

Developing a community-based COVID-19 surveillance system for Rural Kalasin, Thailand

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Received: 10 May 2025 **Revised:** 4 Sep 2025 **Accepted:** 6 September 2025 **Available online:** May 2026

DOI: 10.55131/jphd/2026/240210

ABSTRACT

The transition of COVID-19 from a dangerous communicable disease to a notifiable disease in Thailand highlights the need for robust post-pandemic surveillance systems. Particularly in rural areas, limited resources can affect the performance of disease surveillance. This study aimed to develop a community-based COVID-19 surveillance system. A mixed-methods research approach was employed, consisting of a quantitative phase to evaluate the surveillance system and determine the factors associated with its operation and a qualitative phase to develop and evaluate a surveillance system using Kemmis and McTaggart's framework. The study was conducted from January 2022 to May 2024 and involved 568 public health officials, 414 case reports, and 52 stakeholders who collaboratively designed a surveillance system with brainstorming and used it to support quantitative findings. To analyze the data, multiple linear regression analyses, independent samples t-tests, chi-square tests, and content analyses were employed. Most of the respondents were female (76.06%), with a mean age and surveillance experience of 35.7 and 8.51 years, respectively. The COVID-19 surveillance system, comprising five proactive activities—surveillance strengthening, guideline development, agility, strategic planning, and after-action reviews—showed improvements in data quality, timeliness, and staff operational performance ($P < 0.05$) within the experimental area. The COVID-19 surveillance operational performance of the staff was strongly associated with case notification and verification ($\beta = 0.428$, 95%CI: 0.879, 1.108, $P < 0.001$), application of surveillance data for action ($\beta = 0.328$, 95%CI: 0.589, 0.762, $P < 0.001$) and epidemiological data collection and analysis ($\beta = 0.297$, 95%CI: 0.439, 0.552 $P < 0.001$), with an adjusted R^2 value of 0.854. These findings highlight the need for standardized guidelines, context-specific strategies, interagency collaboration, targeted training, and advanced digital tools—such as real-time mobile reporting and outbreak prediction tools—to enhance system performance, strengthen workforce capacity, and improve preparedness for future epidemics.

Keywords:

COVID-19, surveillance system, rural, post-pandemic

Citation:

Wanich Rungram, Suneerat Yangyuen. Developing a community-based COVID-19 surveillance system for Rural Kalasin, Thailand. *J Public Hlth Dev.* 2026;24(2):142-157 (<https://doi.org/10.55131/jphd/2026/240210>)

INTRODUCTION

The COVID-19 pandemic has had a profound impact on global health systems and economies, including in Thailand. Since the World Health Organization (WHO) declared COVID-19 an international public health emergency¹, countries worldwide have implemented various responsive measures. The WHO continues to emphasize the need for robust surveillance systems to monitor viral mutations and local outbreaks. In addition, the transition from pandemic to endemic status for COVID-19 requires adaptive surveillance.² Some evidence indicates that countries with strong surveillance systems were better equipped to manage COVID-19 outbreaks, even during periods of reduced public health restrictions.³

Globally and nationally, the COVID-19 situation has gradually improved, leading to an updated policy in Thailand that reclassifies COVID-19 from a “dangerous communicable disease” to a “disease under surveillance.”⁴ Thailand has implemented a targeted surveillance strategy for COVID-19. This approach emphasizes monitoring high-risk populations and settings, tracking emerging variants of concern, and informing future outbreak surveillance under the public health surveillance system planning framework⁵ and WHO’s IDSR strategy, which integrates both indicator-based surveillance (IBS) and event-based surveillance (EBS) approaches to early detection of priority diseases, conditions, and events⁶. However, data from the surveillance evaluation revealed delayed reporting, fragmented systems, redundant processes, limited community participation, and local-level decision-making was also constrained by insufficient access to timely and relevant data.⁷ These challenges emphasized the need for integrated multi-level cooperation and local

stakeholder engagement to ensure specific responses to emerging health threats.⁸

Kalasin Province, located in Northeastern Thailand, faced significant challenges in COVID-19 surveillance. From December 9, 2021, and January 7, 2022, incidence reached 25.31 per 100,000—nine times the national rate.⁹⁻¹¹ However, few studies have focused on developing context-specific surveillance systems for rural areas in Thailand.¹² Previous studies in Kalasin Province revealed critical surveillance weaknesses, including limited training and low confidence in data analysis¹³. Reporting was incomplete and inaccurate¹⁴; sensitivity and timeliness were low. Only 39.8% of reports matched field realities,^{13,15} underscoring the need for a context-specific system.

