Discussion: Our survey revealed high levels of knowledge and generally positive attitudes towards people with hepatitis B and infection control practices. While our respondents are unlikely to be representative of all health-care workers in Vanuatu, findings offer useful insights into specific knowledge gaps that could be addressed in planned health-care worker education sessions ahead of the vaccination roll-out.

Chronic hepatitis B is a significant burden in Vanuatu, with an average prevalence of approximately 9%.¹ Prevalence is higher among people aged 30 years and over; in this age group, estimated prevalence is 14–20%, compared to 3–7% in those under 30 years.¹ This difference is likely due to the introduction of hepatitis B immunization in 1989–1990, when a birth dose was added to the routine childhood immunization schedule.²

The current immunization schedule comprises a hepatitis B birth dose (vaccination within 24 hours of birth) and three additional doses at 6, 10 and 14 weeks as part of the pentavalent vaccine.^{2,3} However, despite the long-standing availability of the hepatitis B vaccine in Vanuatu and international partner support, coverage remains suboptimal in some provinces.⁴ For example, in 2022, a timely birth dose was given to between 23% and 90% of newborn infants, while third-dose

^a Burnet Institute, Melbourne, Victoria, Australia.

^b School of Public Health and Preventative Medicine, Monash University, Melbourne, Victoria, Australia.

^c Ministry of Health, Port Vila, Vanuatu.

^d Vila Central Hospital, Port Vila, Vanuatu.

^e Doherty Institute and School of Population and Global Health, University of Melbourne, Melbourne, Victoria, Australia.

^f Department of Infectious Diseases, The Alfred Hospital, Melbourne, Victoria, Australia.

^g WHO Collaborating Centre for Viral Hepatitis, Victorian Infectious Diseases Reference Laboratory, Royal Melbourne Hospital, at the Peter Doherty Institute for Infection and Immunity, Melbourne, Victoria, Australia.

^h Department of Infectious Diseases, University of Melbourne, Melbourne, Victoria, Australia.

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coverage ranged between 41% and 79% depending on the province (unpublished programmatic data from the Ministry of Health, Vanuatu). At present, Vanuatu does not have an adult vaccination programme, including for adults with occupational risk factors such as health-care workers (HCWs). Recent seroprevalence data are sparse, but given the history of variable childhood vaccination rates, there is likely a large number of susceptible adults in the population.⁴⁻⁷

Occupational risk factors for hepatitis B infection among HCWs are well documented globally and arise due to potential exposure to infected blood or body fluids.^{8,9} However, few studies on occupational risk factors and hepatitis B infection in health facilities have been conducted in the Pacific region.¹⁰ While some HCWs in Vanuatu may have been vaccinated while training abroad, this group probably only forms a small proportion of the workforce. It is more likely that a significant proportion of HCWs in Vanuatu are unvaccinated as they were born before the introduction of routine childhood immunization in 1989, and there is no requirement for HCWs in the country to be vaccinated. Additionally, while infection prevention and control (IPC) guidelines exist, adherence levels to recommended practices are not known.

In line with World Health Organization (WHO) recommendations, and because of high prevalence, low vaccine coverage among older people and occupational risks, Vanuatu's National HIV, STI and Viral Hepatitis Committee has declared hepatitis B vaccination of HCWs and people working in health-care settings a priority.¹¹ Roll-out of a programme to vaccinate the workforce was scheduled to start in 2025. Previously documented vaccine hesitancy among HCWs during the COVID-19 pandemic, both in Vanuatu and globally,^{12,13} prompted the Committee to undertake an exploratory study to assess baseline knowledge, attitudes and practices around hepatitis B vaccination among HCWs before the roll-out. In addition, numerous studies have demonstrated that higher levels of health knowledge are associated with positive health behaviours, including vaccine uptake.^{14,15} Thus, a key objective of the study was to identify and better understand barriers to vaccine uptake among

HCWs, and to use the data collected to inform targeted vaccination and education programmes.

METHODS

Target population and recruitment

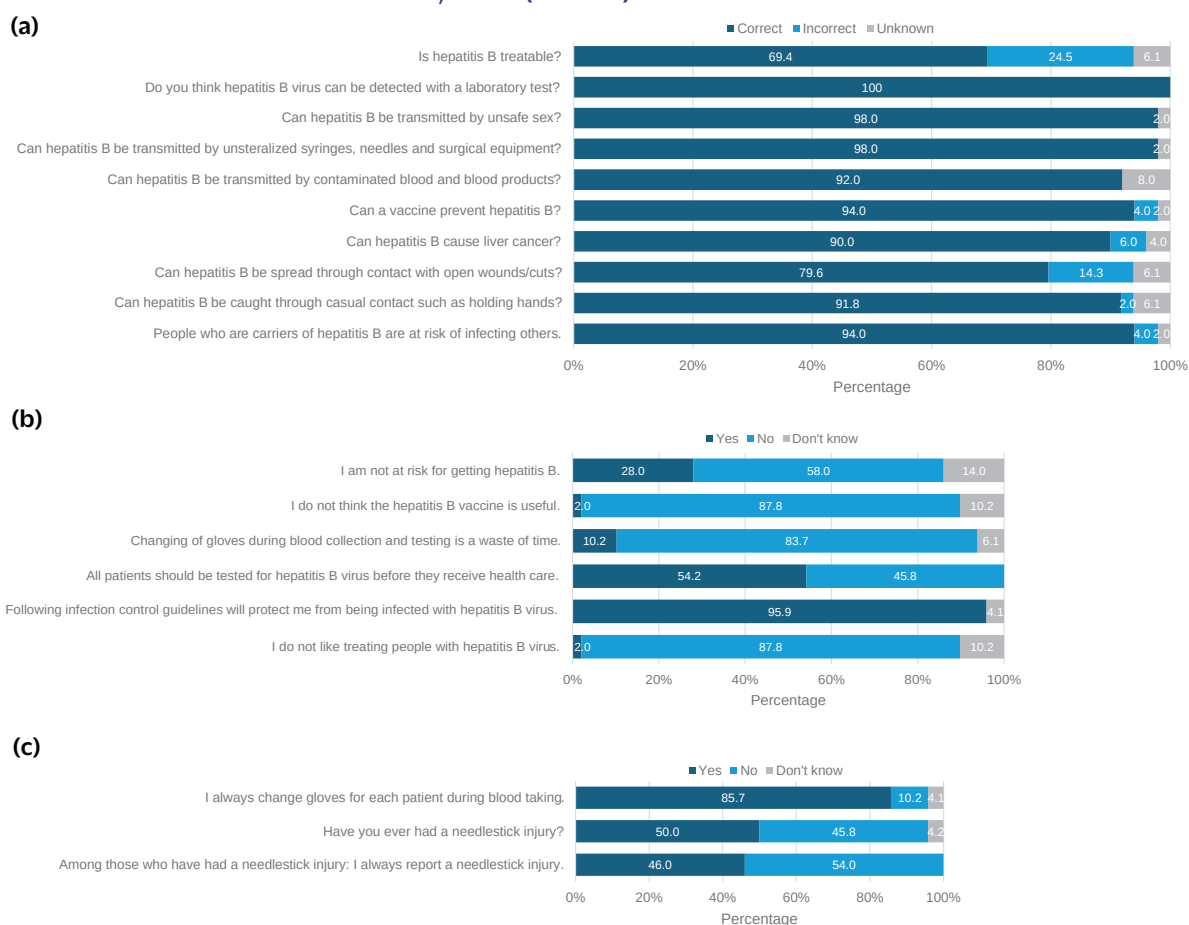
The target population was HCWs at health facilities in Vanuatu, specifically health-care professionals working in a health facility or anyone in a public health role who was at increased risk of hepatitis B infection due to occupational exposure to blood or body fluids. The target population thus included doctors, nurses, midwives, laboratory officers and technicians, dentists, dental technicians, and other allied health professionals including public health officers and drivers, as well as janitorial and administrative staff.

The survey was distributed via email and known online HCW chat groups. All HCWs working in public and private health facilities in Vanuatu at the time of the survey were eligible to participate. Students, interns and volunteers were also eligible to participate. The estimated size of the health workforce in Vanuatu was approximately 1000 people,¹⁶ of whom around 150 were contacted via email; an unknown number of online chat group members were invited to complete the survey.

Study design and data collection

The anonymous survey was open for 2 months (mid-April to mid-June 2024) and was self-administered online using KoboCollect (<https://www.kobotoolbox.org/>). It consisted of 30 questions, grouped as follows: demographic characteristics, including occupational group (11 questions); knowledge about hepatitis B (10 questions, **Fig. 1a**); attitudes towards people living with hepatitis B and hepatitis B prevention methods (6 questions, **Fig. 1b**); and clinical practices related to preventing hepatitis B infection (3 questions, **Fig. 1c**). All questions required “yes,” “no” or “don’t know” answers. The questionnaire was based on similar survey tools used in other countries^{17,18} adapted to the Vanuatu context. The survey was available in English and Bislama and was reviewed by the Vanuatu Ministry of Health Viral

Fig. 1. Survey responses to (a) knowledge,^a (b) attitudes and (c) clinical practices related to hepatitis B among health-care workers in Vanuatu, 2024 (*N* = 50)



^a For knowledge questions, "unknown" means the answer was blank in the survey.

Hepatitis Unit and the Health Promotions Unit to assess the suitability of the questions and the accuracy of the translation.

Data and statistical analysis

All questions were optional except for the question confirming informed consent. A knowledge score was calculated for each participant, based on the total number of correct answers (out of 10). If a knowledge question was not answered, it was marked as incorrect. The distribution of the knowledge score was described in terms of a median and interquartile range. The knowledge score was dichotomized to create a binary categorical variable (10 correct answers vs one or more incorrect answers). Due to small sample numbers in some categories (<5), Fisher's exact test was used to investigate associations

between the dichotomized participant characteristics and knowledge scores.

RESULTS

A total of 50 participants answered the electronic survey; 33 (66.0%) were born before the introduction of the hepatitis B birth dose, and 36 (73.5%) were female. Most participants worked in hospitals (46.9%) or in non-clinical roles within the Ministry of Health (36.7%), while five participants (10.2%) worked in a community health setting at either a dispensary or health centre. Nearly all participants (93.9%) were born in Vanuatu. Two participants (4.1%) had previously been diagnosed with hepatitis B infection, and neither reported starting treatment (**Table 1**). Respondents were from all six provinces in the country.

Table 1. **Demographic characteristics among knowledge, attitudes and practice survey participants, Vanuatu, 2024 (N = 50)**

Characteristic	Value	n (%)
Born before the introduction of the birth dose (n = 50)	Yes	33 (66.0)
	No	17 (34.0)
Sex (n = 49)	Male	13 (26.5)
	Female	36 (73.5)
Born in Vanuatu (n = 49)	Yes	46 (93.9)
	No	3 (6.1)
Province of birth (n = 46)	Malampa	6 (13.0)
	Penama	7 (15.2)
	Sanma	17 (37.0)
	Shefa	11 (23.9)
	Tafea	3 (6.5)
	Torba	2 (4.3)
Education (n = 50)	Secondary school	5 (10.0)
	University	23 (46.0)
	Additional school after university	22 (44.0)
Type of health-care facility (n = 49)	Dispensary	2 (4.1)
	Health centre	3 (6.1)
	Hospital	23 (46.9)
	Ministry of Health	18 (36.7)
	Private clinic	3 (6.1)
Type of work (n = 49)	Doctor	11 (22.4)
	Laboratory	3 (6.1)
	Midwife	8 (16.3)
	Nurse	8 (16.3)
	Public health	13 (26.5)
	Other	6 (12.2)
Length in job (n = 49)	<1 year	1 (2.0)
	1–3 years	5 (10.2)
	3–5 years	4 (8.2)
	5–10 years	12 (24.5)
	>10 years	27 (55.1)
Previous diagnosis with hepatitis B (n = 49)	Yes	2 (4.1)
	No	43 (87.8)
	Unsure	4 (8.2)
For those diagnosed, action taken (n = 2)	Treated	0 (0)
	Never started treatment	2 (100)
Family history of hepatitis B (n = 49)	Yes	10 (20.4)
	No	34 (69.4)
	Don't know	5 (10.2)

Table 2. Associations between demographic factors and hepatitis B knowledge score among health-care workers in Vanuatu, 2024 (N = 50)

Demographic factor	Knowledge score (dichotomized)		
	≥1 incorrect	All correct	Fisher's <i>P</i> value
Born before the introduction of the birth dose			
Yes (<i>n</i> = 33)	16	17	0.075
No (<i>n</i> = 17)	13	4	–
Sex			
Male (<i>n</i> = 13)	9	4	0.348
Female (<i>n</i> = 36)	19	17	–
Born in Vanuatu			
Yes (<i>n</i> = 46)	27	19	0.569
No (<i>n</i> = 3)	1	2	–
Education^a			
University or less (<i>n</i> = 28)	16	12	1.000
Additional education after university (<i>n</i> = 22)	13	9	–
Type of health-care facility^b			
Hospital (<i>n</i> = 23)	13	10	0.721
Other (<i>n</i> = 26)	16	10	–
Type of work^c			
Clinical (<i>n</i> = 27)	15	12	0.771
Non-clinical (<i>n</i> = 22)	14	8	–
Length in job			
≤10 years (<i>n</i> = 22)	13	9	1.000
>10 years (<i>n</i> = 27)	16	11	–
Known family history			
Yes (<i>n</i> = 10)	5	5	0.726
No/unknown (<i>n</i> = 39)	23	16	–

^a Education was dichotomized for this analysis.

^b Type of health facility was divided into hospital versus other, which included non-clinical Ministry of Health roles and community health workers.

^c Clinical category includes doctors, nurses and midwives.

Knowledge

The median knowledge score (out of 10) was 9 (interquartile range: 9–10). The distribution of the scores was highly skewed, with 21 participants scoring 10/10 (100%) and 20 scoring 9/10 (90%). Eight of the 10 questions were answered correctly by over 90% of participants. The two questions with the lowest proportion of correct answers were “Is hepatitis B treatable?” (69.4%) and “Can hepatitis B be spread through contact with open wounds/cuts?” (79.6%) (Fig. 1a). Most respondents (*n* = 47, 94.0%) knew that hepatitis B can be prevented with a vaccine, all 50 (100%) knew that hepatitis B virus can be identified with a laboratory test, and 49 (98.0%) knew that hepatitis B virus can be transmitted by unsterilized

syringes, needles and surgical equipment, and through unsafe sex.

No significant associations between respondents' demographic characteristics and level of knowledge were identified (Table 2).

Attitudes

Most participants (*n* = 43, 87.8%) indicated they thought the hepatitis B vaccine was useful. Most participants (*n* = 47, 95.9%) thought that following IPC guidelines would help to prevent hepatitis B infection in the workplace and that changing gloves was not a waste of time (*n* = 41, 83.7%). Seven participants (14.0%)

reported they did not know if they were at risk of hepatitis B infection, and 14 (28.0%) reported they believed that they were not at risk (**Fig. 1b**).

While only one person reported that they did not like treating people with hepatitis B, 26 (54.2%) respondents thought that all patients should be tested for hepatitis B virus before receiving health care.

Practices

Half of the participants ($n = 24$, 50.0%) reported they had experienced a fingerstick injury, but among them, only 11 (45.8%) said that they always reported the injury. Most participants ($n = 42$, 85.7%) reported that they always change gloves for each patient when taking blood (**Fig. 1c**).

DISCUSSION

Our results indicate that among HCWs in Vanuatu who responded to our survey, general knowledge about hepatitis B was high. Additionally, there was general acknowledgement of the usefulness of hepatitis B vaccination, which may positively influence vaccine uptake by HCWs. The finding that awareness levels were high is encouraging, particularly because before 2021 response efforts were siloed, with separate units within the Ministry of Health responsible for different activities. However, it is also important to note that participants in this survey were likely a highly engaged, well informed set of HCWs, so knowledge levels may be lower among other HCWs who were less well represented in this sample.

The largest knowledge gap was in participants' knowledge about hepatitis B treatment, with over 25% unsure whether treatment was available. While there is no cure for hepatitis B, antiviral treatment can reduce the risk of liver disease, including cirrhosis and hepatocellular carcinoma.^{19,20} Tenofovir disoproxil fumarate, an antiretroviral that has been shown to be highly effective, was added to the Vanuatu Essential Drugs List in 2020, but fewer than 200 people are on treatment, despite the high population prevalence of hepatitis B. Two of our study participants had previously been diagnosed with hepatitis B, neither of whom had initiated treatment. If we extrapolate national prevalence estimates to our respondents, we would expect approximately seven people to be living with hepatitis B. Furthermore, if we extrapolate

these estimates to the nearly 1000 HCWs in Vanuatu who are eligible for screening according to national guidelines,²¹ we would expect approximately 100–140 to be living with chronic hepatitis B. This highlights the need for additional screening efforts to identify people living with hepatitis B and link them to care.

The reasons for non-treatment in the two participants with hepatitis B were not explored (as this was beyond the scope of our survey), but our finding is a reflection of low treatment levels nationally. There are many challenges to initiating treatment for hepatitis B in Vanuatu, including a lack of access to laboratory testing, unclear referral pathways and insufficient clinician training, all of which are essential components of treatment services for prescribing and monitoring those on treatment. Additional barriers include low levels of health-seeking behaviour, possibly due to fear of stigma or general trends in access to health services, as well as high costs. While not all study participants would have been directly involved in prescribing, it is important that awareness about the availability and effectiveness of treatment is increased to improve linkage to care, as well as to drive further improvements to health systems to provide this care.

Our survey also revealed relatively low levels of awareness about transmission risk through contact with open wounds and cuts. Limited data are available, but before the roll-out of childhood hepatitis B vaccination in 1989–1990, horizontal transmission was common among children.^{4,5} While the risk of developing chronic hepatitis B infection from exposure as an adult is significantly lower than childhood exposure,^{22,23} transmission through contact with open wounds is a recognized risk for HCWs. Adult exposures can lead to acute hepatitis B infections, which can be severe and carry a risk of liver failure and death.²⁴ The survey indicated high levels of awareness of IPC protocols and guidelines, so perhaps the risk of transmission in health settings is low, but it is important to increase awareness among HCWs of all potential routes of transmission.

Just over 50% of respondents agreed with the statement that all patients should be tested for hepatitis B virus before receiving care. However, it was not possible to infer the reasoning behind participants' support for universal testing from our study, and this result should be interpreted with caution. While universal testing for hepatitis B is recommended in certain high-prevalence

settings and may be cost-effective in some settings,^{25–27} whether it is feasible in the context of Vanuatu needs careful consideration, given the demand for subsequent referrals for treatment and the monitoring that universal testing would generate. Additionally, issues of stigma and discrimination would need to be addressed. Current levels of stigma and discrimination are not well documented in Vanuatu, but globally, internalized and social stigma are commonly reported among people living with chronic hepatitis B.²⁸ In Vanuatu, current practice is that patients may be tested for hepatitis B before surgery, but not before other types of care.

Additional research is required to understand the significance of this apparent high level of interest in universal testing, specifically whether HCWs viewed testing from the perspective of the provision of care for the patient or as a preventive measure to protect themselves. The latter is understandable in the context of HCWs wanting to know patients' hepatitis B status so they could protect themselves, but this goes against the concept of universal precautions for blood-borne viruses. Further exploration is needed of HCWs' perspectives on stigma and discrimination around hepatitis B, as well as other blood-borne viruses such as HIV and hepatitis C. While both are currently of low prevalence in Vanuatu,¹ they represent an ongoing risk.

Appreciation for the importance of compliance with IPC guidelines among respondents was high, though half of our survey respondents reported fingerstick injuries. More concerning still was the low rate of reporting; among those who had experienced a fingerstick injury, fewer than 50% said that they always reported the event. Globally, hepatitis B is the most commonly acquired infection via needlestick injury.²⁹ While it is likely that most hepatitis B infections in Vanuatu are acquired during childhood, the lower risk of infection in adulthood remains, especially in HCWs. These risks are exacerbated by the absence of an adult vaccine and hepatitis B immunoglobulin in Vanuatu, which are both standard post-exposure prophylaxis for fingerstick injuries in people who are not immunized at birth. Efforts are needed to reduce the risk of fingerstick injury, and to improve reporting among those who experience such injuries and access to post-exposure prophylaxis.

This study has several limitations. First, due to various selection biases, this sample is unlikely to be

representative of all Vanuatu's HCWs. Email-based sampling was limited to those 150 workers who were on available email lists, and among those who responded, there was a notable bias towards staff from hospitals and the Ministry of Health. Additionally, because of how the invitation to participate was circulated, it is not possible to estimate the response rate. The email list comprised approximately 150 eligible persons, but the number of eligible persons in the established messaging groups was unknown. Responder bias is also a concern, given that it is probable that participants may have been more aware of, or more interested in, hepatitis B than those who did not respond. Finally, the sample size was small and therefore reduced the likelihood of observing statistically significant associations.

