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**Outbreak, Surveillance, Investigation & Response (OSIR) Journal**

Field Epidemiology Training Program, Division of Epidemiology, Department of Disease Control,

Ministry of Public Health, Tiwanond Road, Talad Kwan Subdistrict, Muang District, Nonthaburi 11000, Thailand

Tel: +662-5901734, Fax: +662-5918581, Email: osireditor@osirjournal.net

Website: < **https://he02.tci-thaijo.org/index.php/OSIR/**>

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Field Epidemiology Training Program, Division of Epidemiology
Department of Disease Control, Ministry of Public Health, Thailand
Tel: +6625903894, Fax: +6625903845, Email: osireditor@osirjournal.net, http://www.osirjournal.net

## Editorial

# Measles Resurgence: Vaccination Remains the Best Defense

Angela Song-En Huang, Senior Editor

In this issue of OSIR, we continue to report and examine different aspects of surveillance. Finding and reporting diseases are the first steps in understanding and controlling infectious diseases.

As measles outbreaks have been making headlines around the world, and the Western Pacific and Southeast Asia regions are no exception. In 2022 and 2023, India experienced significant measles transmission, followed by outbreaks in Bangladesh and the Philippines in 2023.[1] In Vietnam, a surge in cases in 2024 resulted in 45,550 suspected cases and 16 deaths. The situation worsened in 2025, with nearly 40,000 suspected cases and five deaths recorded by mid-March.[2]

With an incubation period of 7 to 21 days and short transit times between countries, measles spreads easily across international borders. Taiwan's experience clearly demonstrates this risk. During 2020 and 2021, when Taiwan's borders were closed, no measles cases were reported. However, in 2024, there were a total of 12 cases imported from Vietnam, Malaysia, Cambodia, and other countries, leading to 20 locally acquired cases. By mid-March 2025, with over 200,000 travelers from Taiwan had visited Vietnam, there have been 11 imported cases of measles, all linked to travels to Vietnam.[3,4] However, Taiwan has maintained measles-mumps-rubella (MMR) vaccine coverage above 98%, even during the COVID-19 pandemic, preventing sustained measles transmission despite these imported cases.[5]

Vaccination remains the most effective way to prevent measles. However, the COVID-19 pandemic disrupted routine immunization programs worldwide, leading to a decline in vaccination coverage for many childhood immunizations, including measles-containing vaccines. According to WHO-UNICEF estimates, Vietnam's coverage of measles-containing vaccines dropped from 95–99% between 2015 and 2020 to 89% in 2021 and further down to 82% in 2023.[6] This decline has directly contributed to the large outbreaks currently being observed.

In addition to immunization program disruptions, misinformation has played a significant role in lowering vaccine coverage. In some communities, measles is wrongly perceived as a mild childhood illness that only causes fever, rash, cough, coryza (runny nose), and conjunctivitis—the so-called "3Cs." This misunderstanding leads to vaccine hesitancy, leaving populations vulnerable to outbreaks. The United States is currently experiencing measles outbreaks in areas with low MMR vaccine uptake. By 13 Mar 2025, there had been 301 reported cases, with 95% occurring in individuals who were unvaccinated or had an unknown vaccination status. Among them, 50 patients (17%) required hospitalization, and two have died.[7]

So, we can see that measles is far more than a febrile-rash disease that everyone recovers from. Approximately 30% of patients experience complications, with diarrhea being the most common. Other severe complications, in the short-term, include pneumonia, that can lead to death, and encephalitis, which can lead to deafness or intellectual disability. In the long-term, subacute sclerosing panencephalitis (SSPE), a rare but devastating neurological condition, can emerge 7 to 10 years after the initial infection, even in patients who had seem to make a full recovery from measles.[8]

Achieving and maintaining 95% immunization coverage is crucial to preventing sustained measles transmission.[9] However, this requires continued commitment from policymakers, public health authorities, and healthcare providers. Efforts must focus on countering misinformation about vaccine safety, ensuring vaccine accessibility, and strengthening surveillance systems to prevent future outbreaks. Only through our collective action can we protect vulnerable populations and prevent measles from re-emerging as a significant public health threat.