This study addresses this gap by applying Kemmis and McTaggart’s participatory framework¹⁶, emphasizing community-led strategies and active local engagement to strengthen data integration and surveillance capacity in Kalasin Province, where participation remains limited.¹⁴⁻¹⁵ This study aims to develop and implement a context-specific COVID-19 surveillance system (CSS) for post-pandemic rural areas in Kalasin Province. Such a system can enhance early detection and response mechanisms for preparedness for future public health threats.

METHODS

Study design and settings

A mixed-methods research approach was employed in this study, which comprised both quantitative and qualitative action research phases to develop and evaluate a post-pandemic CSS using Kemmis and McTaggart’s framework. The study was conducted from January 2022 to May 2024 in Kalasin Province.

Study participants

Phase 1: Quantitative phase.

A cross-sectional design was employed to explore the context of the CSS, consisting of the following two components:

Part 1: We identified factors affecting COVID-19 surveillance operational performance (CSOP) among participants who (a) were public health officials, (b) had ≥ 1 year CSS experience, and (c) consented; incomplete questionnaires were excluded. The sample size was calculated using Cochran's formula for an unknown population¹⁷, with the percentage of public health officials who received CSS training (88%), as reported by Srisuwan.¹⁸ A 95% confidence interval (CI) with 5% precision, with an additional 10% non-response adjustment. A total of 568 participants were selected through stratified sampling across 18 district strata, with eligible public health officials randomly chosen using computer-generated numbers; in contrast, they were excluded if absent during data collection or declined participation. The researcher collected and verified data; incomplete questionnaires were excluded from analysis.

Part 2: We evaluated the CSS implemented during the pandemic by analyzing all patients under investigation (PUI) and confirmed COVID-19 case reports from January to December, 2021. Data were extracted from the surveillance databases of 18 hospitals using a standardized abstraction form based on the US-CDC surveillance evaluation framework. All records were reviewed for completeness and accuracy; reports with incomplete data were excluded. Of the 430 reports collected, 16 were excluded due to missing data, resulting in 414 reports that were included in the final analysis.

Phase 2: Qualitative Phase

We used action research to develop and evaluate the CSS during the post-

pandemic transition. This was done in a single six-month cycle, applying Kemmis and McTaggart's framework¹⁶ which consists of four key phases: planning, action, observation, and reflection. Purposive sampling involved 52 stakeholders across community to provincial levels, including situation awareness team (SAT) members, laboratory staff, rescue personnel, and village health volunteers.

Data were collected through two brainstorming sessions using a semi-structured questionnaire (IOC: 0.66–1.00). Qualitative data were analyzed via descriptive content analysis; recordings were transcribed, independently categorized by two researchers, and validated by the research team.

Instruments

Quantitative study. A self-administered questionnaire was developed that consisted of four parts:

Part 1: Socio-demographic factors: gender, age, job position, experience in disease surveillance operations, and epidemiological and communicable disease control training.

Part 2: COVID-19 surveillance operations-related factors were measured using a scale adapted from Junwin and Boromthanarat¹⁹, consisting of three dimensions (21 items): management, work motivation, and disease surveillance standards-related factors. The questionnaire was reviewed for content validity by experts (IOC: 0.60–1.00) and demonstrated high reliability (Cronbach's alpha of 0.98). This questionnaire, rated on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), was analyzed by mean scores; higher means indicated stronger operational performance. The mean score ranged from 1.00 to 5.00, which can be interpreted as low performance = 1.00–2.33, moderate performance = 2.34–3.67, and high performance = 3.68–5.00.