Conclusion

These findings have potential implications for public health policy and practice in Vanuatu, particularly in relation to protocols for the introduction of adult and HCW immunization against hepatitis B, as well as priorities for continuing medical education and future research. Further research is needed to explore the knowledge, attitudes and practices of HCWs working in community-based facilities outside the main cities in Vanuatu. There is also a need to better understand the stigma and discrimination associated with hepatitis B. Despite its limitations, this study has provided useful insights that will help guide the development of HCW educational sessions ahead of the planned roll-out of the HCW vaccination campaign.

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Conflicts of interest

LB is an associate editor of the *Western Pacific Surveillance and Response* journal. She was not involved in the editorial decision to publish this article. MS has received investigator-initiated research funding from Gilead Sciences and AbbVie and consultant fees from Gilead Sciences for activities unrelated to this work. MH receives funding from Gilead Sciences and AbbVie for investigator-initiated research unrelated to this work. The other authors have no conflicts of interest to declare.

Ethics statement

Ethics approval was received from the Vanuatu Health Research Ethics Committee and Monash University (Project ID: 41899). Informed consent was confirmed through a mandatory question before participants were able to submit the survey.

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Cholera outbreak among the Sama Badjao Indigenous community, Lucena City, Philippines, 2022

Iris Ann D Bigyan,^a Catherine P Patricio,^b Johnette A Peñas,^c Nelson C Soriano,^d John Bobbie M Roca,^e Ray Justin Ventura,^f Mariz Zheila Blanco-Payuyo^g and Apple Charm Agulto^g

Correspondence to Iris Ann D Bigyan (email: annbigyan@gmail.com)

Objective: On 18 October 2022, diarrhoeal cases among the Sama Badjao indigenous community in the Philippines were reported from a tertiary hospital in Lucena City, Quezon Province. An investigation was conducted to confirm the outbreak, profile cases, identify the source of infection, and recommend prevention and control measures.

Methods: Suspected cases were identified through medical records review, active case finding and key informant interviews. Identified cases were interviewed using a structured questionnaire to collect demographic, clinical and exposure information. Rectal swabs and environmental water samples were collected for bacterial isolation and confirmation.

Results: A total of 75 cases were identified, with 40 (53.3%) hospitalized and four fatalities (case fatality rate: 5.3%). Ages ranged from 2 months to 20 years (median: 4 years). Nine of the 15 rectal swabs were positive for *Vibrio cholerae* Ogawa biotype El Tor. The community practised open defecation, and only 24.7% of households had basic sanitation. Although *V. cholerae* was not found in water samples, faecal contamination was noted in a community well, and *Aeromonas* species were isolated, indicating the presence of multiple gastrointestinal pathogens.

Discussion: A cholera outbreak was confirmed among the Sama Badjao community in Lucena City. Environmental assessment indicated that poor sanitation, open defecation and unsafe water sources likely contributed to the outbreak. The high case fatality rate (5.3%) was influenced by delayed care and limited health-care access. These findings emphasize the need for interventions to improve water, sanitation and hygiene practices and provide culturally appropriate public health programmes to reduce cholera risk among vulnerable communities.

Cholera, an acute bacterial infection caused by *Vibrio cholerae*, is primarily transmitted through contaminated food or water, leading to severe watery diarrhoea that can cause dehydration and death if untreated. The disease is a significant public health issue in regions with inadequate access to safe water, sanitation and hygiene.¹

In the Philippines, cholera is endemic, with cases regularly reported from several regions. However, underreporting of cases is common due to variations in local surveillance capacity and laboratory availability, complicating the understanding of its epidemiology. Few

analyses of surveillance data are available, and detailed outbreak investigations are limited.² Nonetheless, past outbreaks, such as one in Nabua, Camarines Sur in 2012, which resulted in 309 suspected cases and two fatalities, demonstrate the critical influence of water and sanitation conditions on cholera transmission. The outbreak was linked to unchlorinated water sources and inadequate sanitation, while access to piped water proved protective against the disease.³

Lucena City, the capital of Quezon Province, is a highly urbanized coastal city with a population of 278 924 (2020 census). One of the city's 33 barangays

^a Quezon Provincial Health Office, Quezon, Philippines.

^b Lucena City Health Office, Quezon, Philippines.

^c Local Government Unit, San Jose de Buan, Samar, Philippines.

^d Cavite Provincial Health Office, Cavite, Philippines.

^e Center for Health Development, Regional Office IV-A, Department of Health, Manila, Philippines.

^f Department of Health, Manila, Philippines.

^g Field Epidemiology Training Program Alumni Foundation, Inc., Manila, Philippines.

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(administrative units), Dalahican, has 5563 households and a population of 24 640, of whom around 10% ($n = 2465$) are members of the Sama Badjao community. The Sama Badjao are an Indigenous Philippine group who live in stilt houses above shallow waters and practise herbal medicine. They face barriers to health-care services – such as distance, language and perceptions of quality – that lead to reliance on traditional healing and poorer health outcomes.⁴

On 18 October 2022, a nurse in Lucena City reported an increase in acute gastroenteritis admissions, including two deaths, from the Sama Badjao community. The Quezon Provincial Epidemiology and Surveillance Unit confirmed this incident as a potential outbreak. A team from the Field Epidemiology Training Program conducted an investigation on 19 October to confirm the outbreak, profile cases and deaths, identify the infection source, and recommend prevention and control measures.

METHODS

Descriptive study

Medical records from health facilities most likely to have received patients from Dalahican were reviewed, including the Barangay Health Station and referral hospitals in Lucena City. The review focused on patients with suspected cholera or acute gastroenteritis, particularly watery diarrhoea, to create a case list. Demographic data included age, sex, address, consultation/admission date and symptoms. Records from the Philippine Integrated Disease Surveillance and Response system for Lucena City from the previous 5 years (2017–2021) were also analysed. Active case finding involved house-to-house visits within the Sama Badjao community, during which cases were interviewed using a standard questionnaire (**Supplementary Material**). A suspected case was defined as any previously well resident of the Sama Badjao community experiencing acute watery diarrhoea (three or more episodes per day) from 1 October to 2 November 2022, while a confirmed case was a suspected case who tested positive for *V. cholerae*.

Key informant interviews

The barangay captain was interviewed to understand the lifestyle and health-related attitudes and behaviours of

the Sama Badjao community. Hospital staff were also interviewed about the diagnosis and management of diarrhoeal cases.

Clinical and environmental sampling

Rectal swab samples were collected from 15 individuals with active watery diarrhoea meeting the criteria for suspected cases. These samples were placed in Cary-Blair transport medium and transported to the Research Institute for Tropical Medicine (RITM) for bacteriological analysis.

Concurrently, an environmental investigation was conducted to assess water sources, waste management practices, availability of sanitary toilets, and overall water and sanitation conditions in the community. Interviews with local leaders and residents revealed that a communal dug well and a water refilling station were the primary sources of drinking-water. Ten water samples were collected: two from each of five sites – two household water containers, the dug well, a water tank at the refilling station, and raw water from the refilling station. Samples were collected aseptically in sterile 500 mL bottles; one set of samples from each site was sent to RITM for bacteriological analysis, while the second set was sent to the Provincial Water Laboratory to test for total coliforms and *Escherichia coli* using Colilert-18. Additionally, operational records from the water refilling station were reviewed.

RESULTS

Case characteristics

A total of 75 suspected cholera cases were identified through active case finding and health facility records review. The earliest reported onset of illness was on 1 October 2022, with a peak in cases occurring on 15 and 16 October 2022 (**Fig. 1**). Four deaths were recorded, all in children, for a case fatality rate (CFR) of 5.3%.

Cases ranged in age from 2 months to 20 years, with a median of 4 years. The most affected age group was 0–4 years, and 39 (52.0%) were male. All cases had acute diarrhoea; 31 (41.3%) had vomiting, 21 (28.0%) had abdominal pain, and 16 (21.3%) had fever. Hospitalization was necessary for 40 (53.3%) cases

Table 1. Characteristics of suspected cholera cases among the Sama Badjao community, Dalahican, Lucena City, Philippines, 1 October–2 November 2022 (N = 75)

Characteristics	No. (%) of cases
Sex	
Male	39 (52.0)
Female	36 (48.0)
Age group, years	
0–4	39 (52.0)
5–9	20 (26.7)
10–14	11 (14.7)
15–19	4 (5.3)
≥20	1 (1.3)
Signs and symptoms ^a	
Acute watery diarrhoea	75 (100)
Vomiting	31 (41.3)
Abdominal pain	21 (28.0)
Fever	16 (21.3)
Body weakness	11 (14.7)
Sunken eyeballs	10 (13.3)
Hospitalized	
Yes	40 (53.3)
No	35 (46.7)

^a Multiple responses were allowed.

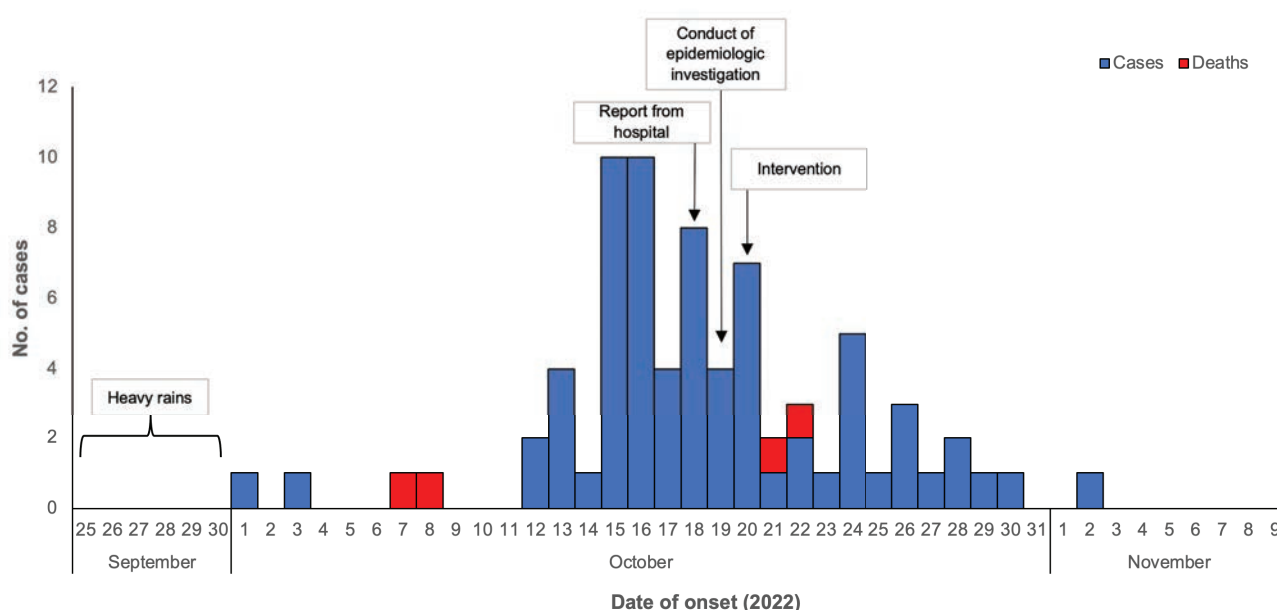
(Table 1). Interview responses revealed that 60 (80.0%) of the cases did not wash their hands before eating, and 70 (93.3%) did not wash their hands after defecation.

Key informant interviews

The barangay captain indicated that no social gatherings took place in the weeks leading up to the incident, although children began experiencing diarrhoea following heavy rains at the end of September (Fig. 1). Additionally, the captain noted that there had been no severe diarrhoeal cases in the village over the past 5 years. A review of surveillance records confirmed the absence of reported cholera cases and outbreaks of acute watery diarrhoea during the same period.

A health worker from the Sama Badjao community indicated that the local population lacks awareness regarding the risks associated with acute diarrhoea, only seeking medical assistance after the fatalities of two children early in the outbreak (Fig. 1). The health worker noted that Sama Badjao individuals generally visit health stations primarily to acquire medicines, rather than for medical consultations.

Fig. 1. Cholera cases by date of onset of illness, Sama Badjao community, Dalahican, Lucena City, Philippines, 1 October–2 November 2022 (N = 75)



Environmental investigation

The communal dug well was shallow, unprotected, and located 50 m from homes, where it was surrounded by debris and lacked a waste disposal area. Residents reported that the water frequently turned brown during heavy rains, and it was rarely treated before use.

The houses, mainly built from light materials, often had makeshift sanitary toilets, with elderly individuals using recycled pails for this purpose. Faecal waste was disposed of underneath houses into the water below, which also doubled as bathing areas.

Laboratory results

Of the 15 rectal swab samples taken, nine (60.0%) were positive for *V. cholerae* Ogawa biotype El Tor. *Aeromonas* (*hydrophilia* and *veronii* biovar) were also isolated in two (13.3%) samples.

All five water samples tested for chromogenic substrate (Colilert-18) at the Provincial Water Laboratory contained total coliforms and *E. coli*. Two of the five samples subjected to bacteriological analysis at RITM – the dug well and the raw water from the refilling station – tested positive for *Aeromonas caviae* and *A. veronii* biovar *sobria*; none tested positive for *V. cholerae*. The records review revealed that water testing at this refilling station was conducted regularly and that water samples passed quality checks, except during a period in September 2022.

Follow-up action: prevention and control measures

After the investigation, local health officials conducted household education, emphasizing household chlorination, boiling water, good hygiene practices and protecting water sources from contamination. They advised sick individuals to avoid participating in food preparation and provided clean water and rehydration sachets. Barangay health workers received refresher training on diarrhoea case notification, emphasizing the need for timely reporting, and reminded community members to seek health care promptly if symptoms appear. A water quality monitoring committee was formed to ensure safe water access and improve coordination among agencies

and the Sama Badjao community for sustainable water, sanitation and hygiene practices.

DISCUSSION

The investigation confirmed an outbreak of cholera among the Sama Badjao community in Dalahican, Lucena City. Environmental findings suggested that contaminated water sources may have contributed to transmission. Although *V. cholerae* was not detected in the water samples, several factors point to the open dug well as the most probable source of transmission. The shallow well was unprotected and located close to households, and testing showed faecal contamination, indicating poor water quality. The outbreak followed heavy rainfall that may have introduced contamination via runoff, a risk exacerbated by the community's practice of open defecation.

Raw water from the refilling station was also considered a potential source of exposure. *Aeromonas* species (*A. caviae* and *A. veronii* biovar) were isolated from both the open dug well and the refilling station's raw water, indicating faecal contamination. Two suspected cases tested positive for *Aeromonas*, which are recognized as gastrointestinal pathogens that produce symptoms similar to cholera.^{5,6} The detection of *Aeromonas* in both water sources suggests that residents may have been exposed to multiple enteric pathogens through contaminated water.

A lack of access to sanitation is recognized as a major contributor to the magnitude and severity of cholera outbreaks. A 2021 report from the Electronic Field Health Information System of Lucena City indicated that only 1363 (24.7%) households in Dalahican had access to basic sanitation facilities (report available upon request). The Sama Badjao settlement exemplified severely unsanitary conditions with a lack of toilets, widespread open defecation and reliance on untreated water sources, creating a favourable environment for waterborne diseases such as cholera. Similar risk factors have been documented in cholera outbreaks in other vulnerable communities,⁷⁻¹⁰ such as during a cholera outbreak in Somalia, where inadequate sanitation, unsafe drinking-water, poor hygiene practices and limited awareness of cholera exacerbated disease transmission.⁸ While both regions are geographically distinct, they share common

structural challenges, including poverty, insufficient water and sanitation infrastructure, and limited access to health services.

Laboratory investigations indicated that the cholera outbreak was caused by *V. cholerae* Ogawa biotype El Tor. This strain is notable for its ability to persist in environmental water sources,¹ effective host-to-host transmission and a higher occurrence of asymptomatic carriers.¹¹ While El Tor strains typically lead to milder disease compared to classical strains,¹² the outbreak nonetheless had a CFR of 5.3%, which surpasses the target of below 1% for cholera outbreaks.¹³ Delayed medical care likely contributed to this elevated CFR, as some community members only sought assistance after the deaths of two children.

The vulnerability of the Sama Badjao community to cholera highlights broader social health inequities. Traditionally nomadic, these communities face difficulties adapting to urban environments. Research in other areas where the Sama Badjao reside, such as Bongao, Tawi-Tawi Province, has documented persistent poverty and limited access to essential services such as education and health care,⁴ contributing to their increased risk of infectious disease outbreaks.

Preventing future outbreaks in similar settings requires an integrated approach that combines improvements in water and sanitation infrastructure with culturally sensitive community engagement. Key measures include increasing access to safe drinking-water, improving sanitation facilities and promoting good hygiene practices.¹⁴ Community health education and improved access to early treatment are also vital for reducing morbidity and mortality during cholera outbreaks. Additionally, strengthening public health policies that prioritize Indigenous Peoples and other vulnerable populations can help address health inequities.¹⁵

This study had several limitations. First, the source of the outbreak was undetermined, with environmental findings suggesting contaminated water, particularly from the open dug well, though all water samples tested negative for *V. cholerae*. This ambiguity could be due to the timing of sample collection, dilution of contaminants during heavy rainfall or limitations of the sampling method. Second, case numbers may be underestimated, as mild

cases might not have sought medical care. Laboratory confirmations were limited by a shortage of testing kits, thereby reducing the detection of additional cases and other pathogens. Finally, while *Aeromonas* species were detected in samples, the available diagnostic methods could not adequately distinguish their role in the outbreak relative to *V. cholerae*. Despite these challenges, the study offered valuable insights into the outbreak's environmental and social factors, guiding public health responses in a vulnerable Indigenous community.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Ethics statement

The operations carried out for this study were part of regular surveillance and response activities, and a standard process for protecting personal information was followed. Therefore, approval from an ethics committee was unnecessary.

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A cluster of co-occurring cases of leptospirosis and brucellosis in a pastoral community of dairy farmers, India, 2023–2024: an epidemiological investigation

Farida Khatoon,^a Srividya K Vedachalam,^b Sushma Choudhary,^b Subodh Kumar Joshi,^c Pankaj Kumar Jain,^c Yogesh Bahurupi,^d Fareeduzzafar,^c Meenu Singh^d and Pankaj Kumar Singh^c

Correspondence to Srividya K Vedachalam (email: drsrividya.eisc8@gmail.com)

Objective: A cluster of leptospirosis and brucellosis cases in a semi-nomadic, pastoral community was reported in October 2023 from Village A, Uttarakhand State, India. This cluster was investigated to describe the epidemiology and potential exposures.

Methods: Suspected cases were residents with sudden-onset fever or myalgia occurring from 1 August 2023 to 7 January 2024; confirmed cases were suspected cases with laboratory confirmation. Suspected cases were identified through a house-to-house case search and were interviewed regarding sociodemographic variables, symptoms and exposures. Those who consented were tested. Data were cleaned and analysed in Microsoft Excel.

Results: Fifty suspected cases were identified among a total of 300 residents across 85 households. Among these, 27 agreed to be tested, and 25 were confirmed (13 with leptospirosis, 7 with brucellosis and 5 with both leptospirosis and brucellosis). The cases began in September 2023 following flooding and continued until January 2024, with no deaths. The median age (range) of cases was 30 (17–82) years for leptospirosis, 39 (25–56) years for brucellosis and 39 (22–50) years for coinfection. Altogether, females accounted for 92% (12/13) of leptospirosis cases, 57% (4/7) of brucellosis cases and 80% (4/5) of coinfections. Symptoms included fever, myalgia and arthralgia. All cases reported contact with floodwater and animal abortus.

Discussion: This was a laboratory-confirmed co-occurring cluster of leptospirosis and brucellosis, including five cases of coinfection, following flooding, predominantly affecting female Van Gujjar dairy farmers. Education was provided to the community about the hygienic disposal of animal waste.