## References


1. World Health Organization. Measles and Rubella Global Update, March 2025 [Internet]. Geneva: World Health Organization; [cited 2025 Mar 24]. 55 p. <https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fimmunizationdata.who.int%2Fdocs%2Flibrariesprovider21%2Fmeasles-and-rubella%2Fglobal-mr-update.pptx%3Fsfvrsn%3D3547ebab_12&wdOrigin=BROWSELINK>
2. Viet Nam News. WHO warns of measles surge in Viet Nam [Internet]. Hanoi: Viet Nam News; 2025 Feb 6 [cited 2025 Mar 24]. <https://vietnamnews.vn/society/1691749/who-warns-of-measles-surge-in-viet-nam.html>
3. Taiwan External Trade Development Council. In the first two months of this year (2025), the number of international tourists from Vietnam exceeded 3.96 million, an increase of 30.2% compared to the same period last year (2024) [Internet]. Taipei: Taiwan External Trade Development Council; 2025 Mar 12 [cited 2025 Mar 24]. <https://www.taitra.org.tw/News_Content.aspx?n=104&s=110848>. Chinese.
4. Taiwan Centers for Disease Control. Taiwan National Infectious Disease Statistics System [Internet]. Taipei: Taiwan Centers for Disease Control; [cited 2025 Mar 24]. <https://nidss.cdc.gov.tw/nndss/GlobalMap?id=055>. Chinese.
5. Taiwan Centers for Disease Control. Vaccination Statistics [Internet]. Taipei: Taiwan Centers for Disease Control; [cited 2025 Mar 24]. <https://www.cdc.gov.tw/Category/MPage/S2UF2-VuMgfzgzpy7qdvlA>. Chinese.
6. World Health Organization. Measles vaccination coverage [Internet]. Geneva: World Health Organization; [cited 2025 Mar 24]. <https://immunizationdata.who.int/global/wiise-detail-page/measles-vaccination-coverage?CODE=WPR+VNM&ANTIGEN=MCV1&YEAR=>.
7. US Centers for Disease Control and Prevention. Measles cases and outbreaks [Internet]. Atlanta: Centers for Disease Control and Prevention; 2025 Mar 21 [2025 Mar 24]. <https://www.cdc.gov/measles/data-research/index.html>
8. US Centers for Disease Control and Prevention. Clinical overview of measles [Internet]. Atlanta: Centers for Disease Control and Prevention; 2024 Jul 15 [2025 Mar 24]. <https://www.cdc.gov/measles/hcp/clinical-overview/index.html>
9. US Centers for Disease Control and Prevention. About global measles [Internet]. Atlanta: Centers for Disease Control and Prevention; 2024 Nov 14 [2025 Mar 24]. <https://www.cdc.gov/global-measles-vaccination/about/index.html>

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Field Epidemiology Training Program, Division of Epidemiology
Department of Disease Control, Ministry of Public Health, Thailand
Tel: +6625903894, Fax: +6625903845, Email: osireditor@osirjournal.net, https://he02.tci-thaijo.org/index.php/OSIR

# An Investigation of Pertussis Outbreak in a Low Vaccination Coverage Area, Mae Lan District, Pattani Province, Thailand, September–December 2023

Tamonwan Chatngoen[1]*, Piyaporn Sae-aui[2], Aree Tamad[2], Sunisa Kaesaman[2], Arunee Suhem[2], Sulaiya Malae[2], Angsumalin Praditsuwan[2], Amornrat Chobkatanyoo[2], Choopong Sangsawang[2]

1 Field Epidemiology Training Program, Division of Epidemiology, Department of Disease Control, Ministry of Public Health, Thailand

2 Office of Disease Prevention and Control 12 Songkhla, Department of Disease Control, Ministry of Public Health, Thailand

*Corresponding author, email address: tamonwan27048@gmail.com

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**Abstract**

On 26 Oct 2023, a pertussis cluster was reported in Muang Tia Subdistrict. We investigated to identify the source, determine contributing factors, and estimate diphtheria-tetanus-pertussis (DTP) vaccine coverage. We reviewed medical records and performed active case findings in three villages. Suspected cases included close contacts with upper respiratory tract infection (URI) symptoms, residents with a week-long cough and a typical pertussis symptom, or those in URI clusters. Confirmed cases were individuals with positive *Bordetella Pertussis* result by polymerase chain reaction. Age-appropriate DTP coverage was estimated. Post-hoc analysis on sensitivity of national (two-week cough with a typical symptom) and modified (any cough duration with a typical symptom or close contact with a URI symptom) pertussis definition was conducted. We found eleven confirmed and four suspected cases (attack rate 0.6%; 15/2,394) with one hospitalized with pneumonia. Cases' age ranged from 11 months to 53 years old (median 5 years). The attack rate among children aged 0–1 year was 2.9%. Thirty-six percent of confirmed cases had a cough lasting at least two weeks. The national definition had a sensitivity of 9.1% (95% CI 0.2%–41.3%), while the modified definition's sensitivity was 81.8% (95% CI 48.2%–97.7%). DTP coverage in children aged 0–1 year was 25.0% (95% CI: 10.4%–39.6%). Pertussis positivity among household and community contacts was 40.0% and 50.0%, respectively. This pertussis outbreak was driven by low vaccine coverage and community transmission. Enhancing vaccine coverage to 90% and using modified definitions are recommended for outbreak control in low-vaccination areas.

**Keywords:** pertussis, outbreak, community, diphtheria-tetanus-pertussis vaccine, Thailand

## Introduction

Pertussis, caused by *Bordetella pertussis*, is a highly contagious respiratory disease with a 7–10-day incubation period. Symptoms progress through catarrhal, paroxysmal, and convalescence stages. It spreads via droplets and is contagious from the catarrhal stage to the third week of paroxysms or until five days after antibiotic initiation.[1,3] One-third of infants require hospitalization.[1,2] Diagnosis involves clinical and laboratory tests such as polymerase chain reaction (PCR). Macrolides and co-trimoxazole are recommended for treatment and postexposure prophylaxis.[4–7]

Although highly contagious, pertussis is vaccine-preventable. Thailand's Expanded Program on Immunization (EPI) schedules five doses of diphtheria, tetanus, and whole-cell pertussis (DTwP) vaccines at 2, 4, 6, 18 months, and 4–6 years of age.[8,9] The diphtheria, tetanus, and acellular pertussis (DTaP) vaccine can be used instead of DTwP.[8] The vaccine effectiveness against pertussis is 94% (95% confidence interval (CI) 88–97%) for DTwP and 84% (95% CI 81–87%) for DTaP.[10] The tetanus, diphtheria, acellular pertussis (Tdap) vaccine is recommended every 10 years for individuals over age seven.[8,11] Studies show that Tdap protects 73% of adolescents in the first year after vaccination.[12] In pregnant women, Tdap at 27–36 weeks lowers pertussis risk in infants under 2 months by 78%.[12]