Part 3: CSS evaluation was assessed using the US- CDC surveillance evaluation²⁰ which was comprised of two measurements: 1) Quantitative indicators including sensitivity, positive predictive value (PPV), timeliness, and data quality—were assessed by valid percentages. ; An 80% cutoff ensures timeliness;²¹, other attributes need higher thresholds for optimal system performance. ; and 2) qualitative measurements involving five attributes: simplicity, stability, flexibility, usefulness, and accessibility.

Part 4: CSOP was assessed using a scale adapted from the WHO.²² This resulted in a 7- item, which included screening capacity, referral and isolation systems, case testing, syndromic surveillance, contact monitoring, and data sharing for risk assessment through standardized digital platforms. This questionnaire, rated on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), was analyzed by mean scores; higher means indicated stronger operational performance. The mean score ranged from 1.00 to 5.00, which can be interpreted as low performance = 1.00-2.33, moderate performance = 2.34-3.67, and high performance = 3.68-5.00. (This scale indicates good internal consistency with a Cronbach's alpha of 0.98.)

Qualitative study. Brainstorming sessions were conducted for additional data collection.²³ A semi-structured questionnaire was used to guide two rounds of structured brainstorming sessions. Three public health experts assessed content validity (IOC: 0.66–1.00). First, two issues guided situation analysis: factors affecting CSOP and CSS evaluation, including qualitative and quantitative data use. Second, four aspects informed CSS development: previous surveillance approaches, strategies to address challenges, roles in prevention and problem-solving, and surveillance goals.

Large-group brainstorming sessions were conducted and audio-recorded for analysis.

Statistical analysis

Quantitative analysis. Descriptive statistics were performed to evaluate the participants' characteristics. We applied Pearson's correlation to examine the correlations between the selected variables and the dependent variable, CSOP. Multiple linear regression analysis was performed to determine the factors associated with CSOP. The variance inflation factor (VIF) test was performed on our model, where the reported VIF was between 2.43-3.26, indicating no evidence of multicollinearity. Some studies show that multicollinearity is present when the VIF is greater than 5, which is taken to indicate multicollinearity.²⁴⁻²⁶ Furthermore, an independent samples t-test was used to compare CSOP values, and chi-square tests were employed to assess changes in proportions of CSS evaluations after the intervention. All statistical analyses were performed using SPSS, version 25.0 (IBM Corp., Armonk, NY, USA), and values for $P < 0.05$ were considered statistically significant.

Qualitative analysis. A descriptive content analysis was used to analyze the qualitative data. The audio recordings were transcribed, and the resulting data were then analyzed and grouped into thematic categories. Additionally, the brainstorming session data were documented, summarized, and validated using researcher triangulation.

Ethical Approval

All participants were informed about the research information and its voluntary nature, after which they were asked to provide written informed consent. This study was approved by the Ethics Committee for Research Involving Human Subjects, Mahasarakham University, on

March 28, 2022 (Ethics number: 097-427/2565).

RESULTS

Quantitative results

Sample characteristics:

Of the study participants, most were female (76.06%), with a mean age of 35.70 years (SD = 8.98), and had an average of 8.51 years of experience in disease

surveillance operations (SD = 7.64). In addition, 42.25% of the participants reported completing epidemiological training more than one year ago. The mean (SD) scores for management factors were 3.57–3.85 (SD = 0.68–0.73), the work motivation factors were 3.57–3.96 (SD = 0.58–0.79), the disease surveillance standards-related factors were 4.09–4.68 (SD = 0.18–0.46), and CSOP was 3.89 (SD = 0.57) (Table 1).

Table 1. Distribution of socio-demographic, COVID-19 surveillance operations-related factors, and COVID-19 surveillance operational performance (n=568).