Leptospirosis, a bacterial zoonosis caused by *Leptospira* spp., has an estimated global burden of 2.9 million disability-adjusted life-years (DALYs) annually; South-East Asia has one of the highest burdens, with 137 DALYs per 100 000 population.¹ Brucellosis, caused by *Brucella* spp., another bacterial zoonosis, has an estimated annual incidence of 2 million cases, with three fourths of the cases in Asia.² Both diseases present with non-specific symptoms, such as fever, myalgia, malaise and headache, complicating diagnosis and treatment.^{3,4} Pastoral communities are at risk for both these zoonoses because of their close contact with livestock.^{5,6} However, few instances of simultaneous

circulation of these pathogens in livestock and of human coinfection with both diseases have been reported, and none have been reported from India.^{7,8}

The Van Gujjars are a forest-dwelling pastoral tribal community inhabiting the northern Indian Himalayan state of Uttarakhand. They follow a semi-nomadic lifestyle and migrate to the alpine regions of the western Himalayas along with their livestock during warmer months.^{9,10}

In October 2023, a One Health camp (OHC) was piloted by the Department of Health in collaboration with the Department of Animal Husbandry in Uttarakhand.

^a Epidemiology Division, National Centre for Disease Control, New Delhi, India.

^b South Asia Field Epidemiology and Technology Network, New Delhi, India.

^c Integrated Disease Surveillance Programme, Haridwar, Uttarakhand, India.

^d All India Institute of Medical Sciences, Rishikesh, Uttarakhand, India.

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The OHC was conducted with the objective of screening high-risk populations for two zoonotic diseases: leptospirosis and brucellosis. The OHC screened the population of Village A, Bahadarabad Block, Haridwar District, Uttarakhand, in October 2023 and identified cases of leptospirosis and brucellosis within the village community. A follow-up investigation was carried out by the State Health Department in December 2023 to determine whether the cluster of cases identified during the OHC constituted an outbreak in Village A, to describe the epidemiology and potential exposures among cases, and to initiate prevention and control measures.

METHODS

A line list of leptospirosis cases was extracted from the Integrated Disease Surveillance Programme (IDSP) unit in Uttarakhand for 2020–2022 to determine the monthly outbreak threshold (calculated as the mean number of cases reported in 1 month from 2020 to 2022 + 2 standard deviations from the mean) and compared with the number of cases reported in 2023 to determine whether the reported cluster met the threshold for confirmation of an outbreak. Brucellosis is not a notifiable disease in the IDSP, so no historical data could be obtained for comparison with the number of reported cases in 2023.

Selected cases from the line list were interviewed using a validated semi-structured questionnaire (**Supplementary Material**). Based on the interviews and the IDSP case definitions of leptospirosis and brucellosis, definitions of suspected and confirmed cases were formulated for investigating this cluster, and additional cases were identified and interviewed.

Case definitions

The definition of a suspected case of leptospirosis or brucellosis was the sudden onset of fever OR myalgia occurring from 1 August 2023 to 7 January 2024 in Village A. We used a broad, combined definition for suspected cases for both diseases because the initial patients in this community presented with these broad and non-specific symptoms. To capture all suspected cases, case-finding in the community started from 1 August 2023 (8 weeks, or two incubation periods, before the date of symptom onset in the index case, that is, 1 October 2023). In addition, to ensure that the investigation then went on to capture

confirmed cases, we had a definition of a confirmed case that was specific for each disease.

The definition of a confirmed case of leptospirosis was a suspected case who tested positive by enzyme-linked immunosorbent assay (ELISA) for immunoglobulin M (IgM) for leptospirosis. The definition of a confirmed case of brucellosis was a suspected case who tested positive by ELISA for IgM for brucellosis. The definition of a confirmed case with coinfection with both leptospirosis and brucellosis was a suspected case who tested positive by ELISA for IgM for both leptospirosis and brucellosis.

Case-finding strategy

The investigation used both active and passive case-finding strategies. For active case-finding, an investigation team comprising an Epidemic Intelligence Service officer from the National Centre for Disease Control, New Delhi, the Haridwar district surveillance officer, the medical officer in charge of the primary health centre and front-line health-care workers conducted house-to-house case-finding in Village A from 15 December 2023 to 7 January 2024, based on the case definitions formulated. Identified cases were interviewed to collect information about their sociodemographic details, clinical symptoms, health-care-seeking behaviour and exposure to floodwaters, cattle, animal abortus and raw animal products.

For passive case-finding, the investigation reviewed the records of the subcentre located in Village A to check for fever cases reported from 1 August 2023 to 7 January 2024.

Laboratory investigation

Serum samples from suspected cases who consented to testing were sent to the district public health laboratory for ELISA analysis.

Interviews with key stakeholders and field observation

Key stakeholders in the district human health sector, including front-line health-care workers and physicians at government health-care facilities, were interviewed to assess awareness of leptospirosis and brucellosis. During

house-to-house case-finding, investigators observed each house's surroundings, general sanitation and drinking-water sources.

Data analysis

Continuous data on age were analysed to determine the median and range, and categorical data were expressed as frequencies and proportions using Microsoft Excel 2021. The distribution of cases by week of symptom onset was plotted on an epidemic curve (**Fig. 1**).

RESULTS

A total of 18 leptospirosis cases including five coinfecting cases were identified, exceeding the annual number reported in each of the previous 5 years in Haridwar district (2018–2021, $n = 0$; 2022, $n = 3$). However, access to testing for leptospirosis at state and district levels was limited until 2021 ($n = 35$ tests), increasing in 2022 ($n = 121$) and 2023 ($n = 632$), with test positivity remaining the same (2%; data not shown). Brucellosis is not a notifiable disease in the IDSP, and this was the first OHC in the district; hence, no historical data for brucellosis could be obtained for comparison with the number of reported cases in 2023.

Descriptive epidemiology

Village A had a population of 300 residents across 85 households. Active case-finding conducted among all residents identified 50 suspected cases, 27 of whom consented to testing for leptospirosis and brucellosis by IgM ELISA; the rest did not consent to testing. Among the 27 cases tested, 25 tested positive (confirmed cases): 13 for leptospirosis, 7 for brucellosis and 5 for both. The attack rate for leptospirosis including coinfections was 6% (18/300) and for brucellosis including coinfections was 4% (12/300). There were no deaths.

Among the 13 confirmed cases with only leptospirosis, the median age was 30 (range: 17–82) years, and 92% (12/13) were female. The most common symptoms were fever (92%, 12/13), myalgia (92%, 12/13) and arthralgia (85%, 11/13).

Among the seven confirmed cases with only brucellosis, the median age was 39 (range: 25–56) years, and 57% (4/7) were female. The most common

symptoms were fever (86%, 6/7), myalgia (57%, 4/7) and arthralgia (43%, 3/7).

Among the five confirmed cases coinfecting with both leptospirosis and brucellosis, the median age was 39 (range: 22–50) years, and 80% (4/5) were female. The most common symptoms were fever (100%, 5/5), myalgia (80%, 4/5) and arthralgia (80%, 4/5).

Among the 50 suspected cases, 25 were laboratory-confirmed, and the remaining 25 were suspected cases (as they either were not tested or tested negative). Among these remaining 25 suspected cases, the median age was 36 (range: 17–70) years, and 80% (20/25) were female. The most common symptoms were fever (76%, 19/25), myalgia (60%, 15/25) and arthralgia (48%, 12/25).

All cases (both suspected and confirmed) occurred among the Van Gujjars, who have a semi-nomadic lifestyle and engage in cattle rearing, dairying and crop farming as their primary occupation. All reported contact with floodwater, wastewater contaminated with animal urine, and close contact with cattle and rodents in the preceding month, and routinely handling animal abortion or their fluids with bare hands. All cases reported that they first contacted a private physician when seeking health care during their illness (**Table 1**). The cases started in the first week of September 2023 and continued until the first week of January 2024 (**Fig. 1**).

Interview with key stakeholders

Six stakeholders were interviewed: one medical officer, two laboratory technicians, two village-level front-line health-care workers and one community leader. Front-line health-care workers had limited awareness of leptospirosis and brucellosis, and of their transmission from animals to humans. The physician was aware of the diseases but did not suspect they were present in the village.

Field observations

Houses were made of mud-plastered brick walls and thatched roofs, with cattle sheds attached to them. All observed households had rodents. General sanitation of the area was poor, with accumulated wastewater

Table 1. Sociodemographic characteristics, symptoms, exposures and laboratory results of suspected and confirmed cases of leptospirosis, brucellosis and coinfection, Village A, Haridwar, Uttarakhand, India, 2023–2024

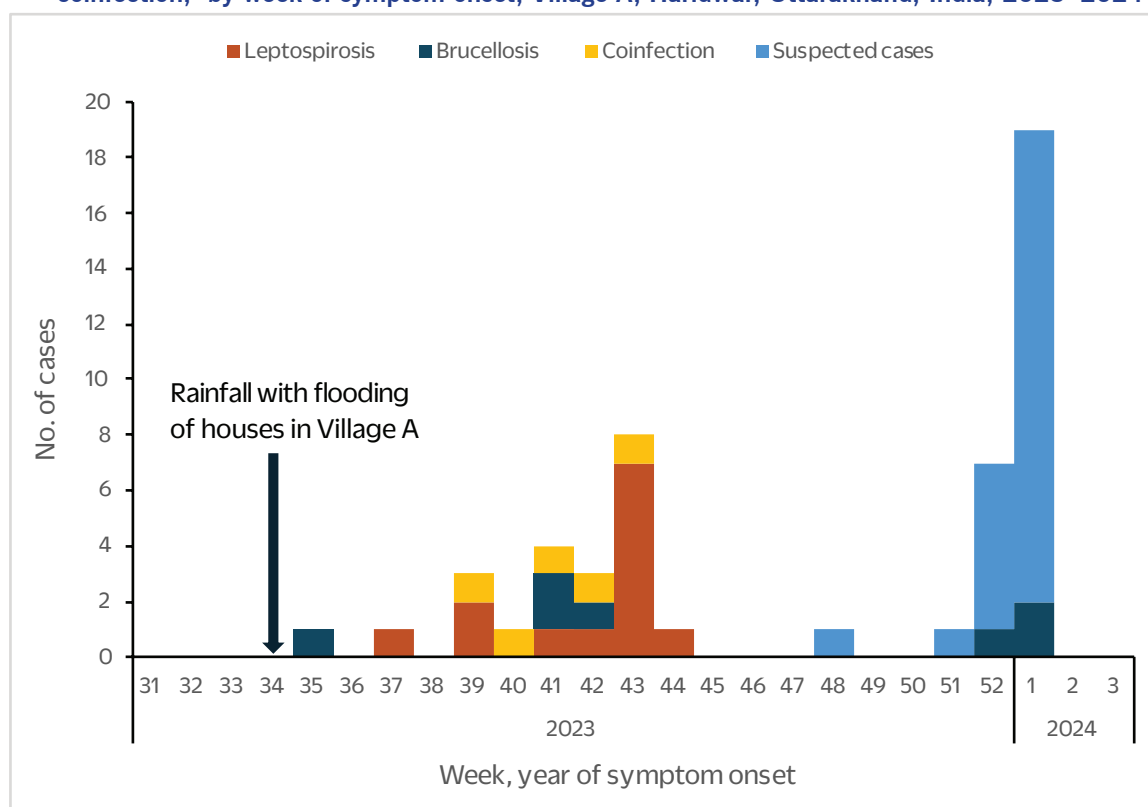
Characteristics	Suspected ^a (N = 25)	Confirmed ^b (N = 25)		
		Leptospirosis (n = 13)	Brucellosis (n = 7)	Coinfection (n = 5)
Median (range) age, years	36 (17–70)	30 (17–82)	39 (25–56)	39 (22–50)
Sex				
Female	20 (80)	12 (92)	4 (57)	4 (80)
Occupation				
Cattle rearing and dairying	25 (100)	13 (100)	7 (100)	5 (100)
Farming	25 (100)	13 (100)	7 (100)	5 (100)
Type of dwelling				
Semi-permanent (mud-plastered walls with straw roof)	25 (100)	13 (100)	7 (100)	5 (100)
Cattle shed				
Attached to house	25 (100)	13 (100)	7 (100)	5 (100)
Educational status				
No formal education	7 (28)	6 (46)	3 (43)	2 (40)
Some formal education	18 (72)	7 (54)	4 (57)	3 (60)
First contact with a health facility seeking care after illness				
Private physician	25 (100)	13 (100)	7 (100)	5 (100)
Symptoms				
Fever	19 (76)	12 (92)	6 (86)	5 (100)
Myalgia	15 (60)	12 (92)	4 (57)	4 (80)
Arthralgia	12 (48)	11 (85)	3 (43)	4 (80)
Headache	0 (0)	9 (69)	1 (14)	4 (80)
Fatigue	0 (0)	8 (62)	3 (43)	2 (40)
Skin rash	0 (0)	0 (0)	1 (14)	0 (0)
Chills	0 (0)	0 (0)	5 (71)	0 (0)
Exposure factors (during month before symptom onset)				
Contact with floodwater	25 (100)	13 (100)	7 (100)	5 (100)
Contact with wastewater contaminated with animal urine	25 (100)	13 (100)	7 (100)	5 (100)
Close contact with cattle	25 (100)	13 (100)	7 (100)	5 (100)
Rodent sighting within the house	25 (100)	13 (100)	7 (100)	5 (100)
History of bathing in a common waterbody	0 (0)	0 (0)	0 (0)	0 (0)
Consumption of raw (unboiled) milk	0 (0)	0 (0)	0 (0)	0 (0)
Consumption of curd/butter made with raw (unboiled) milk	0 (0)	0 (0)	0 (0)	0 (0)
Consumption of raw, uncooked meat	0 (0)	0 (0)	0 (0)	0 (0)
Handling animal abortus or their fluids with bare hands	25 (100)	13 (100)	7 (100)	5 (100)
Positive laboratory results				
Leptospirosis	–	13 (100)	0 (0)	5 (100)
Brucellosis	–	0 (0)	7 (100)	5 (100)

Values are n (%) unless otherwise indicated.

^a Suspected cases were residents of Village A who experienced sudden-onset fever or myalgia from 1 August 2023 to 7 January 2024 and who either declined testing or tested negative.

^b Confirmed cases were suspected cases who tested positive by IgM ELISA.

Fig. 1. Epidemic curve of suspected^a ($N = 25$) and confirmed cases ($N = 25$) of leptospirosis,^b brucellosis^c and coinfection,^d by week of symptom onset, Village A, Haridwar, Uttarakhand, India, 2023–2024



^a Suspected cases were residents of Village A who experienced sudden-onset fever or myalgia from 1 August 2023 to 7 January 2024 and who either declined testing or tested negative.

^b Suspected cases testing positive for leptospirosis by IgM ELISA.

^c Suspected cases testing positive for brucellosis by IgM ELISA.

^d Suspected cases testing positive for both brucellosis and leptospirosis by IgM ELISA (coinfection).

around the houses seen contaminated with cow dung, and animal urine seen mixed with the accumulated wastewater. There was no municipal piped water supply, and the only source of drinking-water was a hand pump surrounded by wastewater. The community leader reported females being primarily engaged in rearing animals at home, while males travelled to the market to sell animal products. He also reported that residents initially sought health care from private physicians due to their accessibility and operational days (all days of the week). The community leader reported a history of pluvial flooding from September to October 2023, which was confirmed by news reports from the time.

DISCUSSION

A laboratory-confirmed mixed cluster of leptospirosis and brucellosis was identified, with simultaneous transmission of both, including a few cases of coinfection, in the Van Gujjar community residing in Village A of

Bahadarabad Block, Haridwar District, Uttarakhand. The onset of cases followed flooding in the area. Fever, myalgia and arthralgia were the main symptoms. Most cases were female dairy farmers, mostly young and middle-aged, who presented with symptoms consistent with leptospirosis and brucellosis.^{3,4} As adequate testing for leptospirosis only started in 2022, the investigation did not have enough evidence to determine whether this cluster of leptospirosis cases in 2023 was an outbreak or an increase in cases due to enhanced testing efforts.

Across the world, rural pastoral communities, similar to those in our investigation, are reported to be at a higher risk for bacterial zoonoses due to their close contact with animals, inadequate sanitation, poor access to health care or poor diagnostic capacity in these remote areas.^{11–13} This risk is further complicated by the lack of awareness of these diseases among local health-care workers, resulting in missed or delayed diagnosis, which we documented in this investigation. The symptoms seen

in these cases are consistent with those generally reported in brucellosis and milder cases of leptospirosis. However, the sex predilection generally reported in leptospirosis (80% males) is reversed in this investigation, with most cases occurring in females.^{1,14} This might be due to higher occupational exposure of females compared to males in this community. Simultaneous transmission of both diseases in the community indicates a need to screen multiple zoonotic pathogens in at-risk communities.

The limitations of this investigation included the increase in testing during the preceding year, which hindered our understanding of whether this cluster was a true increase in cases. Additionally, in the absence of confirmatory testing for all suspected cases, patients with other febrile illnesses could potentially have been misclassified as cases of leptospirosis or brucellosis, leading to an overestimation of suspected cases.

Public health action and recommendations

Following this investigation, the residents of Village A were informed by the investigation team of the need to drain animal urine away from common sources of accumulated water, improve general sanitation and initiate rodent control measures. Confirmed cases were referred for treatment at the nearest health facility. The investigation team also requested the waterworks department to provide a source of piped drinking-water to Village A. Health-care workers in the area were briefed on the symptoms of these diseases and on the need to test suspected cases.

The investigation team recommended that the state health department alert health-care workers to suspect leptospirosis in patients presenting with fever following rainfall and brucellosis among pastoralists.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Ethics statement

This cluster investigation was an observational investigation carried out with the purpose of identifying the extent of the cluster/outbreak, identifying exposure factors and instituting immediate control measures to prevent morbidity and mortality as part of the public health response of the Uttarakhand State Health Department and NCDC. Ethical approval was not applicable, as the investigation was conducted as part of a public health response and was consistent with applicable state and central government law (Epidemic Diseases Act No. 3, 1897). The field response did not involve any human sample collection for research purposes or intervention. Strict data protection protocols reviewed by NCDC, the ethical principles and guidelines of the Government of India, and the 1964 Helsinki Declaration and its later amendments or comparable ethical standards were followed during the public health response.

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A large outbreak of cryptosporidiosis at a pool in Melbourne, Australia, 2025: rapid investigation and public health response

Clarissa Moreira,^a Renae Oliver,^a Norelle L Sherry,^b Karolina Mercoulia,^b Annaliese van Diemen^{a,c} and Claire L Gordon^{a,d}

Correspondence to Claire Gordon (email: claire.gordon@austin.org.au)

Objective: Cryptosporidiosis is a gastrointestinal illness spread via infected people, animals, or contaminated water or food. This article describes a cryptosporidiosis outbreak associated with a swimming pool in Melbourne, Australia in February 2025.

Methods: On 13 February, the North Eastern Public Health Unit was simultaneously notified of a complaint of gastroenteritis symptoms by a social group who swam at Pool A on 4 February and of gastroenteritis symptoms among students at School B who attended the same pool on 5 February. An outbreak was declared and an investigation commenced. Communications were sent to 1034 pool patrons and schools that attended the pool in early February to advise of the outbreak, provide safe swimming messages and encourage testing among symptomatic individuals. Interviews with symptomatic individuals were undertaken. An online questionnaire supported active case finding and information-sharing. Local clinicians and laboratories were alerted to the outbreak and healthy swimming messages were promoted at the pool.

Results: Cryptosporidiosis was suspected due to the 4–9-day incubation period. Due to initial reports of a high attack rate among the students and concerns about ongoing exposure to current pool users, the pool was immediately closed for hyperchlorination. Subsequent urgent faecal specimen testing confirmed *Cryptosporidium*. Overall, 16 confirmed and 59 probable cases were identified. The most common symptoms were diarrhoea (56%), abdominal pain (48%) and nausea (45%). Of those who only attended the pool once, the median incubation period was 7 days (range: 4–9 days). No cases were identified after hyperchlorination.

Discussion: This pool-associated cryptosporidiosis outbreak demonstrates the importance of rapid outbreak investigation and response, and pre-emptive aquatic environmental control measures to prevent ongoing transmission.

Cryptosporidium, a protozoan parasite, is an important and widespread cause of enteric infections. Infection is usually spread through contaminated drinking or recreational water or contact with infected animals or persons. A low infectious dose can cause illness, and oocysts can survive for long periods in the environment.¹ *Cryptosporidium* is resistant to conventional chlorine disinfection and is a major cause of swimming pool-associated gastroenteritis outbreaks in Australia.² Risk factors associated with aquatic cryptosporidiosis outbreaks include faecal contamination, inadequate filtration, high bather load and chlorine-resistant oocysts. Currently, no pool water treatment can prevent *Cryptosporidium* contamination.

The typical incubation period for cryptosporidiosis is 7 days (range: 1–12 days), and the main symptoms are watery diarrhoea and stomach cramps.

Cryptosporidiosis is a nationally notifiable infectious disease.³ In Victoria, medical practitioners and pathology services are required to notify cryptosporidiosis cases within 5 days of diagnosis. In practice, notification occurs via electronic laboratory notification systems to the Victoria Department of Health. Cases are then allocated to a local public health unit for investigation.