The World Health Organization (WHO) recommends at least 90% of a third dose of diphtheria-tetanus-pertussis (DTP3) vaccine coverage.[13] In 2023, Thailand's DTP3 coverage was 88.3%.[15] However, the Deep South—comprising the provinces of Pattani, Narathiwat, Yala, and parts of Songkhla—had lower coverage due to longstanding conflict and social challenges, including declining immunization.[14] Among the provinces in the Deep South, Pattani Province reported the lowest (53.3%).[15]

On 26 Oct 2023, a cluster of six confirmed pertussis cases in Village 5, Muang Tia Subdistrict, Mae Lan District, Pattani Province was notified. The index case was a DTP-unvaccinated 11-month-old Thai boy. We investigated from 31 Oct–1 Nov 2023 to confirm the outbreak and diagnoses, identify the source and contributing factors, assess DTP vaccine coverage, determine the sensitivity and specificity of the pertussis case definitions, and provide recommendations and control measures.

## Methods

### Descriptive Study

We reviewed medical records from Mae Lan Hospital, Pattani Hospital and Hat Yai Hospital, where six cases were diagnosed. We reviewed investigation reports from the Pattani Public Health Office and performed laboratory studies to confirm the diagnosis. We also reviewed the pertussis situation in Pattani Province between 1 Jan and 26 Oct 2023 from Thailand's indicator-based surveillance system (R506), and event-based surveillance, to verify the outbreak.

Active case finding was conducted in Villages 4–6. Community health volunteers and village leaders were explained the field visit's objectives and trained to perform active case finding. Each volunteer performed a walkthrough survey by visiting every household in their area to identify suspected cases, children, and pregnant women. They would then notify the investigation team to conduct face-to-face interviews using semi-structured questionnaires with all suspected cases and all members of households where children aged 0–1 year or pregnant women at 20-36 weeks of gestation lived.

*Operational definition*

A suspected case was a close contact of a confirmed case with at least one upper respiratory-tract-infection (URI) symptom (cough, rhinorrhea, sore throat) or residents in Villages 4–6 who had a week-long cough with a typical pertussis symptom (paroxysmal coughing, inspiratory whooping, post-tussis vomiting, apnea, cyanosis), or residents in Villages 4–6 who were in URI clusters between 22 Sep and 16 Dec 2023. Confirmed cases were suspected cases with positive *Bordetella pertussis* results by PCR technique. Suspected cases with negative PCR results were excluded.

A close contact was a person who had direct exposure to a confirmed case's respiratory secretion or face-to-face contact within one meter for over five minutes, categorized as low or high risk based on the proper use of personal protective equipment.[16] PCR-positive close contacts without symptoms were classified as asymptomatic infections.

*Laboratory investigation*

Nasopharyngeal swabs from suspected cases and high-risk contacts were collected by trained healthcare officers and transported at 2–8 °C to Bamrasnaradura Infectious Diseases Institute for *Bordetella pertussis* testing using the PCR technique.

*Environmental survey*

A walkthrough survey of index houses, communities, schools, and hospitals was conducted using direct observation and interviews with household members, residents, teachers, and healthcare officers. The survey focused on locations and behavioral risk factors such as mask-wearing, hand washing, and sharing personal items.

### Vaccine Coverage Study

As DTP2 coverage data were unavailable, DTP vaccination coverage for doses 1, 3, 4, and 5 in 2023 was reviewed at the level of districts in Pattani Province, subdistricts in Mae Lan District, and villages in Muang Tia Subdistrict using Thailand's Health Data Center dashboard. We performed the DTP vaccination survey in suspected cases and children aged 0–1 year in Villages 4–6 during the active case finding. We interviewed parents about their child's vaccination and reviewed the vaccination record book. Age-appropriate DTP vaccine coverage was assessed as complete, incomplete, or unvaccinated based on age and number of doses received compared to EPI schedules.

### Post-hoc Analysis of Sensitivity and Specificity of National and Modified Pertussis Definitions

To identify a pertussis definition suitable for outbreak periods, we modified the operational pertussis definition and analyzed the sensitivity and specificity of both national and modified definitions. The national definition requires a two-week cough with a typical symptom, while the modified definition includes any cough duration with a typical symptom or close contact with a URI symptom.[17] The study included individuals during this outbreak who underwent PCR testing for pertussis. Sensitivity was the percentage of PCR-positive cases meeting the definition, while specificity was the percentage of PCR-negative cases not meeting the definition. Confidence intervals were calculated using the Clopper-Pearson Exact Method. The sample size was calculated using the finite population proportion formula with 95% confidence, 5% margin of error, and the WHO clinical criteria sensitivity of 95.2%.[18] Given a population of 2,394 in Villages 4–6, the required sample size was 68.

### Ethics

Ethics approval was not required as it was part of an outbreak response by the Department of Disease Control, Ministry of Public Health.