Variables	Number	Percentage
Socio-demographic factor		
Gender		
Female	432	76.06
Male	136	23.94
Age (years)		
<35	308	54.23
≥ 35	260	45.77
(Mean=35.70, SD.=8.98)		
Job positions		
Public health professional	396	69.72
Other	172	30.28
Experience in disease surveillance operations (years)		
1 – 4	216	38.03
5 – 9	144	25.35
10 – 14	124	21.83
≥15	84	14.79
(Mean= 8.51, SD.=7.64)		
Epidemiological training		
Never	160	28.17
Have trained within the past 1 year	168	29.58
Have trained for more than 1 year.	240	42.25
Communicable Disease Control Unit (CDCU) course training		
Never	245	43.10
Have trained within the past 1 year.	124	21.79
Have trained for more than 1 year.	199	35.11
	Mean	SD.
COVID-19 surveillance operations-related factors		
Management factors		
Technology utilization	3.79	0.68
Organizational management	3.79	0.71
Time management	3.85	0.70
Human resources	3.69	0.72
Materials and equipment management	3.67	0.73
Budget administration	3.57	0.72

	Mean	SD.
Work motivation factors		
Professional status	3.61	0.79
Work achievement	3.89	0.62
Recognition and appreciation	3.96	0.62
Responsibility and accountability	3.66	0.58
Job roles and responsibilities	3.91	0.64
Career advancement opportunities	3.86	0.69
Job security	3.89	0.64
Workplace conditions	3.62	0.74
Quality of work life	3.57	0.68
Disease surveillance standards-related factors		
Priority disease	4.17	0.46
Case notification and verification	4.52	0.25
Event-based surveillance and verification	4.37	0.18
Operational network coordination	4.09	0.35
Epidemiological data collection and analysis	4.31	0.34
Application of surveillance data for action	4.68	0.28
COVID-19 surveillance operational performance	3.89	0.57

Bivariate correlations:

All COVID-19 surveillance operations-related factors, including management, work motivation, and disease

surveillance standards-related factors, and all disease surveillance standards-related factors were correlated with CSOP ($P < 0.01$) (Table 2).

Table 2. Correlation between selected variables with COVID-19 surveillance operational performance (n=568)

Variables		Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21
CSOP	(Y)	1																					
Management factors																							
Technology utilization	(X1)	0.662**	1																				
Organizational management	(X2)	0.632**	0.809**	1																			
Time management	(X3)	0.675**	0.803**	0.730**	1																		
Human resources	(X4)	0.414**	0.634**	0.639**	0.631**	1																	
Materials and equipment management	(X5)	0.573**	0.767**	0.801**	0.705**	0.607**	1																
Budget Administration	(X6)	0.518**	0.723**	0.801**	0.695**	0.694**	0.794**	1															
Work motivation factors																							
Professional status	(X7)	0.470**	0.527**	0.462**	0.473**	0.324**	0.416**	0.430**	1														
Work achievement	(X8)	0.676**	0.817**	0.738**	0.855**	0.598**	0.708**	0.651**	0.469**	1													
Recognition and appreciation	(X9)	0.592**	0.686**	0.595**	0.671**	0.479**	0.507**	0.424**	0.445**	0.797**	1												
Responsibility and accountability	(X10)	0.466**	0.600**	0.563**	0.616**	0.524**	0.561**	0.585**	0.418**	0.657**	0.561**	1											
Job roles and responsibilities	(X11)	0.593**	0.717**	0.663**	0.676**	0.495**	0.575**	0.603**	0.514**	0.720**	0.764**	0.655**	1										
Career advancement opportunities	(X12)	0.584**	0.675**	0.612**	0.660**	0.453**	0.597**	0.557**	0.587**	0.691**	0.675**	0.722**	0.779**	1									
Job security	(X13)	0.655**	0.642**	0.542**	0.584**	0.423**	0.524**	0.468**	0.633**	0.633**	0.597**	0.539**	0.608**	0.656**	1								
Workplace conditions	(X14)	0.539**	0.634**	0.608**	0.596**	0.438**	0.623**	0.607**	0.670**	0.603**	0.533**	0.636**	0.671**	0.836**	0.574**	1							
Quality of work life	(X15)	0.609**	0.499**	0.427**	0.465**	0.381**	0.428**	0.422**	0.623**	0.477**	0.395**	0.525**	0.480**	0.576**	0.692**	0.646**	1						
Disease surveillance standards-related factors																							
Priority disease	(X16)	0.894**	0.595**	0.589**	0.606**	0.405**	0.533**	0.495**	0.431**	0.617**	0.577**	0.396**	0.550**	0.500**	0.602**	0.488**	0.574**	1					
Case notification and verification	(X17)	0.894**	0.669**	0.657**	0.659**	0.406**	0.588**	0.524**	0.480**	0.696**	0.591**	0.485**	0.581**	0.561**	0.643**	0.527**	0.565**	0.805**	1				
Event-based surveillance and verification	(X18)	0.794**	0.569**	0.552**	0.560**	0.389**	0.498**	0.461**	0.365**	0.608**	0.547**	0.376**	0.488**	0.438**	0.549**	0.421**	0.538**	0.847**	0.763**	1			
Operational network coordination	(X19)	0.737**	0.546**	0.538**	0.503**	0.343**	0.457**	0.407**	0.380**	0.519**	0.483**	0.350**	0.443**	0.435**	0.483**	0.455**	0.507**	0.728**	0.757**	0.598**	1		
Data collection and analysis	(X20)	0.767**	0.492**	0.456**	0.492**	0.259**	0.381**	0.352**	0.377**	0.451**	0.425**	0.324**	0.390**	0.383**	0.480**	0.355**	0.407**	0.802**	0.625**	0.646**	0.667**	1	
Application of surveillance	(X21)	0.806**	0.558**	0.545**	0.597**	0.416**	0.510**	0.462**	0.340**	0.597**	0.538**	0.383**	0.556**	0.470**	0.536**	0.437**	0.507**	0.832**	0.710**	0.797**	0.435**	0.519**	1