In 2024, Victoria was one of several Australian states to report an increase in the number of cryptosporidiosis

^a North Eastern Public Health Unit, Austin Health, Heidelberg, Victoria, Australia.

^b Microbiological Diagnostic Unit Public Health Laboratory, Department of Microbiology and Immunology at The Peter Doherty Institute for Infection and Immunity, The University of Melbourne, Melbourne, Victoria, Australia.

^c Department of Infectious Diseases, The Peter Doherty Institute for Infection and Immunity, The University of Melbourne, Melbourne, Victoria, Australia.

^d Department of Infectious Diseases and Immunology, Austin Health, Heidelberg, Victoria, Australia.

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cases (38 cases per 100 000 persons, compared with a 10-year average of 14.3 per 100 000), with multiple outbreaks associated with aquatic facilities.^{4,5} While case numbers associated with aquatic facilities were declining by the end of 2024, in early February 2025, the North Eastern Public Health Unit (NEPHU) received notification of a gastroenteritis outbreak linked to a community swimming pool in Melbourne, Victoria. The presence of *Cryptosporidium* was suspected and confirmed on 16 February. This paper describes the rapid investigation of the outbreak, as well as the public health response. This included pre-emptive pool treatment (hyperchlorination) on 14 February.

METHODS

Setting

The NEPHU covers a mostly urban area with a population of 1.8 million in the northeastern part of metropolitan Melbourne. The pool (Pool A) is a seasonal aquatic facility in the eastern suburbs of the city with three outdoor pools: a 50-m pool with its own filtration system, and a leisure pool and a toddler pool that share the same filtration system. The treated calcium hypochlorite filtration systems were updated in 2024 and are tested every 4 hours while the pool is open.

Outbreak identification

The outbreak investigation was triggered on 13 February when NEPHU received simultaneous reports of gastroenteritis symptoms among a social group who had swam at Pool A on 4 February and among students at School B who had attended the same pool for a whole-of-school swimming carnival on 5 February. The social group reported their symptoms to the local council on 12 February (Council C, the regulator of the facility), who in turn referred the complaint to NEPHU on 13 February.

The cluster at School B was identified when a gastroenteritis outbreak at a school camp was reported to the neighbouring South Eastern Public Health Unit (SEPHU). SEPHU made the potential link with the school swimming carnival and communicated cases to NEPHU on 13 February.

Epidemiological investigation

Social group cases and unwell students from School B who had visited Pool A on 4 and 5 February, respectively, were interviewed by telephone using the standard *Cryptosporidium* interview template to ascertain symptom details, symptom onset date and pool attendance. All individuals in the social group (or parents/guardians in the case of minors) were interviewed. Parents or guardians of the symptomatic students were interviewed sequentially based on a list of contact details provided by the school.

Once the outbreak had been confirmed, active case finding was undertaken using an online questionnaire developed specifically for the outbreak (**Supplementary Material**). The questionnaire collected information on pool attendance, symptoms, symptom onset date and school attendance. The questionnaire link was sent to all Pool A patrons, and to parents or guardians of all students at School B, as well as two additional schools that held swimming carnivals at Pool A during 4–13 February. The online questionnaire was anonymous (although an option to leave contact details was provided), giving rise to the possibility of duplicated responses with the telephone interviews. Potential duplicates remained in the analysis.

Laboratory investigation

Symptomatic individuals were requested to provide a faecal sample for testing. To expediate pathogen identification once the outbreak had been declared (and cryptosporidiosis suspected), Council C staff visited individuals' homes on 14 February to collect samples. Initial samples were couriered to the Microbiological Diagnostic Unit Public Health Laboratory (MDU PHL) and underwent urgent testing using the FilmArray® Gastrointestinal (GI) Panel (BioFire Diagnostics LLC, Salt Lake City, UT, USA) after hours on 16 February. The GI panel simultaneously detects nucleic acids from bacteria, viruses and parasites commonly associated with gastrointestinal disease.

In addition, collection pots were made available at School B and Council C's offices, and symptomatic individuals were encouraged to submit a faecal sample for testing. These samples were forwarded to the MDU

PHL, with testing for parasites and bacterial GI pathogens performed on the BD MAX System using the BD MAX Enteric Bacterial, Extended Bacterial and Parasite Panels (Becton Dickinson, Franklin Lakes, NJ, USA). All samples were referred to the Victorian Infectious Diseases Reference Laboratory for further viral studies as per state guidelines for the investigation of gastroenteritis.⁶ Some symptomatic individuals chose to attend a medical practitioner and were tested via alternative pathways. As cryptosporidiosis is a notifiable condition in the State of Victoria, all positive detections were notified to the Victoria Department of Health regardless of where the sample was submitted for testing.

Outbreak case definitions

A probable case was defined as an individual with onset of gastroenteritis symptoms between 5 and 26 February who had swum in Pool A between 4 and 13 February 2025. A confirmed case was defined as a probable case with laboratory-confirmed *Cryptosporidium*.

The window for symptom onset dates reflects the incubation period for *Cryptosporidium*, and thus spans from 1 day after the first group of unwell individuals swam (5 February) to 12 days post-hyperchlorination of the pool (26 February). The start and end of the risk period, i.e. the dates of potential acquisition in Pool A, were defined by the date the first unwell individual swam (4 February) and the last date before hyperchlorination (13 February).

Data analysis

Questionnaire data were collected using Microsoft Forms and Microsoft Excel, and descriptive analysis of identified cases (probable and confirmed) was conducted in R (version 4.2.0). An epidemic curve was generated to visualize trends in exposure and symptom onset.

RESULTS

Outbreak investigation

In total, our investigation identified 75 cases of cryptosporidiosis: 38 confirmed or probable cases from telephone interviews and 37 probable cases from active case finding (Table 1). Faecal samples were received from 19 individuals, of which 16 were positive for

Cryptosporidium (10 from the social group, 6 from School B). No other pathogens were identified.

Telephone enquiries to members of the social group determined that 13 individuals from five families experienced gastroenteritis symptoms with onset dates between 8 and 10 February, 4–6 days after attendance at Pool A on 4 February. Council C confirmed no recent faecal accidents at the pool and no mechanical issues with pool filtration systems.

As previously noted, the cluster of cases among School B students was identified following a gastroenteritis outbreak at a school camp reported to SEPHU. Around one third of students attending the camp (28/80, 35.0%) had gastroenteritis symptoms. In most cases, symptoms were present upon arrival on 11 February, before students had eaten or drunk anything at the camp or had participated in camp activities. Once the potential link to the swimming carnival was made, and NEPHU notified, the investigation focused on identifying symptomatic students who had attended the swimming carnival. It emerged that the swimming carnival had been attended by 426 School B students, and all had swum in the 50-m pool at the aquatic facility. Moreover, approximately 15% (65/470) of all School B students were absent due to gastroenteritis symptoms in the days following the swimming carnival on 5 February. Telephone interviews identified 25 students who experienced symptoms with onset dates between 9 and 14 February (Table 1).

A link to the online questionnaire was sent to over 1500 individuals (including 1034 Pool A patrons and 476 parents or guardians of School B students, as well as to parents or guardians of students from two other schools who held swimming carnivals at Pool A on 7 and 12 February), and 197 completed questionnaires were received. Among the respondents, 176 had attended Pool A between 4 and 13 February, of whom 37 (21.0%) experienced symptoms of gastroenteritis. No cases were reported in the two other schools who held swimming carnivals during the risk period.

Demographic characteristics of the 75 identified cases are summarized in Table 1. Six individuals identified through active case finding did not provide contact details, and based on their age and school attendance could have also been in the School B cohort who were interviewed by telephone. Among the students who took

Table 1. **Demographic and clinical characteristics of confirmed and probable cases during a cryptosporidiosis outbreak, Melbourne, Australia, February 2025 (N = 75)**

Characteristic	Confirmed		Probable		Total	
	n	%	n	%	n	%
Total	16	21.3	59	78.7	75	100
Respondent group						
Interviewed student	6	37.5	19	32.2	25	33.3
Interviewed pool attendee	10	62.5	3	5.1	13	17.3
Questionnaire respondent	0	0.0	37	62.7	37	49.3
Sex						
Male	10	62.5	8	13.7	18	24.0
Female	2	12.5	10	16.9	12	16.0
Not stated	4	25.0	41	69.5	45	60.0
Age group, years						
0–9	8	50.0	1	1.7	9	12.0
10–19	6	37.5	32	54.2	38	50.7
20–29	1	6.3	0	0.0	1	1.3
30–39	0	0.0	4	6.8	4	5.3
40–49	0	0.0	10	16.9	10	13.3
50–59	0	0.0	3	5.1	3	4.0
60–69	1	6.3	6	10.2	7	9.3
≥70	0	0.0	1	1.7	1	1.3
Not stated	0	0.0	2	3.4	2	2.7
Symptoms reported						
Diarrhoea	9	56.3	33	55.9	42	56.0
Abdominal pain	11	68.8	25	42.4	36	48.0
Nausea	7	43.8	27	45.8	34	45.3
Headache	7	43.8	18	30.5	25	33.3
Vomiting	6	37.5	19	32.2	25	33.3
Lethargy	3	18.8	21	35.6	24	32.0
Fever	2	12.5	12	20.3	14	18.7

part in the swimming carnival on 5 February, the attack rate was 6% (25/426); this is likely an underestimate, as not all cases were contacted or interviewed. Among the social group who swam in the pool ($n = 13$), the attack rate was 100%.

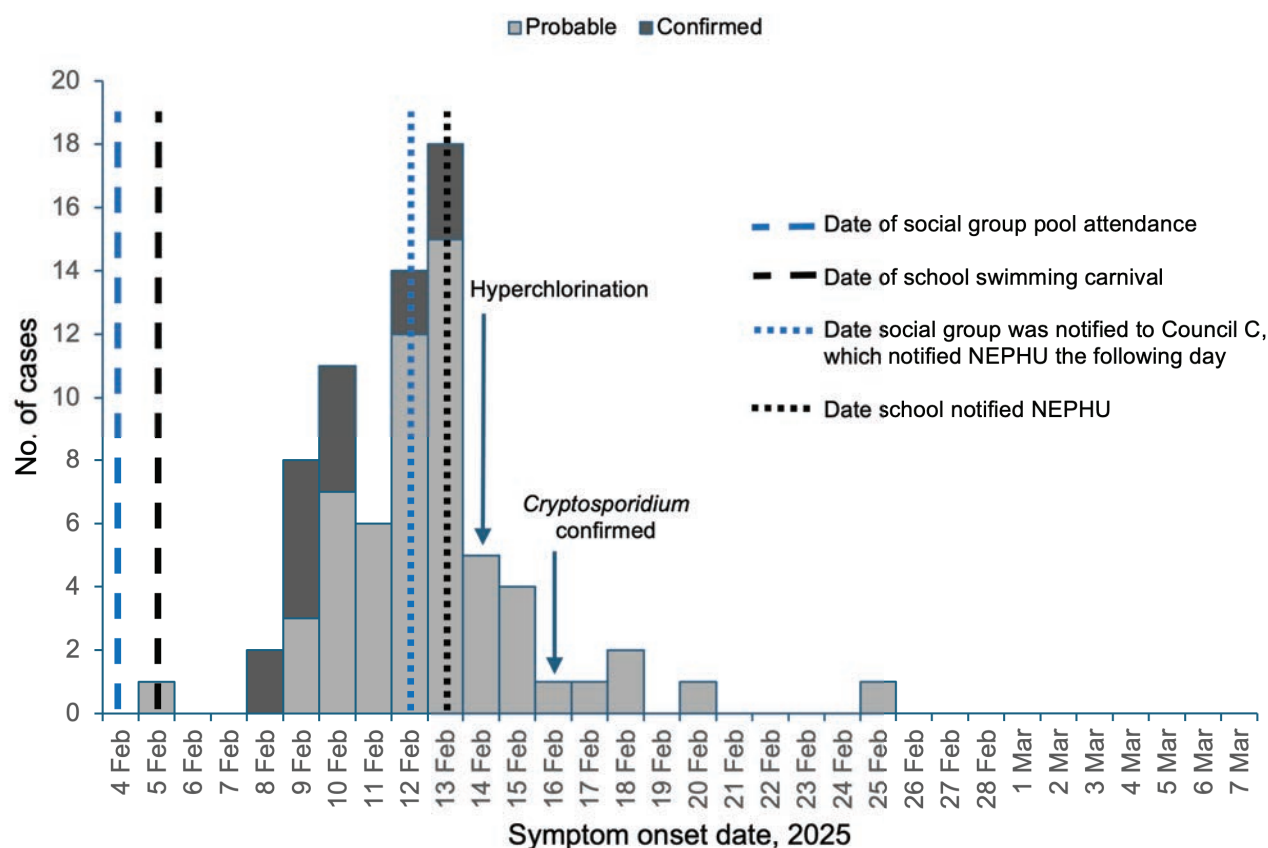
Symptom onset dates ranged from 5 to 25 February (Fig. 1). The most common symptoms were diarrhoea (56%), abdominal pain (48%) and nausea (45%) (Table 1). No cases reported hospitalization. The median time between last attendance at Pool A and symptom onset was 6 days (range: 0–14 days), noting that 18 of the symptomatic online questionnaire respondents reported swimming at the pool more than once during

their incubation period. Of those who only attended the pool once, the median time between attendance and symptom onset was 7 days (range: 4–9 days). The median interval between last attendance and symptom onset was similar between the two groups and consistent with the incubation period for *Cryptosporidium* infection. Additionally, the temporal distribution of illness onset was peaked, indicating a point-source exposure, with Pool A being the most likely source (Fig. 1).

Immediate public health response

Given the high attack rates and strong suspicion of cryptosporidiosis, NEPHU recommended on the

Fig. 1. **Epidemiological curve of cryptosporidiosis outbreak cases by symptom onset date, Melbourne, Australia, February 2025 ($N = 75$)**



NEPHU: North Eastern Public Health Unit.

evening of 13 February that Pool A be closed for hyperchlorination. Council C worked with pool operators to carry out hyperchlorination and a gastroenteritis clean as per state guidelines on 14 February.⁷⁻⁹ The pool reopened on 16 February. No water testing was done before hyperchlorination. Water sampling is not part of the recommended cryptosporidiosis outbreak response and was not conducted.

Communications were developed by NEPHU and sent by the school on 14 February to all School B students to inform them of a gastroenteritis outbreak associated with the school swimming carnival, as well as to 1034 Pool A patrons to inform them of an investigation into a gastroenteritis outbreak in people who attended the pool in the first 2 weeks of February. The letter advised symptomatic individuals to be tested or to see their health practitioner to discuss any testing or treatment requirements, to stay at home until 48 hours after symptom resolution and to avoid swimming for 14 days after symptom resolution. The letter also contained

general gastroenteritis prevention and healthy swimming advice.⁹ A poster describing the situation was created and displayed at Pool A.

Subsequent public health response

Cryptosporidium was identified on 16 February, allowing a more focused public health response. The priorities included preventing re-infection of Pool A with *Cryptosporidium* by advising cases to avoid swimming for 14 days after symptom resolution and reminding all pool users of pool hygiene.

An update on the gastroenteritis outbreak was sent to the School B community and Pool A patrons on 18 February, informing that *Cryptosporidium* had been identified as the cause of the outbreak and that the pool had completed treatment. Posters containing the update and healthy swimming messages were displayed at Pool A. Communications were also sent to students at the two schools that had held swimming carnivals at Pool A

during the risk period and to schools that were scheduled to hold swimming events in the following week.

NEPHU alerted local general practice clinics to the outbreak and requested clinicians to consider testing for *Cryptosporidium*, especially if there was recent exposure to aquatic facilities and to advise patients with gastroenteritis to avoid swimming for 14 days after symptom resolution. Local pathology services were notified that they may receive an increased number of faecal samples for *Cryptosporidium* testing.

Surveillance and outbreak closure

Surveillance using the state-wide notification system for laboratory-confirmed *Cryptosporidium* did not identify additional cases linked to the outbreak in the two incubation periods after the last case (24 days), at which time, 7 March, the outbreak was considered closed.

DISCUSSION

The initial report of a high attack rate of gastroenteritis in two independent groups who swam at Pool A over 2 successive days prompted urgent action at the pool to remove ongoing risk to current pool users. *Cryptosporidium* was the suspected cause of the outbreak due to initial evidence of an incubation period of 4–9 days and the known ability for *Cryptosporidium* to survive standard pool disinfection processes and standard daily cleaning of shared areas.

Hyperchlorination of pools in response to a cryptosporidiosis outbreak is usually only recommended after *Cryptosporidium* is confirmed as the causative agent. However, in this outbreak, the ongoing risk to pool users was considered significant, and immediate pool hyperchlorination was recommended by NEPHU as a precaution. Confirmation of *Cryptosporidium* was received 72 hours after hyperchlorination was performed, suggesting that early hyperchlorination likely prevented further cases. Proactive hyperchlorination has occurred elsewhere, with epidemiological evidence similarly suggesting early control measures prevented a larger outbreak¹⁰ and should be considered in similar large outbreaks.

It is unclear if this outbreak would have been identified so quickly without the social group reporting symptomatic individuals to Council C or without the School B camp outbreak. Not all people with gastroenteritis present to a medical practitioner, and fewer still undergo faecal testing. Without early reports, standard surveillance alone may have delayed public health action, increasing the risk of further transmission. This highlights the importance of timely reporting of suspected gastroenteritis outbreaks by the community and schools to local authorities.

The use of email communications and an online questionnaire allowed rapid and large-scale dissemination of information about the outbreak, case management advice and healthy swimming messages, as well as expediting active case finding. The online self-completed questionnaire was a practical and feasible way to assess the size of the outbreak and has since been implemented in other outbreaks at NEPHU.

Questionnaire results indicated continual swimming among symptomatic individuals, which suggests limited knowledge of *Cryptosporidium* in aquatic environments and pool hygiene among pool patrons, as previously reported.^{11,12} While healthy swimming messages were included in all communications to pool patrons and school groups, a wider strategy to raise awareness of healthy swimming and hygiene practices among the general public would be beneficial, especially to reduce the risk of re-contamination of pools, which can occur after hyperchlorination.

Limitations

The main limitation of this investigation is its reliance on self-reported data and the implicit risk of recall bias among interview and questionnaire respondents. The limitations of active case finding via anonymous online questionnaire included a lack of demographic information; the anonymous nature of the questionnaire resulted in potential duplicated responses with phone interviews. Additionally, it was not possible to distinguish between household transmission (secondary cases) and transmission at the pool (primary cases), a common limitation of outbreak investigations.^{13,14} Lastly, the lack

of pre-hyperchlorination water testing precluded confident attribution of *Cryptosporidium* infection to swimming in the pool. Nevertheless, epidemiological evidence was strongly suggestive of Pool A as a point-source of the outbreak. However, it should be noted that the detection of *Cryptosporidium* in water does not confirm whether the organism is viable or a risk for human infection, and water sampling is not part of cryptosporidiosis outbreak response in Victoria.

Conclusion

In conclusion, this outbreak highlights the critical role of rapid outbreak investigation and response, targeted risk communication, active case finding and pre-emptive aquatic facility control measures to prevent ongoing *Cryptosporidium* transmission.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Ethics statement

Ethics approval was not required for this investigation, as it was conducted under the auspices of public health legislation.

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Lessons from the 2024–2025 measles outbreak in southern Viet Nam

Thang Nguyen-Tien,^{a,b} Hoa Minh Tran^{c,d,e} and Anh Vu Le^a

Correspondence to Thang Nguyen-Tien (email: thangk5hsph@gmail.com, tiennguy@utmb.edu)

Control of measles outbreaks can be ensured only when herd immunity is greater than 95%.¹ There is no specific treatment, but vaccination is the most effective public health intervention that has saved millions of lives.² Recently, many countries worldwide have experienced a resurgence of measles.^{3–5}

In 2024, Viet Nam experienced an increase in measles cases, with the southern province of Dong Nai reporting one of the worst outbreaks. Dong Nai covers 5897.8 km², with approximately 3.1 million residents, including approximately 246 000 children aged <5 years.⁶ The province has 2258 health-care facilities and 17 503 health workers. Its numerous industrial zones and high migrant population pose challenges for childhood vaccination campaigns.

In Viet Nam, measles cases are classified for surveillance as suspected (clinical) or confirmed. A suspected case is defined as a patient with a history of contact with a confirmed case or residence in an endemic area, who presents with fever and rash, and one of the following symptoms: cough, runny nose, conjunctivitis, Koplik spots, lymphadenopathy, joint swelling or pain. Confirmed cases are identified through laboratory testing, including enzyme-linked immunosorbent assay detecting measles-specific immunoglobulin M antibodies or polymerase chain reaction. Under routine surveillance procedures, suspected cases are reported to the health information system and investigated by the Dong Nai Provincial Center for Disease Control (CDC), with specimens sent to the Pasteur Institute in Ho Chi Minh City for confirmation.