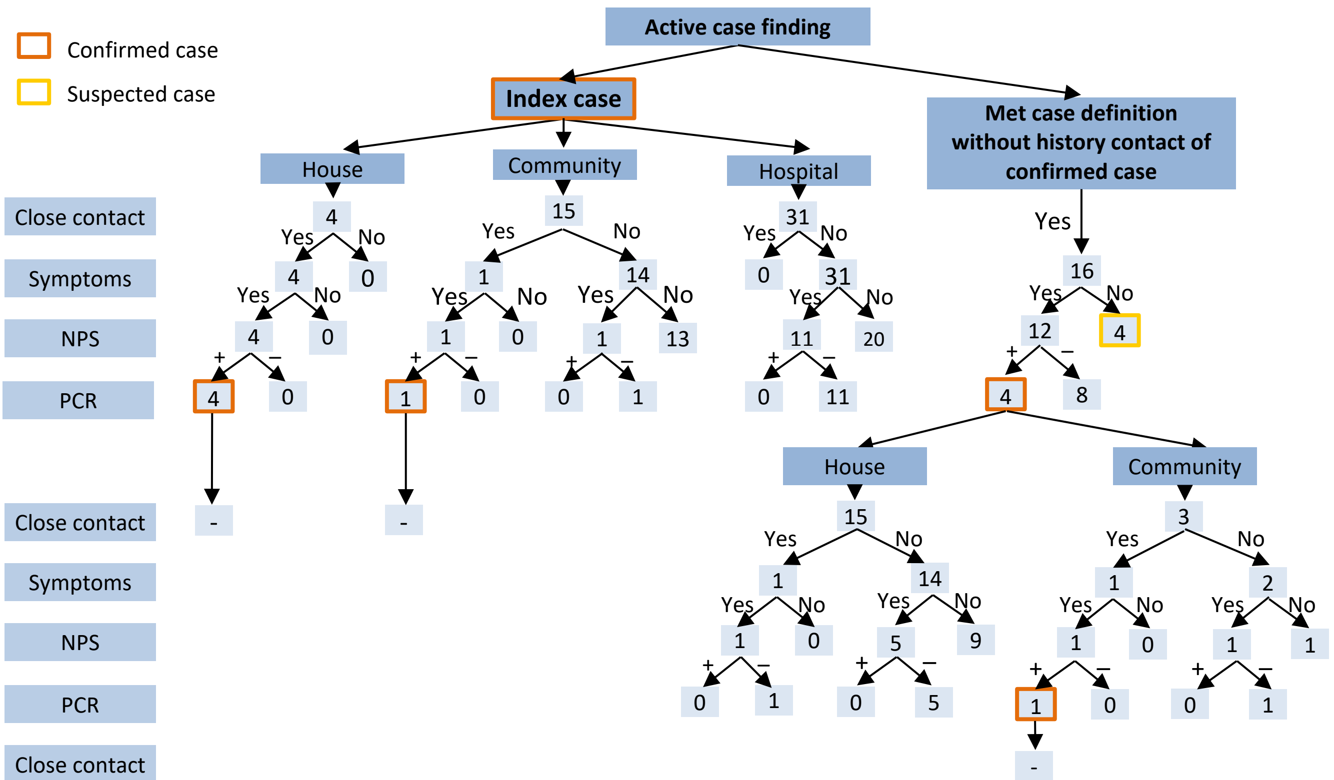
## Results

Between 1 Jan and 26 Oct 2023, no pertussis cases were reported in Muang Tia Subdistrict, Mae Lan District, Pattani Province, from either the R506 or event-based surveillance systems. Muang Tia Subdistrict consists of six villages. The population is 90% Muslim. The adult-to-child-to-elderly ratio is 5.2:2.1:1.0. This investigation focused on Villages 4–6, with 594 households and 2,394 populations.

### Outbreak Description and Magnitude

We traced close contacts of the index case and searched for suspected cases in the community (Figure 1). The index case had 50 close contacts. Of these, 17 close contacts underwent nasopharyngeal swabs, with five testing positive, confirming the previously notified cases. Additionally, we identified 16 symptomatic individuals who met the case definition without contact with confirmed cases; four met suspected cases definition, and 12 were tested with four positive. Among their close contacts, eight were tested and one was positive. In summary, we found an additional nine cases apart from the six notified cases. Among 19 household contacts, four of ten were positive (positivity rate 40%); among 18 community contacts, two of four tested positive (positivity rate 50%). No asymptomatic PCR-positive cases were found.

In total, we identified 15 cases (4 suspected and 11 confirmed cases). Five cases were from Village 4 and ten from Village 5. Age ranged between 11 months and 53 years (median 5 years, interquartile range 2–13 years). The male-to-female ratio was 1:1. There were eight students, four preschoolers, two vendors, and one army volunteer. Among 12 cases with DTP vaccination data (excluding three adults with unknown vaccination status), five were unvaccinated, four had 1–2 doses, and three had at least 3 doses. Considering age-appropriate DTP vaccination, five were unvaccinated, seven were incomplete, and none were completely vaccinated.




*NPS: nasopharyngeal swabs. PCR: polymerase chain reaction.*

**Figure 1. Diagram of active case finding in Villages 4-6, Muang Tia Subdistrict, Mae Lan District, Pattani Province, September–December 2023**

Among 11 confirmed cases, cough symptoms lasted 2–19 days (median 7 days, interquartile range 5–14 days), with four lasting 2 weeks. Typical symptoms included paroxysmal cough (n=4), post-tussive vomiting (n=2), whooping cough (n=1), and cyanosis (n=1) with no apnea. One case was hospitalized, and no deaths occurred. The hospitalized case was the 11-month-old boy index case from Village 5. He had no underlying diseases and never received the DTP vaccine. On 13 Oct 2023, he developed inspiratory whooping and dyspnea and went to the hospital the next day. He was diagnosed with acute bronchitis. He was admitted due to suspected leukemia with a white blood cell (WBC) count of 63,000 cells per microliter, neutrophil 21.4%, and lymphocyte 75.3%. He was subsequently referred to another hospital and diagnosed with pertussis pneumonia and leukemoid reaction with lymphocyte predominate at the third hospital, 11 days after the onset date. He received azithromycin and DTP vaccination and recovered.