Note: ** Correlation is significant at $P < 0.01$, * Correlation is significant at $P < 0.05$

Factors associated with CSOP:

The stepwise multiple linear regression analysis identified nine variables significantly associated with CSOP at the 0.001 level. Professional status ($\beta = -0.045$, $P = 0.006$) and responsibility and accountability ($\beta = -0.055$, $P = 0.002$) were negatively associated with CSOP. In contrast, case notification and verification had the strongest positive association with

CSOP ($\beta = 0.428$, $P < 0.001$), followed by application of surveillance data for action ($\beta = 0.328$, $P < 0.001$), epidemiological data collection and analysis ($\beta = 0.297$, $P < 0.001$) and the remaining four variables presented in Table 3, after adjusting for all other variables. These predictors collectively accounted for 85.4% of the variance in CSOP (adjusted $R^2 = 0.854$).

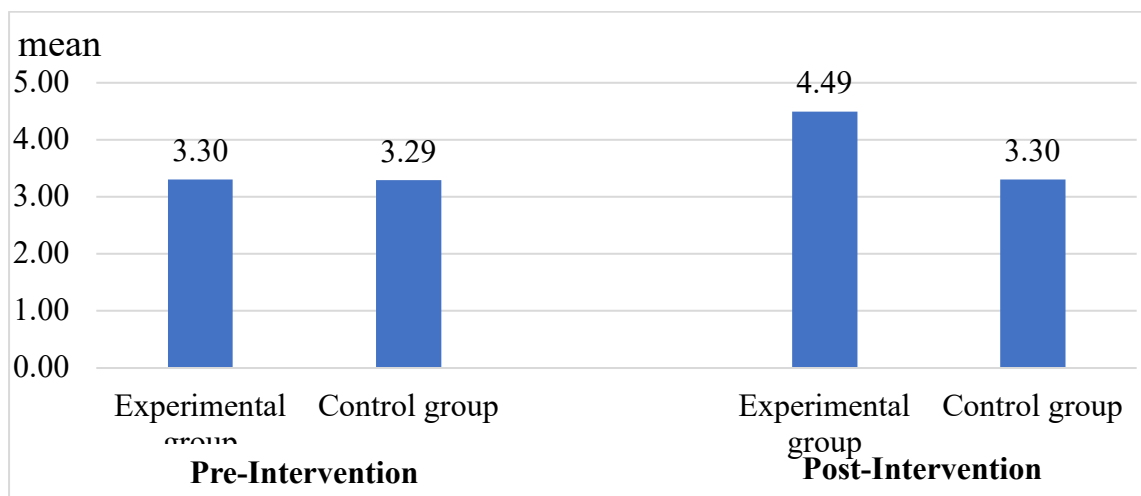


Figure 1. Comparison of CSOP scores pre- and post-intervention.