Surveillance data from Dong Nai CDC indicated that first-dose measles vaccination coverage was 73.1% in 2021 and 73.9% in 2022. Although coverage increased to 91.9% in 2023, it remained below the recommended herd immunity threshold. Dong Nai observed sporadic measles cases initially in mid-2024, accelerating during the fourth quarter of the year. Reported cases peaked in week 50 and 51 with around 900 cases per week, totalling 7173 cases in 2024. Cases were high during the first 2 weeks of 2025, at more than 800, and then began to decline, from approximately 600 cases in week 3 to 80 cases in week 14. Among the recorded cases, 55.9% (6388/11 434) occurred in children aged <5 years, 24.3% (2778/11 434) in those aged 5–10 years, and 19.8% (2268/11 434) in individuals aged >10 years.

In accordance with the World Health Organization's *Measles outbreak guide*,⁷ Dong Nai CDC implemented context-appropriate response strategies. The first strategy was to determine the most high-risk age groups and then prioritize immunization in children aged 0–10 years. The second strategy was to promote catch-up immunization by actively engaging with communities and offering vaccinations at several locations, including commune health stations, district health centres, hospitals and schools, and by using community health volunteers to identify unvaccinated children.

Additional successful measures taken during the preparedness phase included strong leadership, efficient policy coordination among the national and provincial governments, and utilization of mobile vaccination teams trained annually to vaccinate inaccessible populations.

^a Vietnam Public Health Association, Ha Noi, Viet Nam.

^b University of Texas Medical Branch, Galveston, Texas, United States of America.

^c Hong Bang International University, Ho Chi Minh City, Viet Nam.

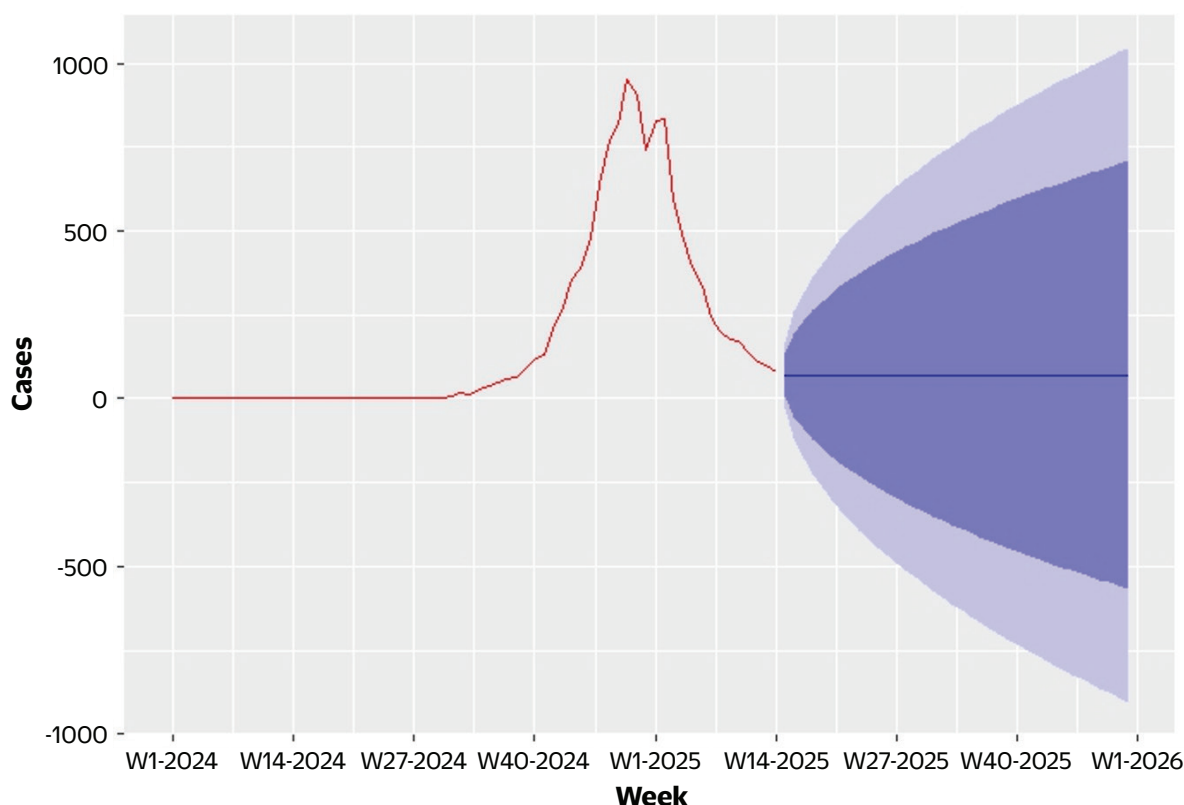
^d Dong Nai Center for Diseases Control, Dong Nai, Viet Nam.

^e Dong Nai Provincial Public Health Association, Dong Nai, Viet Nam.

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Fig. 1. Observed and projected trends in measles cases in Dong Nai province from week 1 of 2024 to week 52 of 2025 using the ARIMA (0,1,1) model



The red line represents the epidemiological trend of reported cases from week 1 of 2024 to week 14 of 2025. Forecast values for the subsequent weeks of 2025 are shown as a blue line, with purple areas representing the 80% and 95% confidence intervals. The negative projected values reflect statistical uncertainty in low-incidence periods and should be interpreted as near-zero case estimates.

These measures helped bring the outbreak under control. Immunization campaigns conducted from 27 September 2024 to 24 March 2025 achieved 97.5% coverage (112 340/115 209 people at risk), including health staff (4369/4408) and children aged 0–10 years (107 971/110 801), which was above the level required for herd immunity.

To describe the epidemiology of the measles outbreak and forecast trends in Dong Nai for the remainder of 2025, we fitted several autoregressive integrated moving average (ARIMA) models and selected an ARIMA (0,1,1) model based on the best fit to weekly case data (Fig. 1). The model captured outbreak progression and projected a continued decline or stabilization in cases. However, widening forecast confidence intervals indicated increasing uncertainty over time, underscoring the need for continued surveillance in longer term public health planning.

Despite these achievements, several root causes of the outbreak were recognized once a summary after-action report was prepared by Dong Nai CDC:

- Failure to vaccinate: The COVID-19 pandemic disrupted routine immunization services, particularly among migrant populations.^{8,9}
- High mobility and tracking challenges: Dong Nai's large industrial zones have a high migrant population, facilitating rapid outbreak spread and complicating immunization tracking.¹⁰ Many parents did not have vaccination records, and children born before 2017 were not registered in the National Immunization Information Management System, delaying identification of targets for vaccination.
- Delayed surveillance and operation: Initial cases in weeks 33–39 of 2024 were not promptly investigated, delaying outbreak declaration and catch-up immunization activities.

- Policy limitations: Unclear policies between the health and finance ministries related to health-worker per diem hindered outbreak planning and resource mobilization.
- Obstacles to resources and communication: The campaigns relied on residential health volunteers to collect information about targeted groups, especially in large communes, where this proved time-consuming. Communication between commune health stations, schools and families was inconsistent. Instructions were often sent informally via social messaging apps, which led to missed or inaccurate information.
- Vaccination misinformation and hesitancy: Social media misinformation significantly reduced vaccine coverage and increased hesitancy.¹¹
- Standardize risk communication protocols. Develop standardized communication protocols for health centres, schools and families to reduce information loss and improve coordination.

Our focus was on how health-system resilience and community engagement interact in measles outbreak control. Overcoming systemic and behavioural barriers, such as surveillance gaps, strengthening cross-sectoral partnerships and leveraging community trust are central to preventing future outbreaks and progressing towards measles elimination in Viet Nam and the Western Pacific Region.

Conflicts of interest

The authors have no conflicts of interest to declare.

Take-home messages and recommendations

Enhancing routine immunization is crucial in preventing future measles outbreaks. Recommendations from this analysis include:

- Accelerate catch-up campaigns through school-based delivery, mobile clinics and child health weeks, especially in low-coverage areas.
- Foster multisectoral coordination, particularly with the education and health sectors, to identify undervaccinated children. Active engagement with primary schools and kindergartens is key to improving outreach.
- Boost digital communication interventions and public awareness campaigns. Disseminate clear, concise, accurate messages about vaccine safety via social media, SMS and community influencers. Use targeted information campaigns in schools to promote vaccine acceptance and address misinformation.
- Strengthen surveillance and immunization information systems, especially for high-risk and migrant populations.

Ethics statement

Not applicable.

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Trends in the incidence of influenza and influenza-like illness in Cambodia, 2006–2023: insights from national sentinel surveillance

Sokly Mom,^{a,b,c} Khanuengnij Yueayai,^{a,d} Seng Heng,^b Hay Puthik Long,^{b,c} Sopheavy Seng,^{b,c} Nathaprang Nittayasoon,^{a,d} Sengdoeurn Yi^{b,c} and Sovann Ly^b

Correspondence to Sokly Mom (email: sokly.moh@gmail.com)

Understanding the patterns and occurrence of influenza is crucial for effective public health responses. National sentinel surveillance systems provide invaluable data that can be used to track the prevalence, seasonality and evolution of influenza viruses, and to inform timely interventions and early warning systems for disease control. This study aimed to describe the trends in influenza-like illness (ILI) and influenza incidence based on data obtained from ILI surveillance conducted among patients presenting to health facilities with symptoms indicative of influenza in Cambodia during 2006–2023. A total of 27 098 samples were tested, of which 15.5% were positive for influenza. Of these, 63.6% were influenza A, 36.2% were influenza B, and 0.2% were both influenza A and B. The annual incidence of influenza among the outpatient population varied, averaging 8.2 cases (range: 0.05–23.8) per 1000 population. Incidence rates were highest in 2007, 2008 and early 2023. The overall positivity rate was 16%. Not all ILI surveillance sites were consistently active during the study period, primarily due to funding constraints. Given the constraints of sentinel site coverage and data collection inconsistency, the study emphasizes the vital need for ongoing and improved ILI surveillance to accurately assess influenza incidence. To gain a more detailed picture of influenza dynamics in Cambodia, surveillance systems should be strengthened and data collection should be expanded to include asymptomatic patients and other important patient characteristics. These results are needed to guide regional and national influenza preparedness, prevention and control initiatives.

Influenza A and B have driven worldwide epidemics both historically and recently.¹ According to World Health Organization (WHO) estimates, 3–5 million severe influenza cases and 290 000–650 000 deaths occur annually worldwide.¹ Studies conducted between 2006 and 2016 suggest influenza has a substantial public health burden in Cambodia, with a high prevalence of both influenza A and B and influenza positivity in the range of 8–16%.^{2–4} Furthermore, analysis of national data for 2015–2016 has revealed consistently high influenza hospitalization rates across all age groups, averaging 56 cases per 100 000 population.⁴

The Department of Communicable Disease Control of Cambodia's Ministry of Health (CCDC) plays a lead role in the response and control of infectious diseases,

including influenza. While influenza is a year-round endemic disease in Cambodia, infection rates peak during the June–November rainy season. Surveillance mechanisms for influenza-like illness (ILI) were established in 2006 in collaboration with WHO, the United States Centers for Disease Control and Prevention (US CDC) and other health partners. Since 2014, Cambodia has been a recipient of Partnership Contributions through the WHO Pandemic Influenza Preparedness Framework, which have enabled the country to strengthen capacities in influenza surveillance, laboratory capacity and pandemic preparedness at the national and provincial levels.⁵ Cambodia currently contributes data to WHO's Global Influenza Surveillance and Response System.⁶ Cambodia's ILI surveillance monitoring network has since proved invaluable for responding to national influenza

^a International Field Epidemiology Training Program, Ministry of Public Health, Nonthaburi, Thailand.

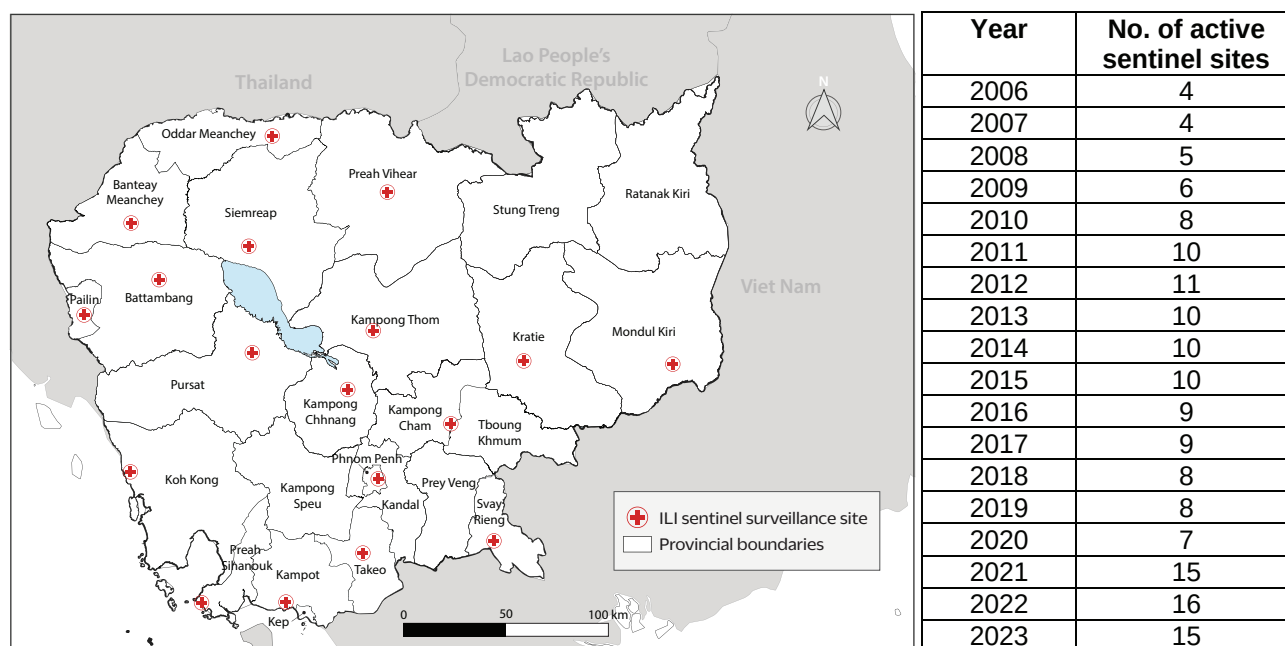
^b Department of Communicable Disease Control, Ministry of Health, Phnom Penh, Cambodia.

^c Cambodia Field Epidemiology Training Program, Department of Communicable Disease Control, Ministry of Health, Phnom Penh, Cambodia.

^d Division of Epidemiology, Department of Disease Control, Ministry of Public Health, Nonthaburi, Thailand.

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Fig. 1. Location and number of ILI sentinel surveillance sites across Cambodia, June 2006–July 2023

ILI: influenza-like illness.

outbreaks and for tracking the emergence of individual subtypes and strains, in relation to both seasonal influenza and avian influenza.^{7,8}

This study aimed to describe trends in the incidence of ILI and influenza in Cambodia over an extended period, 2006–2023, based on data obtained from Cambodia's sentinel ILI surveillance network. Understanding the trends in influenza and ILI incidence through sentinel surveillance data remains crucial for enhancing Cambodia's capacity to respond effectively to seasonal influenza outbreaks and has direct implications for national public health planning. This data analysis also contributes to the global effort to improve influenza surveillance and preparedness.

METHODS

Study design and setting

This cross-sectional study analysed retrospective data collected by the ILI surveillance system in Cambodia between June 2006 and July 2023. During the study period, 18 sentinel sites for ILI surveillance were in operation across the country (Fig. 1). The sites comprised a mix of health centres, referral hospitals and national hospitals; two sites were located at paediatric hospitals

that treat only patients under the age of 16 years. Routine operation of ILI surveillance was not consistent across all sites throughout the study period due to resource constraints and protocol modifications (Fig. 1).

Data sources

CCDC manages the ILI surveillance system in collaboration with multiple agencies such as the National Institute of Public Health (NIPH) and the Institut Pasteur du Cambodge (IPC), which provide laboratory testing services. Data obtained by CCDC from its network of ILI surveillance sites for the period from June 2006 to July 2023 were used for analysis. Weekly aggregate ILI data are reported from sentinel surveillance sites, including the number of ILI cases and total outpatients. In cases where a sample is collected for testing, individual-level data with laboratory results are reported to CCDC.

The extracted ILI surveillance data included the total number of outpatients, the number of ILI patients, the number of specimens collected from ILI patients for laboratory testing and the number of influenza-positive individuals. Extracted data also included demographic characteristics (age, sex), self-reported signs and symptoms (including fever, cough, runny nose, sore throat, headache, vomiting/nausea, body aches and

diarrhoea), the date of symptom onset and the date of sample collection.

Case definition and laboratory testing

The ILI case definition is a person presenting with sudden onset of fever (≥ 38.0 °C measured by axillary temperature) with cough and/or sore throat in the absence of another diagnosis. Approximately 5–10 nasopharyngeal swabs from patients presenting with ILI per site per week were collected for laboratory testing. The ILI case definition and the frequency of sample collection varied over the course of the study due to minor protocol changes. Influenza diagnosis was confirmed by a positive test result for influenza A or B viruses using multiplex real-time polymerase chain reaction (RT–PCR). Then, specimens confirmed positive for influenza A and/or B were extracted, and RNA was isolated to determine the virus subtype using a singleplex RT–PCR method following the US CDC protocol for detecting and characterizing seasonal influenza viruses. Influenza A and B testing was performed by NIPH, and IPC reconfirmed all positive specimens and 10% of negative specimens.

Descriptive data analysis

The data were extracted from the ILI surveillance database into Microsoft Excel. Data on demographic characteristics were categorized for analysis. Age was categorized as <1 year, 1–4 years, 5–14 years, 15–24 years, 25–49 years and ≥ 50 years. Sex was categorized as male and female. Clinical symptoms were categorized as “yes”, “no” and “don’t know” based on patient reports; “don’t know” was treated as missing data. Time to diagnosis was categorized into two groups, early diagnosis (≤ 2 days) and diagnostic delay (> 2 days), calculated as the time from the patient-reported date of symptom onset to the date of sample collection.

Statistical analysis

The influenza positivity rate was calculated by dividing the total number of specimens that tested positive for influenza by the total number of specimens tested for influenza. ILI incidence (per 1000 population) was determined by dividing the number of outpatients presenting with ILI symptoms by the total number of outpatients. Influenza incidence (per 1000 population) was calculated using the methodology adopted by Fowlkes et al.⁹ Influenza

incidence was calculated by multiplying the positivity rate (number of cases positive for influenza by PCR test divided by the total number of tested cases) by the total number of ILI cases who visited a health facility as an outpatient, and then dividing this by the total number of outpatient visits as the population denominator. Sentinel ILI surveillance sites were categorized by province. Data analyses were carried out using Stata version 14 (StataCorp 77845, College Station, TX, USA).

RESULTS

Characteristics of ILI cases

Between June 2006 and July 2023, a cumulative total of 3 270 768 people visited ILI sentinel sites as outpatients, of whom 206 359 (6.3%) presented with ILI symptoms. A total of 28 092 samples were collected for PCR testing, of which 27 098 (96.5%) were tested, excluding 994 with missing or pending results (**Fig. 2**). Of the tested specimens, 4202 (15.5%) were positive for various influenza subtypes (**Table 1**).

Among the positive cases, 2671 (63.6%) were attributed to influenza A, 1523 (36.2%) to influenza B and 8 (0.2%) to both influenza A and B (**Table 1**). The median age of the positive cases was 2.3 years (interquartile range: 1–8 years).