The overall attack rate was 0.6% (15/2,394), highest in Village 5 (1.6%). Children aged 1–4 years were most affected (3.4%), followed by those under 1 year (2.9%). The attack rate among household and community contacts was 21.1% (4/19) and 11.1% (2/18), respectively. Regarding DTP vaccination in children aged 0–7 years, the attack rate was highest in the unvaccinated (10.8%), lower in the incomplete (6.6%), and 0.0% in the complete group (Table 1).

### Source of Infection and Risk Factors of Disease Transmission

Seven days after the index case's onset, some household and community contacts developed symptoms. The index case shared a room with his family, spent time with his babysitter and grandmother, and slept with his parents. They rarely wore masks, frequently played and ate together, and shared personal items.

**Table 1. Attack rate of pertussis cases by village, gender, age group, DTP vaccination status, and type of contact in Villages 4-6, Muang Tia Subdistrict, Mae Lan District, Pattani Province, September–December 2023**

| Classification | | Population | Cases | Attack rate (%) |
|---|---|---|---|---|
| **Village** | Village 4 | 969 | 5 | 0.5 |
| | Village 5 | 639 | 10 | 1.6 |
| | Village 6 | 786 | 0 | 0.0 |
| | Total | 2,394 | 15 | 0.6 |
| **Gender** | Male | 1,194 | 8 | 0.7 |
| | Famale | 1,200 | 7 | 0.6 |
| **Age group (years)** | <1 | 35 | 1 | 2.9 |
| | 1–4 | 177 | 6 | 3.4 |
| | 5–9 | 238 | 3 | 1.3 |
| | 10–19 | 490 | 2 | 0.4 |
| | 20–29 | 401 | 0 | 0.0 |
| | 30–39 | 342 | 2 | 0.6 |
| | 40–49 | 228 | 0 | 0.0 |
| | 50–59 | 225 | 1 | 0.4 |
| | ≥60 | 258 | 0 | 0.0 |
| **DTP vaccination status in children aged 0–7 years** | None | 37 | 4 | 10.8 |
| | Incomplete | 79 | 5 | 6.3 |
| | Complete | 174 | 0 | 0.0 |
| **Type of contact** | Household | 19 | 4 | 21.1 |
| | Community | 18 | 2 | 11.1 |
| | Hospital | 31 | 0 | 0.0 |

*DTP: diphtheria, tetanus, pertussis.*

As shown in Figure 2, cases in Villages 4 and 5 developed symptoms concurrently without obvious direct contact with one another (Figure 3). Among 15 cases, 52.2% had identified sources, including household and community contacts. The remaining 47.8% had unidentified sources, including visits to crowded places like markets, where two confirmed cases were vendors. Mask-wearing was rare among vendors and clients. No URI clusters were reported in two related schools, and no cases had a travel history to epidemic districts.

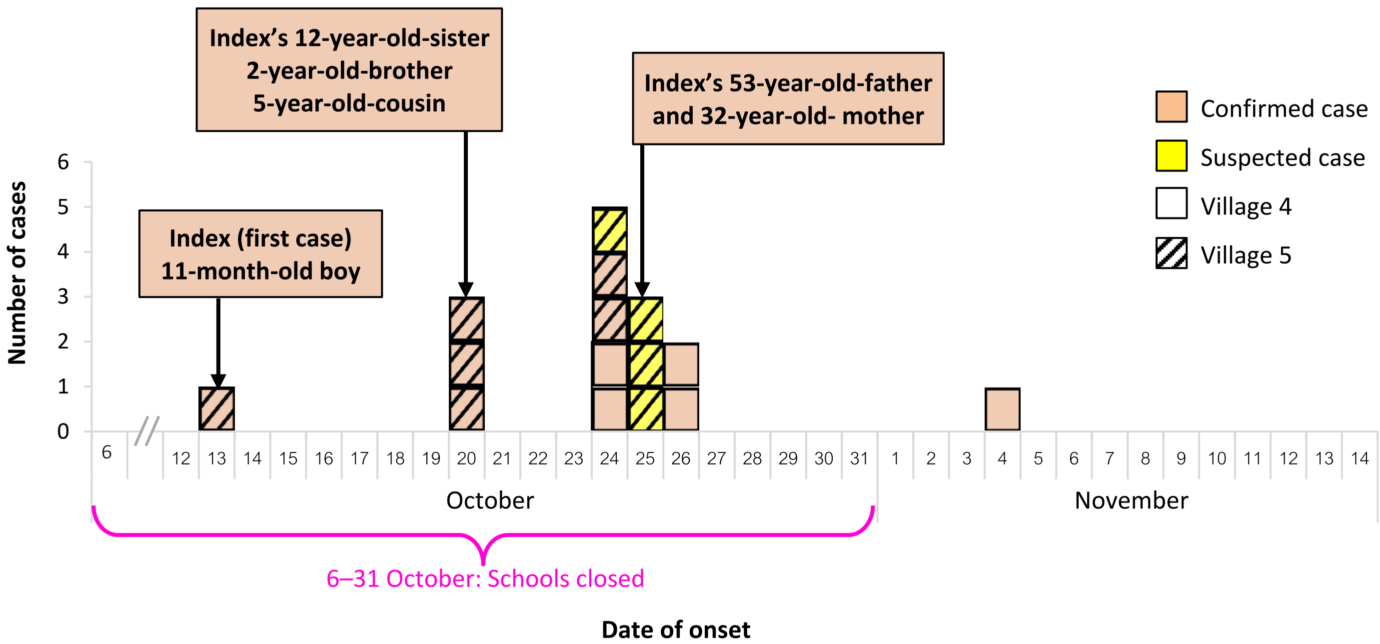



**Figure 2. Number of pertussis cases in Villages 4-6, Muang Tia Subdistrict, Mae Lan District, Pattani by onset date during 22 Sep–16 Dec 2023 (n=15)**