Table 3. Multivariate linear regression analysis toward COVID-19 surveillance operational performance (n=568)

Variables	B	SE	β	<i>t</i>	95% CI of B	<i>P</i> -value
Work motivation factors						
Professional status	-0.032	0.012	-0.045	-2.748	-0.055, -0.009	0.006*
Responsibility and accountability	-0.054	0.017	-0.055	-3.190	-0.087, -0.021	0.002*
Career advancement opportunities	0.079	0.016	0.095	4.905	0.047, 0.110	<0.001*
Quality of work life	0.076	0.015	0.090	5.119	0.047, 0.104	<0.001*
Disease surveillance standards-related factors						
Case notification and verification	0.993	0.058	0.428	17.082	0.879, 1.108	<0.001*
Event-based surveillance and verification	0.258	0.073	0.081	3.518	0.114, 0.403	<0.001*
Operational network coordination	0.113	0.034	0.070	3.357	0.047, 0.180	0.001*
Epidemiological data collection and analysis	0.495	0.029	0.297	17.168	0.439, 0.552	<0.001*
Application of surveillance data for action	0.676	0.044	0.328	15.404	0.589, 0.762	<0.001*

R^2 adjusted = 0.854, R^2 Change = 0.007, $F = 335.205$, $P < 0.001$.

Note: Adjusted for gender, age, job position, experience in disease surveillance operations, epidemiological training, and Communicable Disease Control Officers (CDCU) course training; B, unstandardized coefficients; SE, standard error; β , standardized coefficients; CI, confidence interval; * Statistically significant

Surveillance evaluation:

Quantitative measurements were conducted using PUI and confirmed COVID-19 case reports. The results showed that sensitivity and PPV were equal, with high data consistency and high data accuracy across variables. However, timeliness remained a concern, with fewer than half of the reports submitted within 24 hours (Table 4).

Qualitative measurements identified several limitations related to CSS operation: 1) it involved complex procedures and frequent guideline changes; 2) it was unstable due to workforce shortages; 3) its flexibility was limited as the system adapted to changing circumstances; and 4) data were underutilized, especially locally.

Table 4. The evaluation of the COVID-19 surveillance system (Before developing a surveillance system) (n=414)

Variables	Number	Percentage
Sensitivity	414	100.00
Positive predictive value (PPV)	414	100.00
Data quality		
- Gender	413	99.74
- Age	406	97.95
- Illness onset date	374	90.26
- Residence at the time of illness	379	91.54
Timeliness		
- Timely (Within 1 day)	205	49.49
- Delayed (more than 1 day)	209	50.51

Note: sensitivity = (true positives x 100) / (true positives + false negatives)

Positive predictive value = (true positives x 100) / (true positives + false positives)

Table 5. Comparison of the COVID-19 surveillance system evaluation and COVID-19 surveillance operational performance between intervention and control groups after intervention.

Variables	Experimental group (n=127)		Control group (n=114)		P-value
	Number	Percentage	Number	Percentage	
Sensitivity	127	100.00	108	94.74	0.009^{a*}
Positive predictive value (PPV)	127	100.00	107	93.86	0.005^{a*}
Data quality					
- Gender	127	100.00	111	97.37	0.066 ^a
- Age	125	98.43	108	94.74	0.111 ^a
- Onset date	119	93.70	94	82.46	0.007^{a*}
- Residence at the time of illness	110	86.61	92	80.70	0.213 ^a
Timeliness	119	93.71	87	76.32	<0.001^{a*}
	Mean	SD.	Mean	SD.	
COVID-19 surveillance operational performance	4.49	0.32	3.30	0.32	<0.001^{b*}