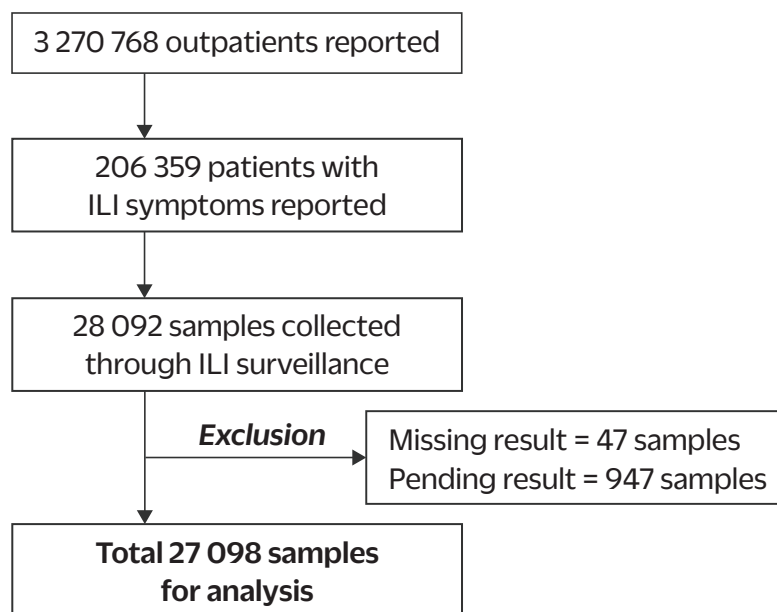
Positivity varied by age group; for children aged <1 year, the positivity rate was 10.3% (687/6672), rising to 15.6% (1626/10 428) in those aged 1–4 years, and peaking at 25.7% (1401/5446) in those aged 5–14 years. The rate dropped back to 16.5% (227/1373) in those aged 15–24 years, and to <10% in the two oldest age groups (8.8% [202/2308] in those aged 25–49 years, 6.8% [59/871] in those aged ≥ 50 years). Positivity was similar between the sexes; 14.8% (1928/13 068) of females and 16.2% (2274/14 030) of males tested had a positive result for influenza (**Table 2**).

The 18 sentinel sites were active for a mean of 7.8 years (range: 1–18 years) during the 18-year study period. Those that were active for longer tended to report more ILI cases, which ranged from 22 at a site that was active for 2 years to 126 002 at a site that was active for 16 years. The percentage of influenza-positive patients at each site ranged from 0% to 13.5%. The two paediatric hospitals cumulatively saw more patients with

Table 1. Total specimens, influenza-positive specimens and influenza subtypes by year, Cambodia, June 2006–July 2023

Year	Total specimens	No. (%) of influenza-positive specimens	No. (%) of influenza viruses by subtype or lineage						B (lineage not determined)	B/Victoria	B/Yamagata
			A (not subtyped)	A(H1N1)pdm	A(H3N2)	A(H5N1)	A(H3N2) and A(H1N1)pdm	A and B			
Total	27 098	4202 (15.5)	6 (0.1)	1019 (24.3)	1644 (39.1)	1 (0.02)	1 (0.02)	8 (0.2)	967 (23.0)	390 (9.3)	166 (4.0)
Jun–Dec 2006	474	21 (4.4)	–	–	21 (100)	–	–	–	–	–	–
2007	1218	91 (7.5)	4 (4.4)	11 (12.1)	25 (27.5)	–	–	2 (2.2)	49 (53.8)	–	–
2008	1360	214 (15.7)	–	26 (12.1)	115 (53.7)	–	–	–	73 (34.1)	–	–
2009	2319	400 (17.2)	–	93 (23.3)	215 (53.8)	–	–	–	92 (23.0)	–	–
2010	2577	387 (15.0)	–	134 (34.6)	153 (39.5)	–	–	–	100 (25.8)	–	–
2011	2808	571 (20.3)	–	139 (24.3)	53 (9.3)	–	–	4 (0.7)	375 (65.7)	–	–
2012	2805	344 (12.3)	–	20 (5.8)	238 (69.2)	–	–	–	86 (25.0)	–	–
2013	1558	259 (16.6)	–	66 (25.5)	18 (6.9)	1 (0.4)	–	2 (0.8)	172 (66.4)	–	–
2014	1554	189 (12.2)	–	18 (9.5)	155 (82.0)	–	1 (0.5)	–	15 (7.9)	–	–
2015	1549	262 (16.9)	–	18 (6.9)	195 (74.4)	–	–	–	1 (0.4)	1 (0.4)	47 (17.9)
2016	1524	397 (26.0)	–	137 (34.5)	50 (12.6)	–	–	–	4 (1.0)	193 (48.6)	13 (3.3)
2017	1069	130 (12.2)	–	40 (30.8)	83 (63.8)	–	–	–	–	4 (3.1)	3 (2.3)
2018	1262	214 (17.0)	–	106 (49.5)	3 (1.4)	–	–	–	–	16 (7.5)	89 (41.6)
2019	1201	276 (23.0)	–	130 (47.1)	52 (18.8)	–	–	–	–	80 (29.0)	14 (5.1)
2020	1286	199 (15.5)	–	17 (8.5)	182 (91.5)	–	–	–	–	–	–
2021	1097	2 (0.2)	2 (100)	–	–	–	–	–	–	–	–
2022	1025	170 (16.6)	–	2 (1.2)	85 (50.0)	–	–	–	–	83 (48.8)	–
Jan–Jul 2023	412	76 (18.4)	–	62 (81.6)	1 (1.3)	–	–	–	–	13 (17.1)	–

Fig. 2. Inclusion and exclusion criteria for data analysis of the samples collected from ILI surveillance, Cambodia, June 2006–July 2023



ILI: influenza-like illness.

ILI symptoms (78.3%) and influenza-positive patients (51.1%) than all other sites combined (**Table 3**).

The most frequently reported symptoms among influenza-positive cases were fever (99.7%), cough (98.7%) and runny nose (86.3%). Of positive cases with a recorded date of diagnosis, 78.1% (2506/3208) were diagnosed in ≤ 2 days and 702 (21.9%) were diagnosed in > 2 days (**Table 4**).

Estimated incidence and positivity rate of ILI and influenza

The estimated incidence of ILI among the outpatient population for the entire study period was 52.6 cases per 1000 population (**Table 5**). The annual incidence ranged from 23.3 to 191.2 cases per 1000 population. The highest annual incidence rates occurred in 2007 and 2008, which were more than double all other years. The estimated incidence of influenza for the entire study period was 8.2 per 1000 population. The annual incidence ranged from 0.05 to 23.8 per 1000 population, and rates were highest in 2007, 2008 and early 2023. Influenza trends were consistently high between May and December in most years. Monthly trends in influenza

cases, categorized by subtype and showing clear seasonal peaks, are illustrated in **Fig. 3**.

DISCUSSION

This study explored trends in ILI and influenza incidence in Cambodia over an 18-year period from June 2006 to July 2023, based on data collected by the national sentinel surveillance network. Our analysis showed that influenza positivity averaged 15.5% over the study period, a proportion that falls within the range reported in previous studies (8–36%).^{2–4} Influenza positivity was found to be spread across all age groups, with proportions ranging from 6.8% to 25.7% (**Table 2**), in line with these previous studies. However, influenza was more prevalent in individuals aged < 15 years, which aligns with a previous study conducted in Cambodia that examined influenza associated with hospitalized patients from severe acute respiratory infection surveillance.⁴

Positivity was similar in females (14.7%) and males (16.3%) and ranged from 6.8% among those aged > 50 years to 25.7% among those aged 5–14 years. Among influenza-positive cases, 63.6% were attributed to various subtypes of influenza A, while 36.2% were subtypes of

Table 2. Influenza positivity and subtypes by age and sex, Cambodia, June 2006–July 2023

Table 2: Influenza positivity and subtypes by age and sex, Cambodia, June 2008–July 2013													
Characteristic	Total outpatients	No. (%) of patients with ILI	Total specimens	No. (%) of influenza-positive specimens	No. (%) of influenza viruses by subtype or lineage								
					A (not subtyped)	A(H1N1)pdm	A(H3N2)	A(H5N1)	A(H3N2) and A(H1N1)pdm	A and B	B (lineage not determined)	B/Victoria	B/Yamagata
Total	3 270 768	206 359 (6.3)	27 098	4202 (15.5)	6 (0.1)	1019 (24.3)	1644 (39.1)	1 (0.02)	1 (0.02)	8 (0.2)	967 (23.0)	390 (9.3)	166 (4.0)
Age group, years													
<1	258 494	11 538 (4.5)	6672	687 (10.3)	1 (0.1)	188 (27.4)	305 (44.4)	1 (0.1)	–	–	145 (21.1)	30 (4.4)	17 (2.5)
1–4	1 382 839	115 136 (8.3)	10 428	1626 (15.6)	2 (0.3)	368 (22.6)	709 (43.6)	–	1 (0.1)	1 (0.1)	322 (19.8)	163 (10.0)	60 (3.7)
5–14	933 395	64 982 (7.0)	5446	1401 (25.7)	3 (0.1)	335 (23.9)	425 (30.3)	–	–	5 (0.4)	402 (28.7)	160 (11.4)	71 (5.1)
15–24	155 143	2341 (1.5)	1373	227 (16.5)	–	64 (28.2)	90 (39.6)	–	–	2 (0.9)	43 (18.9)	21 (9.3)	7 (3.1)
25–49	352 769	9394 (2.7)	2308	202 (8.8)	–	46 (22.8)	88 (43.6)	–	–	–	44 (21.8)	14 (6.9)	10 (5.0)
≥50	188 128	2968 (1.6)	871	59 (6.8)	–	18 (30.5)	27 (45.8)	–	–	–	11 (18.6)	2 (3.4)	1 (1.7)
Sex													
Female	–	–	13 068	1928 (14.7)	2 (0.1)	470 (24.4)	757 (39.3)	–	–	6 (0.3)	452 (23.4)	165 (8.6)	76 (3.9)
Male	–	–	14 030	2274 (16.3)	4 (0.2)	549 (24.1)	887 (39.0)	1 (0.04)	1 (0.04)	2 (0.1)	515 (22.6)	225 (9.9)	90 (4.0)

ILI: influenza-like illness.

Table 3. ILI and influenza-positive patients by sentinel site active during the study period, Cambodia, June 2006–July 2023

ILI surveillance site	No. of patients with ILI symptoms	No. (%) of influenza-positive patients	No. of years (year range) as an active ILI sentinel site
National Paediatric Hospital ^a	126 002	929 (0.7)	16 (2008–2023)
Angkor Hospital for Children ^a	35 590	1218 (3.4)	18 (2006–2023)
Battambang Hospital	13 908	417 (3.0)	15 (2006–2017, 2021–2023)
Kampong Cham Hospital	13 664	451 (3.3)	18 (2006–2023)
Takeo Hospital	5715	131 (2.3)	7 (2006–2012)
Mondulhiri Hospital	2664	356 (13.4)	14 (2010–2023)
Kampot Hospital	2528	275 (10.9)	14 (2010–2023)
Svay Rieng Hospital	2363	263 (11.1)	15 (2021–2023)
Anlong Veng Hospital	1541	32 (2.1)	1 (2011)
Paillin Hospital	743	100 (13.5)	8 (2011–2017, 2022)
Koh Kong Hospital	643	1 (0.2)	3 (2020–2022)
Kratie Hospital	302	22 (7.3)	2 (2022–2023)
Pursat Hospital	234	1 (0.2)	2 (2020–2021)
Preash Vihear Hospital	178	0 (0)	2 (2021–2022)
Tbong Kmum Hospital	95	0 (0)	1 (2021)
Banteay Meanchey Hospital	86	0 (0)	1 (2011, 2013)
Sihanukvill Hospital	81	4 (4.9)	2 (2020–2021)
Kampong Thom Hospital	22	2 (9.1)	2 (2020–2021)
Total	206 359	4202 (15.5)	18 (2006–2023)

ILI: influenza-like illness.

^a Hospitals that treat children and adolescents.**Table 4. Clinical symptoms and time to diagnosis in ILI patients who were tested for influenza and influenza-positive patients, Cambodia, June 2006–July 2023**

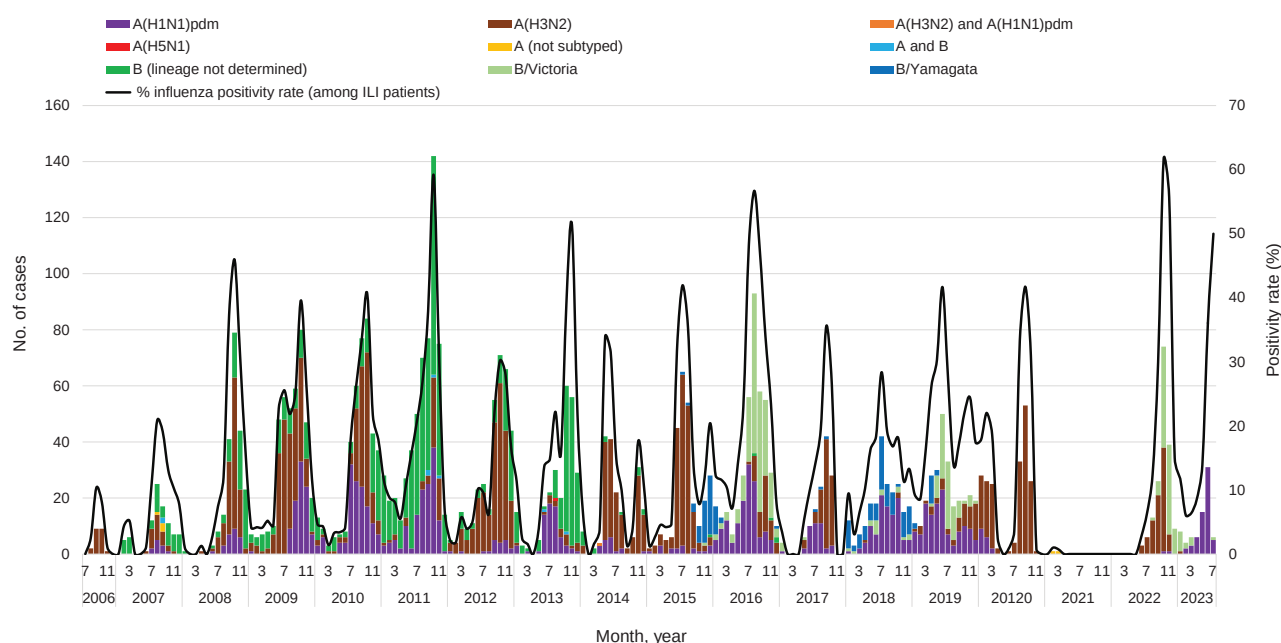
Variable	Tested for influenza, <i>n</i> (%)	Influenza-positive, <i>n</i> (%)
Clinical symptom	<i>n</i> = 27 098	<i>n</i> = 4202
Fever ^a	26 922 (99.4)	4190 (99.7)
Cough	26 384 (97.4)	4146 (98.7)
Runny nose	21 877 (80.7)	3628 (86.3)
Sore throat	10 887 (40.2)	1994 (47.5)
Headache	6146 (22.7)	1417 (33.7)
Vomiting/nausea	5287 (19.5)	931 (22.2)
Body aches	2989 (11.0)	690 (16.4)
Diarrhoea	2921 (10.8)	349 (8.3)
Other symptoms	497 (1.8)	78 (1.9)
Time to diagnosis^b	<i>n</i>^c = 20 241	<i>n</i>^c = 3208
Early diagnosis (≤ 2 days)	15 390 (76.0)	2506 (78.1)
Diagnostic delay (> 2 days)	4851 (24.0)	702 (21.9)

^a A total of 122 (116/27 098 and 6/4202) specimens were missing data for fever.^b The median (interquartile range) time to diagnosis was 2 (1–2) days.^c Cases with a missing diagnosis date were excluded from the total.

Table 5. Trends in estimated ILI and influenza incidence among outpatients, Cambodia, June 2006–July 2023

Year	No. of ILI sites	No. of outpatients	No. (%) of outpatients with ILI symptoms	No. of specimens tested	No. (%) of influenza-positive specimens	Estimated incidence per 1000 outpatients ^a	
						ILI symptoms	Influenza
Total	18	3 921 609	206 359 (5.3)	27 098	4202 (15.5)	52.6	8.2
Jun–Dec 2006 ^b	4	217 867	13 311 (6.1)	474	21 (4.4)	61.1	2.7
2007 ^b	4	217 867	41 663 (19.1)	1218	91 (7.5)	191.2	14.3
2008 ^b	5	217 867	32 966 (15.1)	1360	214 (15.7)	151.3	23.8
2009	6	220 592	11 596 (5.3)	2319	400 (17.2)	52.6	9.1
2010	8	230 593	9817 (4.3)	2577	387 (15.0)	42.6	6.4
2011	10	231 824	10 511 (4.5)	2808	571 (20.3)	45.3	9.2
2012	11	256 927	9731 (3.8)	2805	344 (12.3)	37.9	4.6
2013	10	209 589	8723 (4.2)	1558	259 (16.6)	41.6	6.9
2014	10	219 847	8236 (3.7)	1554	189 (12.2)	37.5	4.6
2015	10	228 821	9255 (4.0)	1549	262 (16.9)	40.4	6.8
2016	9	270 523	10 112 (3.7)	1524	397 (26.0)	37.4	9.7
2017	9	221 831	6976 (3.1)	1069	130 (12.2)	31.4	3.8
2018	8	266 148	6190 (2.3)	1262	214 (17.0)	23.3	3.9
2019	8	278 769	7938 (2.8)	1201	276 (23.0)	28.5	6.5
2020	7	184 829	5031 (2.7)	1286	199 (15.5)	27.2	4.2
2021	15	157 914	4091 (2.6)	1097	2 (0.2)	25.9	0.05
2022	16	197 074	6006 (3.0)	1025	170 (16.6)	30.5	5.1
Jan–Jul 2023	15	92 727	4206 (4.5)	412	76 (18.4)	45.4	10.3

ILI: influenza-like illness.

^a Estimated influenza incidence per 1000 outpatients = (number of influenza-positive specimens/number of specimens tested) x (number of outpatients with ILI symptoms/number of outpatients).^b Data on outpatient visits were missing for 2006–2008 and were replaced with the average annual number of outpatient visits per site.**Fig. 3. Trends in influenza cases by subtype and lineage detected by ILI surveillance sites, Cambodia, June 2006–July 2023**

influenza B and the remaining 0.2% were both A and B, consistent with data from the Asia–Pacific.¹⁰

During the study period, the estimated incidence of ILI was highest in 2007 and 2008 (191.2 and 151.3 per 1000 population, respectively), but since then has ranged between 23.3 and 52.6 per 1000 population. Importantly, the estimated incidence of influenza was consistently low, averaging <10 per 1000 population across all years. The high incidence observed in 2007 and 2008, followed by a decline in subsequent years, aligns with the cyclical nature of influenza epidemics. The increase in the incidence of ILI and influenza might be attributed to the change in the ILI case definition.² Other studies conducted in China between 2006 and 2015 revealed similar trends in influenza incidence, except for the influenza A(H1N1) pandemic in 2009, which had a higher incidence.^{11,12}

There was a notable drop in the number of ILI and influenza cases detected in 2021 and early 2022. The demands on laboratory resources (human resource capacity for testing SARS-CoV-2 specimens) meant that influenza virus testing was stalled during the height of the COVID-19 pandemic but resumed in October 2022. This drop mirrors trends seen in many countries and is attributed to the impact of the COVID-19 pandemic, which led to lockdowns globally, including in Cambodia.¹³

Limitations

The study had several limitations. First, the true incidence of influenza was only recorded for individuals with symptoms, and asymptomatic cases were not captured. As a result, the incidence in the study might be underestimated, though we attempted to adjust our analysis by using outpatients as our population denominator in place of the general population. Second, not all sentinel sites were consistently active during the study period, which could have influenced our findings. Some hospitals were not used as ILI surveillance sites due to their small sample size and the limited duration of surveillance and funding constraints. Third, we were unable to obtain data on several potentially relevant variables, such as education level, occupation, and time from onset to discharge from

the health facility, preventing us from fully measuring the factors contributing to the outcomes in this study. The limited data completeness at specific sites, coupled with uncertainty regarding whether the data were collected at the health centre level or hospital level, restricted the scope of our analysis in comprehending ILI and influenza trends across all health facilities.

Conclusion

This study highlights the long-term trends and incidence of ILI and influenza in Cambodia over an 18-year period. The findings reveal that influenza affects all age groups, with the highest positivity rates observed among children aged 5–14 years and a predominance of influenza A subtypes. Despite a consistently low overall incidence of influenza (annual mean of <10 per 1000 population), significant annual and seasonal variations were observed, with peaks aligning with the rainy season. Not all ILI surveillance sites were consistently active, primarily due to funding constraints. The study underscores the critical need for sustained and enhanced ILI surveillance to capture the true incidence of influenza, particularly given the limitations of sentinel site coverage and variability in data collection. Strengthening surveillance systems and expanding data collection to include asymptomatic cases and other key variables would provide a more comprehensive understanding of influenza dynamics in Cambodia. These findings serve to inform national and regional strategies for influenza prevention, control and preparedness.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Ethics statement

CCDC considers sentinel surveillance for ILI and influenza as a part of routine public health surveillance, and therefore did not require formal ethical review because reported data are used for public health surveillance purposes. The collected data underwent anonymization, ensuring that authors did not have access to any identifying information.