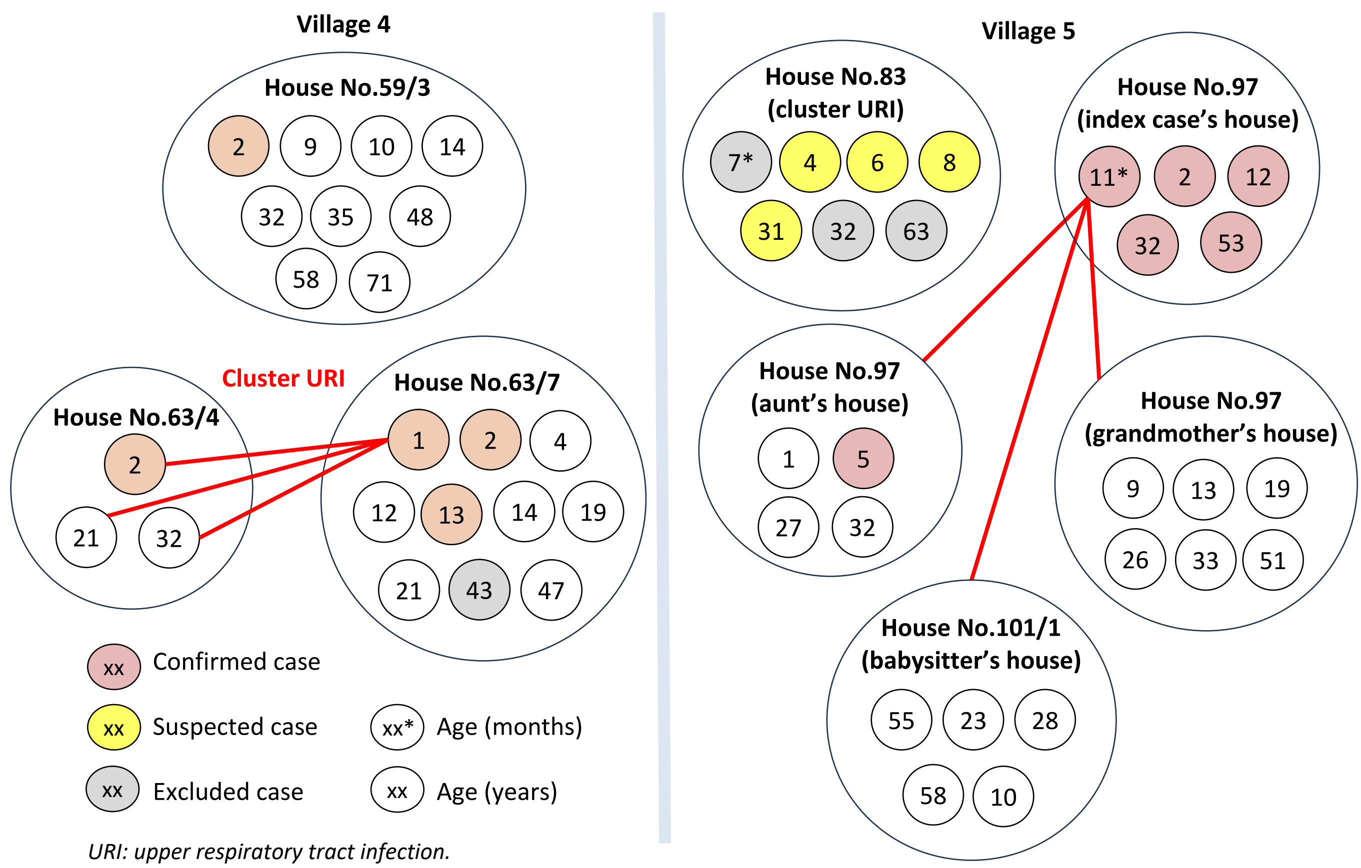



**Figure 3. Linkage of pertussis cases in Villages 4 and 5, Muang Tia Subdistrict, Mae Lan District, Pattani Province, September–December 2023**

### Vaccine Coverage in the Community

In 2023, DTP3 vaccine coverage was low across many districts in Pattani Province, including Mae Lan District (64.3%). In Mae Lan District, Muang Tia Subdistrict had the lowest DTP3 vaccine coverage (54.3%), with Villages 4–6 showing particularly low rates (68.2%, 35.7%, and 35.7%, respectively) as shown in Figure 4.