Note: SD, standard deviations; ^a P-value for Chi-square; ^b P-value for independent samples t-test

The values shown in the 'Number' column reflect only cases that met the defined criteria. * Statistically significant (values highlighted in bold and marked with*)

Qualitative results

Planning phase. Stakeholders collaborated to design a CSS using the brainstorming technique and quantitative evidence. The main themes of stakeholders' opinions on the surveillance system were as follows:

Barriers to surveillance system operation: Most participants identified the following limitations in resources and budget (such as a lack of trained or specialized personnel, insufficient medical equipment, and a lack of technology for case reporting), inadequate network cooperation, a lack of understanding of operational guidelines, low work motivation, and a high workload.

Enablers of surveillance system operation: The participants stated the factors that can support the operation include 1) reviewing operational guidelines that are easy to understand and follow improves the quality of data collection and reporting; 2) availability of a trained and specialized workforce is crucial for managing surveillance data and operations; 3) robust and user-friendly technology for timely and accurate case reporting, data collection, and analysis; 4) strong collaboration between different levels of government (e.g., central, provincial, local), healthcare facilities, and the community; 5) high work motivation among staff, often driven by a clear understanding of their role's importance and a supportive work environment.

System improvements: The participants suggested four key methods that can improve the surveillance system included 1) strengthening human resources (e.g., staff training and implementing feedback loops to quickly resolve issues); 2) improving operational guidelines (e.g., easy-to-follow protocols for data collection and reporting); 3) enhancing technology and data management (e.g., data platform for faster case reporting and analysis); 4) inter-agency

cooperation (e.g., government, healthcare facilities, and community).

Action phase. We implemented a CSS developed in the planning phase, comprised of five proactive activities:

1) *Strengthening CSS:* This activity strengthened multi-level surveillance by reviewing personnel, resources, systems, and operational guidelines to enhance overall effectiveness.

2) *Operational Guidelines Development:* This activity developed standardized operational guidelines to enhance disease and health hazard surveillance: (1) form SAT teams of 4–5 members with seven-day rotations; (2) use Google Forms for district-level reporting; (3) use Line app to confirm and standardize daily reports; (4) notify and verify events via Google Sheets; (5) hold weekly handover meetings; (6) coordinate networks for COVID-19 monitoring; and (7) prepare preliminary reports for decision-makers, improving surveillance quality and consistency.

3) *Agile Mechanism for CSS:* Hybrid work models combining office and remote work and efficient digital tools enhanced system flexibility and agility.

4) *Strategic Planning and Capacity Building:* This study developed a context-specific CSS strategy via directive review, capacity building, accountability, and career motivation.

5) *After-Action Reviews (AAR):* This activity enhanced surveillance teams' capacity to detect and monitor alert signals.

Observation phase. The CSS was evaluated for one year in an experimental area. The experimental area showed significantly higher sensitivity and PPV than the control ($P < 0.05$). In addition, illness onset date accuracy improved significantly in the experimental area ($P < 0.05$); with no differences by gender, age, or residence. The experimental area

demonstrated significant improvements in reporting timeliness and CSOP ($P < 0.05$), with the CSS showing enhanced simplicity, stability, and flexibility through standardized guidelines, digital reporting, structured teams, and agile, hybrid operations, and event-based surveillance integration.

Reflection phase. Findings were presented, proposing a context-specific CSS for Kalasin Province, with five components: (1) strengthening CSS, (2) developing operational guidelines, (3) enhancing agility for CSS, (4) planning strategies and building capacity, and (5) AAR. Additionally, the key factors in the CSS success were inclusive stakeholder engagement, standardized operational guidelines, agile work mechanisms that enhanced flexibility and real-time communication, strategic planning and capacity building that strengthened staff competency and accountability, and continuous feedback through AAR to support system learning and adaptation. This reflection phase enhanced CSS performance, particularly in timeliness and operational decision-making.