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National surveillance of tick- and mite-borne diseases in Japan, 1999–2025: a rapid surveillance reporting framework using the jpinfect R package

Tomonori Hoshi,^{a,b,*} Erina Ishigaki,^{a,c,*} Richard Paul^{d,e} and Satoshi Kaneko^{a,b,c,f}

Correspondence to Tomonori Hoshi (email: tomonori.hoshi.japan@gmail.com)

The Government of Japan has conducted weekly national surveillance of notifiable infectious diseases for over 25 years. As of December 2025, 87 notifiable diseases are under surveillance, although the list has changed over time as new infections have emerged and others have been reclassified. Although weekly data are openly available, their formatting and preparation have been labour-intensive. An open-source R package, jpinfect, has the potential to improve data accessibility and analytical workflows for these datasets. In this study, we used the jpinfect package to summarize national surveillance data for 12 acari-borne diseases in Japan from week 14 of 1999 to week 52 of 2025, by prefecture and sex. In total, 18 295 acari-borne disease cases were reported nationwide. Eight diseases reported at least one case. Of these, scrub typhus (56.6%), Japanese spotted fever (32.9%) and severe fever with thrombocytopenia syndrome (6.7%) together accounted for more than 95% of all cases. Scrub typhus case numbers remained stable and widely distributed across the country, except for in the northern island of Hokkaido. Confirmed cases of the other two tick-borne diseases increased, notably in western Japan, but with new cases also reported in northern Japan. Lyme disease, relapsing fever and Q fever were sporadically reported at very low incidence levels (<0.2 per 100 000 population). In addition to providing an updated epidemiological overview of acari-borne diseases in Japan, this report highlights the potential of jpinfect to streamline the generation of national situation reports. The surveillance and analytical framework described here could serve as a model for other countries in the Western Pacific Region.

In Japan, the government has conducted weekly national surveillance of notifiable infectious diseases for over 25 years. As of December 2025, 87 notifiable diseases are under surveillance, although the list has changed over time in response to changing risks.¹ These diseases are classified into five categories, with the higher categories indicating greater public health risk. Currently, seven Category I, seven Category II, five Category III, 44 Category IV and 24 (of 49) Category V infectious diseases are notifiable. Data on notified cases are aggregated by the Ministry of Health, Labour and Welfare and published as weekly national surveillance reports.²

While severe fever with thrombocytopenia syndrome (SFTS) has attracted considerable public health attention in recent years,^{3,4} several other tick- and mite-borne diseases (collectively referred to as acari-borne diseases) also pose significant health concerns in Japan. Currently, 12 acari-borne diseases are classified as notifiable and subject to national surveillance: in Category I, Crimean-Congo haemorrhagic fever; and in Category IV, Japanese spotted fever (JSF), Kyasanur Forest disease, Lyme disease, Omsk haemorrhagic fever, Q fever, relapsing fever, Rocky Mountain spotted fever, scrub typhus, SFTS, tick-borne encephalitis and tularaemia. Although all 12 of these acari-borne diseases are part of the national

^a Institute of Tropical Medicine, Nagasaki University, Nagasaki, Japan.

^b School of Tropical Medicine and Global Health, Nagasaki University, Nagasaki, Japan.

^c Graduate School of Biomedical Sciences, Nagasaki University, Nagasaki, Japan.

^d Department of Global Health, Institut Pasteur, Paris, France.

^e Institut Pasteur–Kyoto University International Mixed Research Unit for Vaccinomics, Institut Pasteur, Paris, France.

^f DEJIMA Infectious Disease Research Alliance, Nagasaki University, Nagasaki, Japan.

* These authors contributed equally to this work.

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notifiable disease surveillance network, only data on SFTS and Lyme disease are regularly compiled and assessed by the government.⁵ As a result, understanding of distribution and trends in the wider group of acari-borne diseases has remained limited. From a public health perspective, assessing acari-borne diseases as a group is important because they share common vectors, ecological characteristics and surveillance frameworks.

As noted above, infectious disease surveillance reports and routine epidemiological summaries are published weekly by the government, as the Infectious Diseases Weekly Report. These reports and summaries comprise tabulations of cumulative and newly reported infectious disease case counts, with graphical visualizations available for some diseases.² However, for many of the acari-borne diseases, reporting is restricted to numerical listings. More importantly, although the weekly national surveillance reports are available from government webpages, these tend to be scattered across multiple webpages in various formats, and substantial effort is required to collate the case count data for analysis.^{2,6,7} Such reporting practices do not lend themselves to the timely interpretation of surveillance data for public health response.

An open-source R package, *jp infect*, has made it possible to extract and process national surveillance data from multiple webpages to create epidemiological summaries within R, offering epidemiologists an effective tool to streamline analytical workflows.⁸ In this report, we describe the current status of acari-borne diseases in Japan based on routinely available national surveillance data, which we extracted and processed using the *jp infect* package. In addition to providing a much-needed update on the status of acari-borne diseases in Japan, this report also assesses the strengths and weaknesses of the *jp infect* package as a tool for summarizing surveillance data to support effective public health response.

METHODS

Data source

Physicians and veterinarians are legally required to report notifiable diseases to local public health centres, either immediately or within 7 days depending on the disease. Reports are then forwarded to prefectural governments.⁹

When submitting a report, patient information such as name, age, sex and other relevant details must be provided. When necessary, biological samples are also submitted to local health authorities. All case information is subsequently forwarded to the Ministry of Health, Labour and Welfare through the prefectural offices, and aggregated and published as weekly national surveillance reports of provisional case counts. Confirmed cases require laboratory evidence based on pathogen isolation or identification, detection of the pathogen genome, or serological evidence of infection, in accordance with national case definitions.¹⁰

Provisional case counts are typically reported within 2 weeks of notification. In contrast, laboratory-confirmed case data are released with a substantial lag, often exceeding a year, depending on the disease and reporting year. The provisional weekly reports are available in electronic form in CSV format, while confirmed case counts are provided as Microsoft Excel spreadsheets (52–53 for each year). Provisional reports contain case counts by prefecture without individual demographic details, while the confirmed datasets also include information on sex by prefecture but not on age.

Data analysis

The *jp infect* R package was employed to obtain the weekly case counts from official government archives.^{8,11} Specifically, the commands `jp infect_get_confirmed()` and `jp infect_get_bullet()` were used to retrieve weekly laboratory-confirmed and provisional case reports, respectively. After obtaining all available reports for the period from week 14 of 1999 to week 52 of 2025 (a total of 1290 spreadsheets from 25 Excel files and 104 CSV files), data were imported and automatically formatted using `jp infect_read_confirmed()` and `jp infect_read_bullet()`. These commands standardize disease names in English and organize the weekly spreadsheets into structured R datasets. The length of the available records for each of the 12 included diseases is listed in **Table 1**.

The imported weekly reports were then aggregated into three groups: provisional cases (2024–2025), confirmed cases from the most recent 5 years (2019–2023) and earlier confirmed cases (1999–2018). These time periods were chosen to allow us to compare the regional distribution of cases over time (**Table 2**).

Table 1. Acari-borne diseases under national surveillance, Japan, 1999–2025

Disease	Category	Surveillance start date
Crimean-Congo haemorrhagic fever	I	Week 14 of 1999
Japanese spotted fever	IV	Week 14 of 1999
Kyasanur Forest disease	IV	Week 1 of 2007
Lyme disease	IV	Week 14 of 1999
Omsk haemorrhagic fever	IV	Week 1 of 2007
Q fever	IV	Week 14 of 1999
Relapsing fever	IV	Week 14 of 1999
Rocky Mountain spotted fever	IV	Week 1 of 2007
Scrub typhus	IV	Week 1 of 2001
Severe fever with thrombocytopenia syndrome	IV	Week 1 of 2013
Tick-borne encephalitis	IV	Week 1 of 2007
Tularaemia	IV	Week 1 of 2006

Table 2. Total cases of acari-borne diseases reported in Japan, 1999–2025

Disease	Provisional (2024–2025)	Confirmed (2019–2023)	Earlier confirmed (1999–2018)	Total
Scrub typhus	568 (29.2)	2398 (45.1)	7394 (67.0)	10 360 (56.6)
Japanese spotted fever	1040 (53.4)	2187 (41.1)	2790 (25.3)	6017 (32.9)
Severe fever thrombocytopenia syndrome	285 (14.6)	541 (10.2)	396 (3.6)	1222 (6.7)
Lyme disease	35 (1.8)	109 (2.0)	230 (2.1)	374 (2.0)
Q fever	6 (0.3)	4 (0.1)	177 (1.6)	187 (1.0)
Relapsing fever	12 (0.6)	80 (1.5)	29 (0.3)	121 (0.7)
Tularaemia	0 (0.0)	0 (0.0)	8 (0.1)	8 (<0.1)
Tick-borne encephalitis	2 (0.1)	0 (0.0)	4 (<0.1)	6 (<0.1)
Crimean-Congo haemorrhagic fever	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Kyasanur Forest disease	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Omsk haemorrhagic fever	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Rocky Mountain spotted fever	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Total	1948 (100)	5319 (100)	11 028 (100)	18 295 (100)

Values are *n* (%).

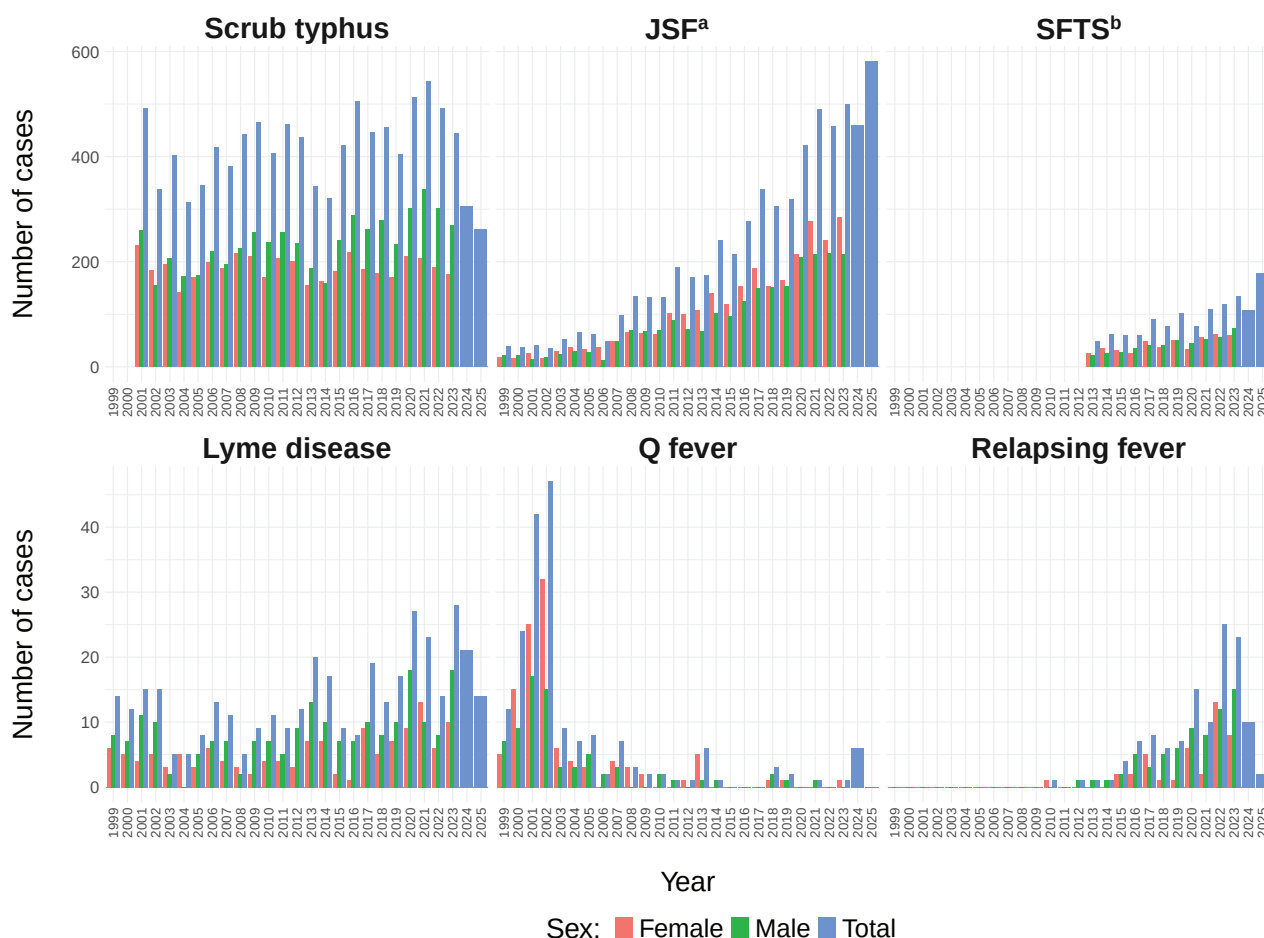
Data analysis was limited to descriptive statistics. We calculated total case numbers for each disease by year and sex (confirmed cases only), and case numbers by prefecture for the three time periods. No inferential analyses were conducted because the primary objective of this report was to provide an updated epidemiological overview.

In addition to mapping case numbers by prefecture, incidence rates per 100 000 population were calculated using census-based population estimates. As Japan conducts a national census every 5 years, population figures for intermediate years were estimated via log-

linear interpolation. For 2025, the population figure was extrapolated from the most recent census data. For the purposes of data visualization, only diseases reporting more than 100 cases were selected. Shapefiles from the Geospatial Information Authority of Japan were modified in accordance with the United Nations map policy.¹²

RESULTS

In total, 18 295 cases of acari-borne disease (1948 provisional and 16 347 confirmed) were reported in Japan between 1999 and 2025 (Table 2). At least one case was reported for eight of the 12 acari-borne

Fig. 1. Six major acari-borne diseases in Japan with more than 100 reported cases, 1999–2025

^a JSF: Japanese spotted fever.

^b SFTS: severe fever with thrombocytopenia syndrome.

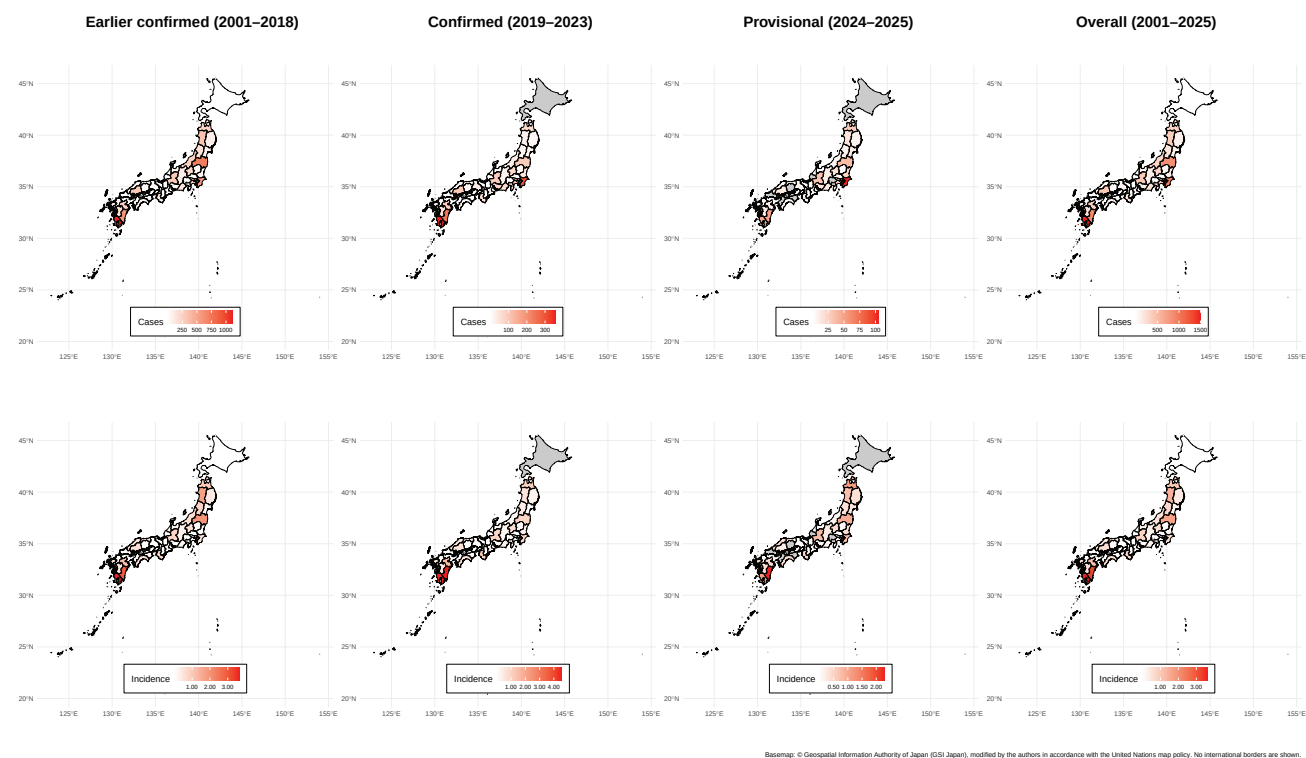
Sex-specific and total counts are shown for confirmed cases (week 14 of 1999 to week 52 of 2023); only total counts are presented for provisional data (week 1 of 2024 to week 52 of 2025).

diseases under surveillance: scrub typhus ($n = 10\,360$), JSF ($n = 6017$), SFTS ($n = 1222$), Lyme disease ($n = 374$), Q fever ($n = 187$), relapsing fever ($n = 121$), tularaemia ($n = 8$) and tick-borne encephalitis ($n = 6$) (Table 2). Three diseases reported more than 1000 cases, indicating endemic status in Japan. Indeed, scrub typhus (56.6%), JSF (32.9%) and SFTS (6.7%) together accounted for more than 95% of all reported cases. The next three most prevalent diseases, Lyme disease, Q fever and relapsing fever, reported more than 100 but fewer than 400 cases, suggesting minor risk.

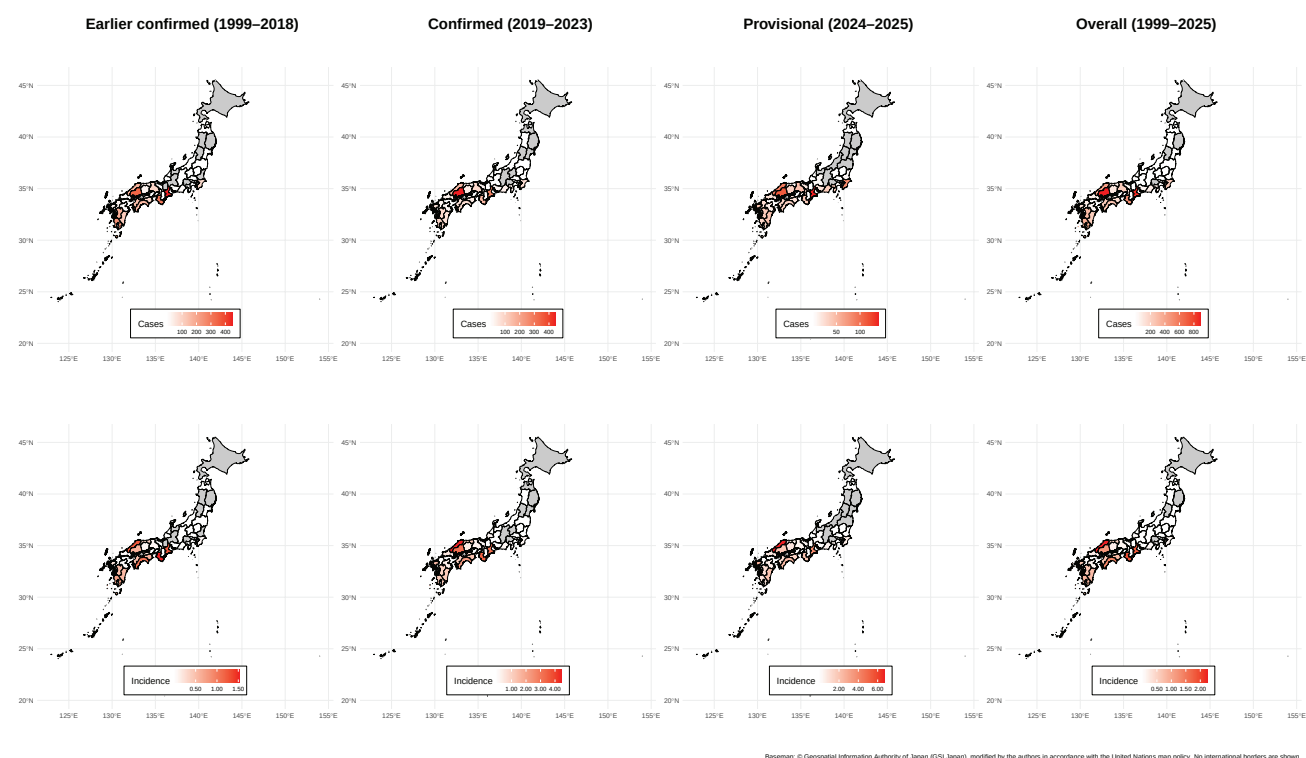
Between 1999 and 2025, scrub typhus, which is transmitted by mites, accounted for over half of all reported cases (56.6%, Table 2). However, comparison of confirmed case numbers across the two earlier time periods (1999–2018 vs 2019–2023) indicated that the

two other tick-borne diseases accounted for an increasing proportion of all cases (scrub typhus: 67.0% vs 45.1%; JSF: 25.3% vs 41.1%; SFTS: 3.6% vs 10.2%). National trends in case numbers are presented in Fig. 1, revealing that scrub typhus cases have remained relatively consistent (300–500 cases annually), whereas JSF and SFTS cases have steadily increased since their inclusion in national surveillance. Of the two, SFTS has been increasing faster than JSF. Sex patterns showed a clear male predominance for scrub typhus, while females were more affected by JSF. In contrast, SFTS did not show marked sex differences.