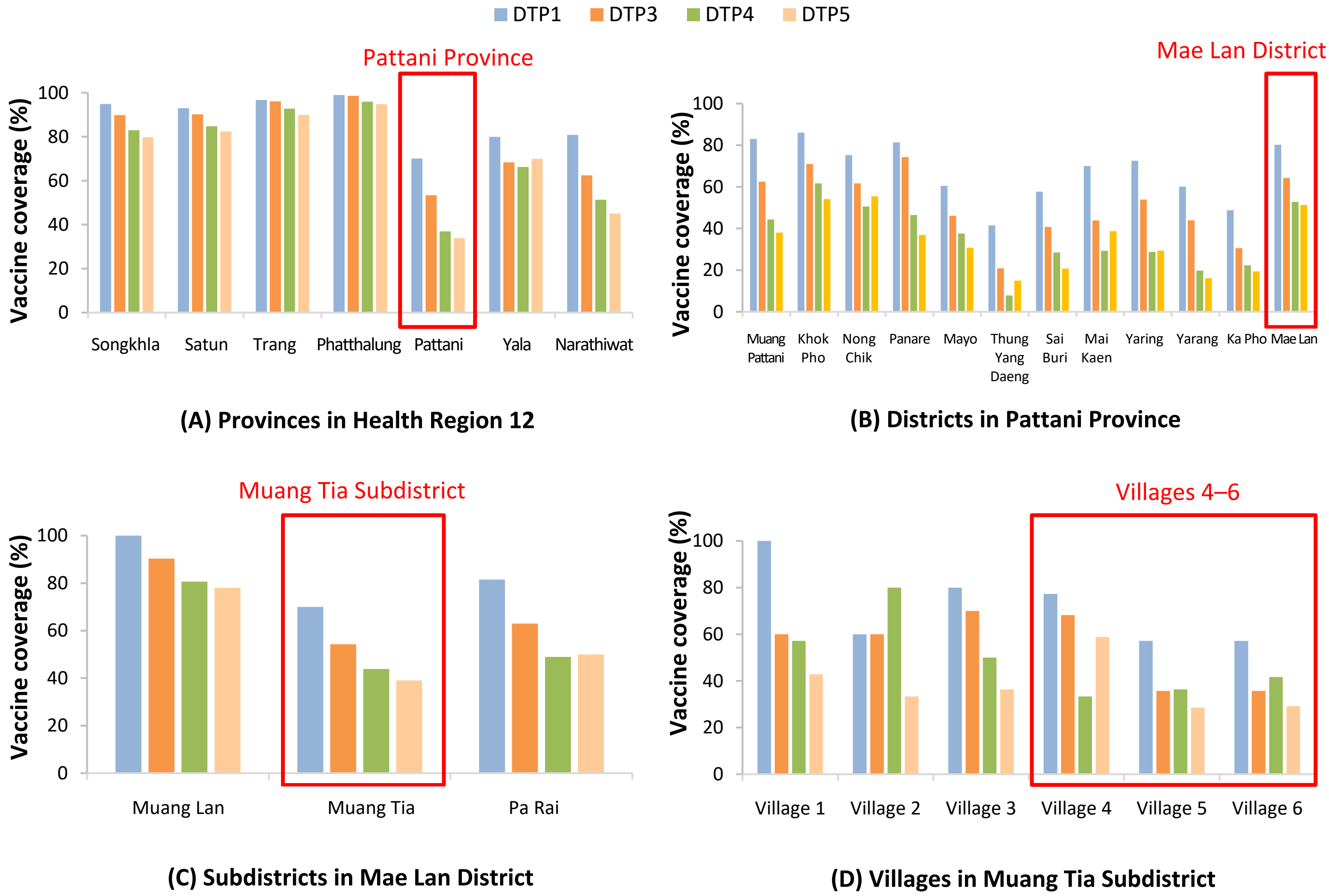



**Figure 4. DTP vaccine coverage for Doses 1, 3, 4, and 5 in Thailand in 2023 by province in Health Region 12 (A), districts in Pattani Province (B), subdistricts in Mae Lan District (C), and villages in Muang Tia Subdistrict (D), with study areas highlighted**

Regarding the vaccination survey in Villages 4–6, we surveyed 84.0% (42/50) of children aged 0–1 year from 81.8% (36/44) of households with children aged 0–1 year, along with 2 households with pregnant women. Age-appropriate DTP coverage in children aged 0–1 year was lowest in Village 4 (15.4%), followed by Villages 6 and 5 (Table 2). Interviews revealed that low coverage was due to parents' fear of fever or adverse reactions, concerns about missing work, low awareness of immunization benefits, and caregiver migration.

**Table 2. Age-appropriate DTP vaccine coverage in children aged 0–1 year from the survey in Villages 4–6, Muang Tia Subdistrict, Mae Lan District, Pattani Province**

| Village | Age-appropriate DTP vaccine coverage in children aged 0–1 year* | 95% CI |
|---|---|---|
| **4** | 15.4% (2/13) | 1.9–45.4 |
| **5** | 40.0% (4/10) | 12.2–73.8 |
| **6** | 25.0% (3/12) | 5.5–57.2 |
| **Total (weighted)** | **25.0%** | **10.4–39.6** |

**Seven children aged less than two months were excluded (two, three, and two persons from Villages 4, 5, and 6).*
*CI: confidence interval.*

**Post-hoc Analysis of Sensitivity and Specificity of National and Modified Pertussis Definitions**

The national definition had a sensitivity of 9.09% (95% CI 0.2%–41.3%) and specificity of 88.9% (95% CI 70.8%–97.6%). The modified definition had a sensitivity of 81.8% (95% CI 48.2%–97.7%) and specificity of 70.4% (95% CI 49.8%–86.2%), as shown in Figure 5.