DISCUSSION

This study identified key factors influencing CSOP. Work motivation, professional status, and accountability were negatively associated with performance, reflecting qualitative findings of complex procedures, frequent guideline changes, and staff shortages. These results contrast with prior studies emphasizing the positive impact of clear responsibilities and professional standing on surveillance effectiveness.^{22,27} A possible explanation is that lower professional status and accountability scores may reflect high COVID-19 surveillance workload, operational pressure, and perceived inadequacy of recognition despite strong performance.²⁸⁻²⁹

Moreover, career advancement and quality of work life positively influenced surveillance performance, consistent with Khamsena et al.³⁰, highlighting motivation and organizational support's impact on job performance.

Regarding disease surveillance standards-related factors, case notification and verification were strongly associated with CSOP, emphasizing effective case management and data utilization, consistent with prior studies.³¹ Additionally, operational network coordination aligns with evidence that multi-sectoral collaboration improves surveillance effectiveness.³² In addition to the quantitative evaluation, the CSS showed high sensitivity, PPV, and data consistency, outperforming figures reported in similar middle-income countries, unlike lower values in India and Africa.³³⁻³⁴ However, only 49.49% of reports were submitted within 24 hours, consistent with findings by WHO and Karo et al.^{35,36} Additionally, Qualitative assessment revealed system complexity, inflexibility, and workforce shortages, aligning with Jang et al.³⁷, who identified human resource gaps and underutilization of surveillance data for timely outbreak response, consistent with Namara et al.³⁸

Furthermore, CSS evaluation showed significant improvements in sensitivity, PPV, data accuracy, timeliness, and CSOP, confirming the system's effectiveness, consistent with prior studies in Korea.³⁹ where The surveillance system improved reporting timeliness, diagnostic accuracy, and all five qualitative attributes, demonstrating effectiveness consistent with findings by McNabb et al.⁴⁰, who emphasized that complexity hinders surveillance efficiency; defined team roles, staff rotation, and technology use enhance stability and adaptability, aligning with CDC recommendations for effective pandemic response.⁴¹ Enhanced data use for timely decisions aligns with Choi et al.'s

view on the pivotal role of data in public health responses.⁴²

This study has three main limitations. First, its cross-sectional design precludes causal inference, warranting future longitudinal research. Second, self-reported measures may be affected by social desirability, to minimize this bias, validated and standardized instruments were used. Third, as the study was conducted in rural northeastern Thailand, generalizability is limited; future studies should include nationally representative samples. Despite these, the study offers insights into COVID-19 surveillance improvements and key factors affecting staff performance (e.g., work motivation and disease surveillance standards-related factors), supported by multi-level stakeholder engagement.

Our study found that the CSS improved data quality, timeliness, and staff performance. In Thailand, the CSS can be integrated with the national surveillance system through digital reporting, structured teams, clear guidelines, and event-based surveillance and verification. The system's community engagement and agile workflows can complement existing systems, providing scalable strategies to enhance infectious disease monitoring, rapid response, and policy planning.

RECOMMENDATIONS

This study demonstrated that work motivation and adherence to disease surveillance standards significantly influence staff operational performance. Short-term improvements should focus on enhancing these factors, implementing standardized guidelines, hybrid work models, and AAR to improve data accuracy, flexibility, and continuous improvement. Long-term strategies include context-specific planning, targeted training, investment in digital infrastructure, and

interagency coordination to support evidence-based decision-making and sustainable local implementation. These findings can inform national policy and guide practical actions. Future research should test this model in diverse regions and explore advanced technologies, such as real-time mobile reporting and outbreak prediction tools, to enhance surveillance responsiveness.

AUTHOR CONTRIBUTIONS

SY: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing—original draft and Writing—review & editing. WR: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing—original draft and Writing—review & editing.

ETHICAL CONSIDERATION

This study was approved by the Ethics Committee for Research Involving Human Subjects, Mahasarakham University, on March 28, 2022 (Ethics number: 097-427/2565).

ACKNOWLEDGMENTS

We thank the Mahasarakham University for its research funding, and we sincerely thank all study subjects for their participation.

FUNDING

This research project was financially supported by Mahasarakham University.

CONFLICTS OF INTERESTS

The authors declare no conflicts of interest.

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