Visualizations of prefectural distribution patterns revealed that scrub typhus occurred across Japan with the exception of Hokkaido, with two aggregations in the north-east and western parts of mainland Japan (Fig. 2). Cases

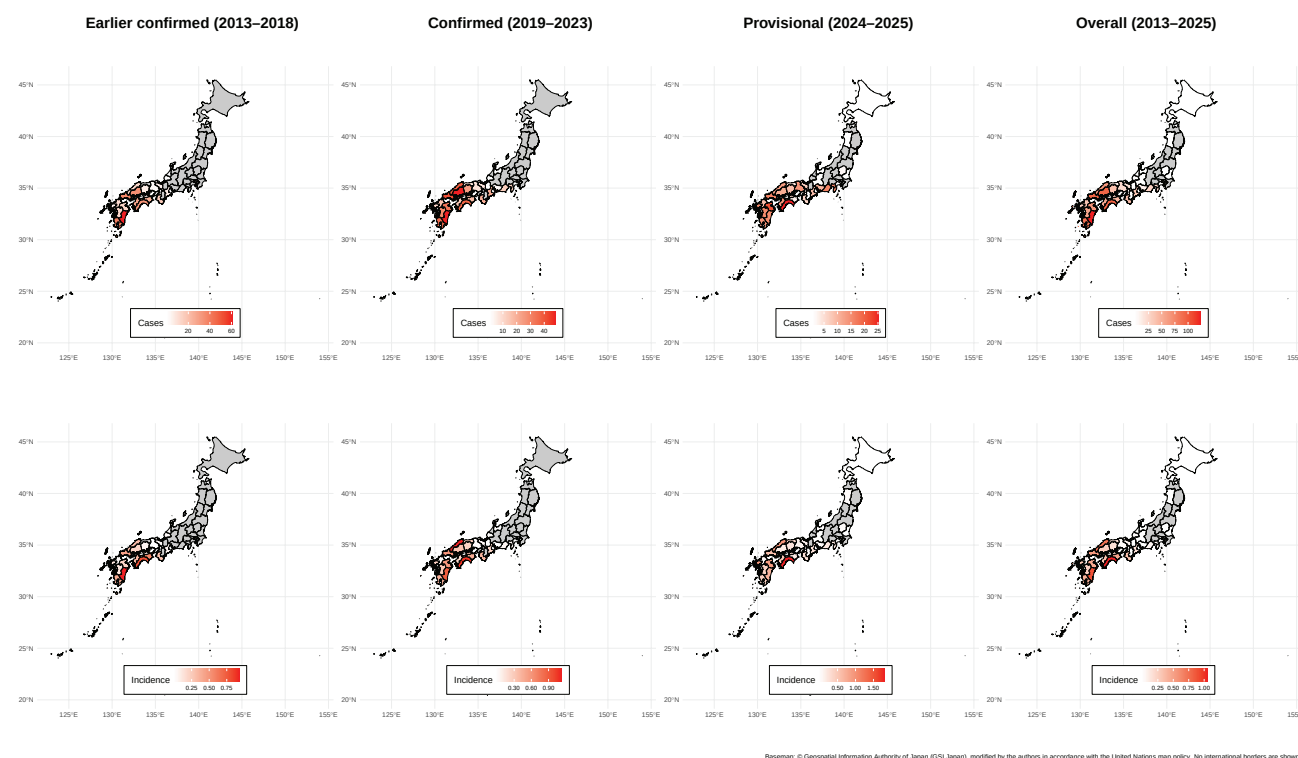
Fig. 2. Scrub typhus distribution of cases (upper panels) and incidence rates (lower panels) in Japan, 2001–2025

Prefectures in grey indicate no reported cases during the surveillance period (week 1 of 2001 to week 52 of 2025), while darker red indicates higher case numbers or incidence rates.

Fig. 3. Japanese spotted fever distribution of cases (upper panels) and incidence rates (lower panels) in Japan, 1999–2025

Prefectures in grey indicate no reported cases during the surveillance period (week 14 of 1999 to week 52 of 2025), while darker red indicates higher case numbers or incidence rates.

Fig. 4. Severe fever with thrombocytopenia syndrome distribution of cases (upper panels) and incidence rates (lower panels) in Japan, 2013–2025



Prefectures in grey indicate no reported cases during the surveillance period (week 1 of 2013 to week 52 of 2025), while darker red indicates higher case numbers or incidence rates.

of JSF and SFTS were concentrated mainly in western Japan. However, the latest provisional case reports for 2024 and 2025 revealed new case occurrences of SFTS in six prefectures (Akita, Gifu, Hokkaido, Ibaraki, Nara and Tochigi), located in the central and northern regions of Japan. Prefectures with higher JSF and SFTS incidence rates were mainly located south of 35°N (Fig. 3 and 4).

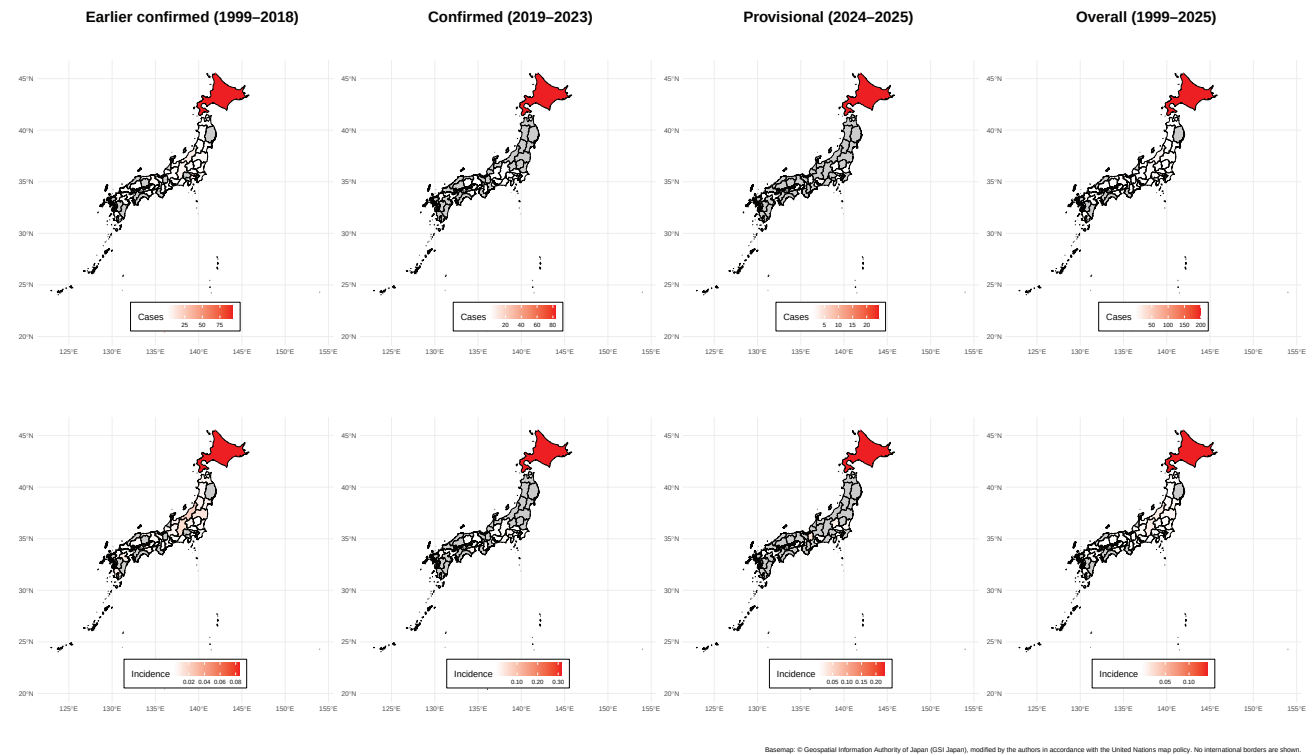
Among the three acari-borne diseases with lower reported case numbers, incidence rates were below 0.2 per 100 000 population (Fig. 5–7). Lyme disease and relapsing fever were predominantly reported from Hokkaido, showing a clear northern distribution (Fig. 5 and 7). Q fever showed irregular reporting patterns with relatively high case numbers in the early years of surveillance, but the incidence has since stabilized at a low level (Fig. 1 and 6).

DISCUSSION

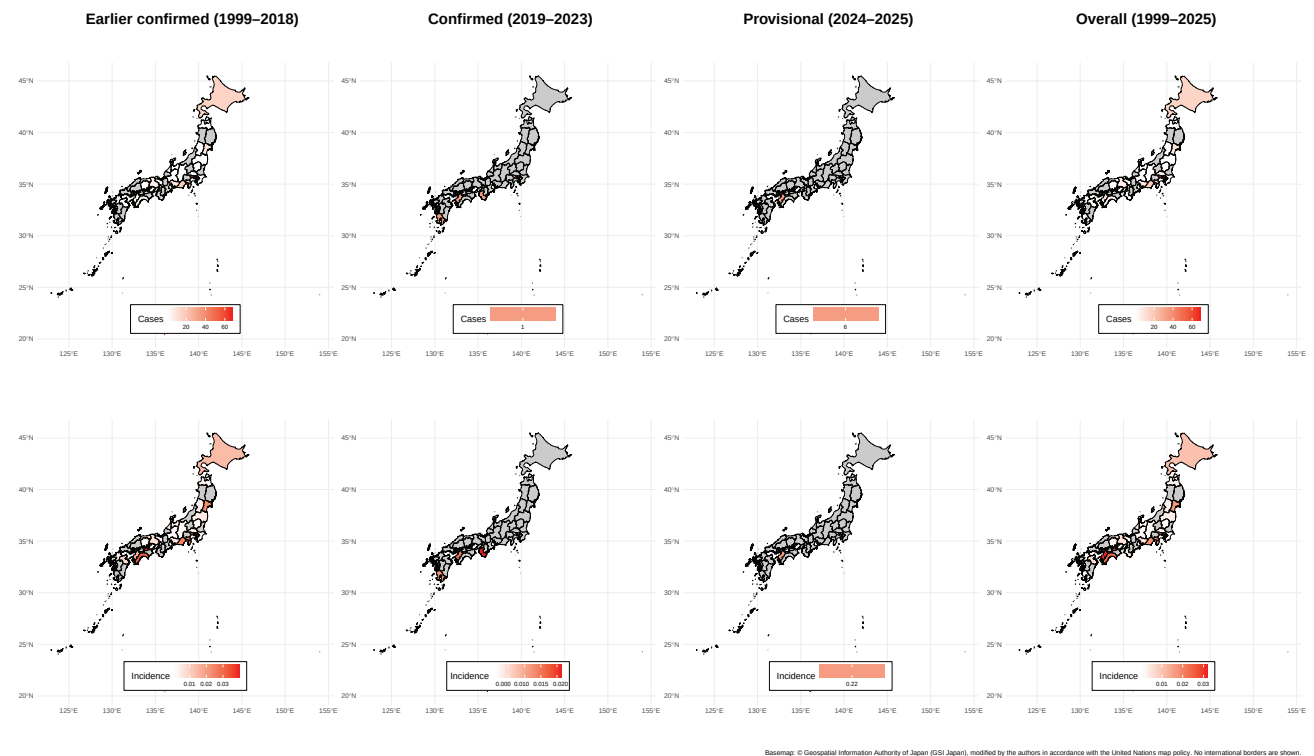
For this report, which provides a picture of acari-borne disease dynamics in Japan over the past 27 years, we aggregated and visualized surveillance data using the open-source jpinfect package in R.⁸ The package

facilitated the processing of the government's routinely collected surveillance data, generating summaries in a format that increased the utility of these data for public health decision-makers.

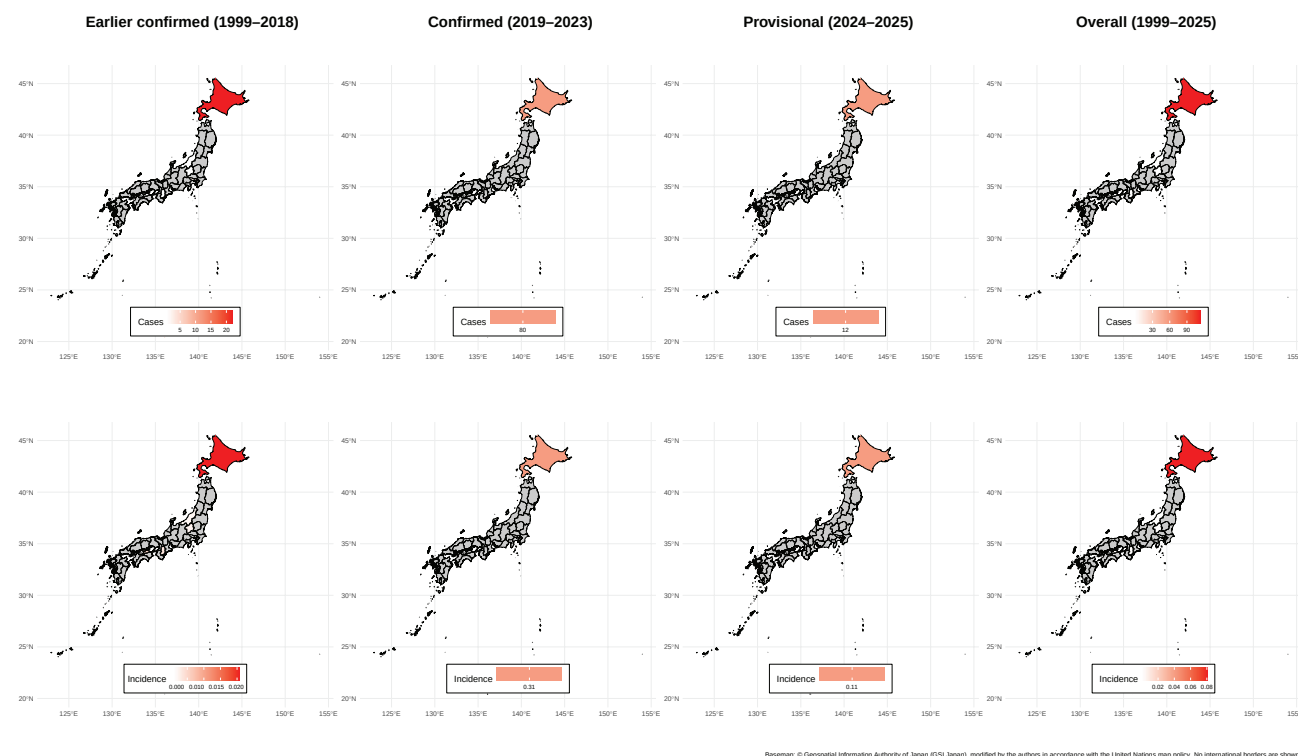
Acari-borne disease epidemiology in Japan has previously been described by Yamaji et al. in 2018.¹³ Since then, various reports and updates have been intermittently published in Japanese, but these were fragmented and difficult to systematically track or reference internationally. This report is the first since 2018 to provide a comprehensive overview of the distribution of multiple acari-borne diseases based on national notifiable disease surveillance data for the international community. Our study confirmed that eight of 12 acari-borne diseases are present in Japan, with three diseases now endemic: scrub typhus, JSF and SFTS. Since SFTS was first identified in 2012, confirmed case numbers have risen across the country, invading new prefectures in a gradual but inexorable manner.⁴ Although improved diagnostic practices and increased awareness may have contributed to increased case detection, potentially through heightened clinical suspicion and a higher number of samples submitted for laboratory testing,

Fig. 5. Lyme disease distribution of cases (upper panels) and incidence rates (lower panels) in Japan, 1999–2025

Prefectures in grey indicate no reported cases during the surveillance period (week 14 of 1999 to week 52 of 2025), while darker red indicates higher case numbers or incidence rates.

Fig. 6. Q fever distribution of cases (upper panels) and incidence rates (lower panels) in Japan, 1999–2025

Prefectures in grey indicate no reported cases during the surveillance period (week 14 of 1999 to week 52 of 2025), while darker red indicates higher case numbers or incidence rates.

Fig. 7. Relapsing fever distribution of cases (upper panels) and incidence rates (lower panels) in Japan, 1999–2025

Prefectures in grey indicate no reported cases during the surveillance period (week 14 of 1999 to week 52 of 2025), while darker red indicates higher case numbers or incidence rates.

the pattern of the geographical spread does suggest that the virus is slowly colonizing new areas across the country. This is cause for concern, as the overall pooled case fatality rates in endemic areas have been reported to be 7.80% (95% confidence interval: 7.01–8.69%), albeit with much geographical variation.¹⁴ Likewise, the geographical extent of JSF is growing since it first emerged in 1999, with all prefectures in the Shikoku, Chugoku, Kansai and Kyushu regions now reporting cases annually. The underlying reasons for the spread of SFTS and JSF cases are hard to pinpoint, but the geographical pattern of incidence is consistent with a progressive invasion of new territories, possibly mediated by the spread of ticks and changes in animal populations due to climate change.¹⁴ Although scrub typhus and JSF are not life-threatening when promptly diagnosed and treated, their non-specific symptoms and limited access to laboratory facilities for confirmatory analyses have resulted in several deaths annually.^{13,15} This underlines the importance of documenting geographical risk, identifying risk factors and raising public health awareness of tick- and mite-borne diseases. The other diseases included in national surveillance all showing stable low-level incidence rates tended to occur in limited geographical areas and remain

low risk. It should be noted that data for 2024 and 2025 are as yet provisional and might either underestimate or overestimate current disease risks, particularly for diseases requiring longer laboratory confirmation times.

While we were able to disaggregate case numbers by sex, the current lack of age information in the weekly surveillance reports limits consideration of age in risk analyses. We strongly encourage the inclusion of age in the openly available datasets, though personal information protection might need to be discussed. In addition, infection locations are not specified at the prefectural level and cases are therefore reported based on the location of diagnosis rather than the probable site of infection. This limitation makes it difficult to distinguish between locally acquired and imported cases within Japan, particularly when the first reported cases appear in new prefectures.

In its present form, jpinfect functions primarily as a facilitation tool for retrieving and post-processing segmented surveillance data files.⁸ In this role, we found it performed well but acknowledge that epidemiologists and practitioners may require more user-friendly visualization platforms or dashboards to maximize the

utility of surveillance data. For instance, public health decision-makers often need incidence rates, for which population datasets are required but are not included in the *jpinfect* package. The development of an integrated data infrastructure that incorporates demographic and environmental information to facilitate the calculation of incidence rates and other epidemiological metrics remains a critical challenge.

Conclusion

This study showcased the utility of the newly available *jpinfect* package in R for streamlining the post-processing of infectious disease surveillance data using acari-borne diseases in Japan as an example. The package enables a smooth data manipulation workflow and facilitates timely dissemination of national surveillance data to the international community. Routine application of *jpinfect* could facilitate the rapid generation of updated situation reports and contribute to data-driven public health actions. The surveillance and analytical framework described here could serve as a model for other countries in the Western Pacific Region.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Ethics statement

This study used openly available secondary data obtained from the Japan Institute for Health Security. Therefore, no ethical approval was required.

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wpsar@who.int | <https://ojs.wpro.who.int/>