**A) National definition:**

Cough ≥2 weeks AND a typical pertussis symptoms (paroxysmal cough, inspiratory whooping, post-tussis vomiting, apnea)

| | PCR positive | PCR negative |
|---|---|---|
| Met definition | 1 | 3 |
| Did not meet | 10 | 24 |

**Sensitivity** 9.09% (95% CI 0.23%–41.28%)
**Specificity** 88.89% (95% CI 70.84%–97.65%)

**B) Modified definition:**

1. Cough (any duration) AND a typical pertussis symptom (paroxysmal cough, inspiratory whooping, post-tussive vomiting, cyanosis, apnea) OR

2. Close contact with a confirmed case AND a URI symptom (cough/rhinorrhea/sore throat)

| | PCR positive | PCR negative |
|---|---|---|
| Met definition | 9 | 8 |
| Did not meet | 2 | 19 |

**Sensitivity** 81.82% (95% CI 48.20%–97.72%)
**Specificity** 70.37% (95% CI 49.82%–86.25%)

*URI: upper respiratory tract infection. PCR: polymerase chain reaction.*

**Figure 5. Sensitivity and specificity of national (A) and the modified (B) pertussis case definitions**

## Action Taken

Post-exposure prophylaxis and treatment were provided to all 68 close contacts and 16 individuals who met case definitions while awaiting laboratory results, following the same regimen. These included azithromycin for adults (500 mg orally on day 1, followed by 250 mg daily on days 2–5) and erythromycin for children (40 mg/kg/day orally, divided into four doses for 14 days). Catch-up DTP vaccination was offered to 49 children, but only four parents/guardians accepted. Two pregnant women were offered the Tdap vaccine, but neither received it. Disease surveillance was set up; however, we identified no more pertussis cases until 16 Dec 2023. We also attended meetings with the Pattani Provincial Communicable Disease Committee and the Communicable Disease Control Unit Team from the provinces of Pattani, Yala, and Narathiwat to present findings, propose surveillance definitions, and discuss control measures.

## Discussion

*Bordetella pertussis* was confirmed as the cause. Confirmed cases manifested fewer typical symptoms compared to other studies, where paroxysmal cough ranged from 63–90%, whooping cough 8–79%, and post-tussive vomiting 42–53%.[19] In our study, only 36% had a cough lasting 2 weeks. As a result, relying on the national definition may delay case identification. In contrast, the modified definition, which focuses on typical symptoms rather than cough duration, demonstrated higher sensitivity. This approach could enable earlier detection and reduce transmission, particularly in low DTP vaccination areas.

An 11-month-old index case, diagnosed with a leukemoid reaction and pertussis pneumonia, highlights the severe risk in children. A leukemoid reaction is a nonleukemic WBC elevation above 50,000 cells per microliter. This can be typically found in infants and is linked to a tenfold higher risk of death.[20] Children under 1 year are particularly vulnerable to pertussis complications, with 33% requiring hospitalization and 22% developing pneumonia.[1,2] Despite early medical attention, the index case's diagnosis occurred 11 days after onset. The modified definition could aid early diagnosis. Healthcare providers should suspect pertussis in respiratory infections, considering symptoms, DTP history, and WBC results.

This pertussis outbreak was likely due to low DTP coverage below the WHO recommendation of 90%.[13] Our findings highlighted low DTP3 coverage and inadequate age-appropriate DTP coverage among children aged 0–1 year in Villages 4–6. The highest attack rates were among unvaccinated and incompletely vaccinated groups, with a 2.9% rate in children under 1 year. Studies showed that children aged 0–1 year are highly vulnerable and benefit from completing three DTP doses, with efficacy rising from 55.3% for one dose to 83.5% for three doses.[21]

Low vaccine coverage was influenced by factors such as fear of side effects, low awareness, and caregiver migration. This aligns with studies highlighting parental concerns about fever and pain, particularly in low-health-literacy areas.[14,22] Improving coverage in children aged 0–1 year through early immunization starting at 6 weeks of age, with subsequent doses 4 weeks apart, is essential for achieving herd immunity.[23,24] In addition, strategies should include post-immunization follow-up, awareness campaigns, and healthcare providers' training to address parental concerns through easy-to-understand educational materials and community engagement. Offering DTaP instead of DTwP could reduce side effect concerns, despite its higher cost and slightly lower efficacy.[10,25–27] Additionally, ensuring pregnant women receive Tdap or aP at 27–36 weeks of gestation is crucial to protect newborns.[8]

Household and community contacts played a key role in disease transmission, as individuals shared living spaces and items while rarely wearing masks. High attack rates were observed among these contacts, consistent with studies showing 70–90% transmission in households and up to 50% in the community.[28–31] The simultaneous clusters in Villages 4 and 5 suggested widespread community transmission. Adolescents and adults with milder symptoms can still transmit pertussis.[32,33] The index case likely contracted the infection from family members with unrecognized symptoms, as family members are often the source in infants.[34] These findings underscore the importance of public health measures, including distancing, mask-wearing, and hand washing, to control outbreaks, particularly in crowded areas.

Post-exposure prophylaxis is crucial in controlling pertussis spread, particularly in high-risk settings such as households, healthcare facilities, and communities. Macrolides and co-trimoxazole should be administered within 21 days of exposure, regardless of vaccination history.[4] These agents effectively eliminate *Bordetella pertussis* from the nasopharynx, reduce duration, severity, and transmission.[4,5] Prophylaxis is recommended for all household contacts and high-risk individuals such as infants, pregnant women, or those with pre-existing conditions.[4,5]

## Limitations

Our study had limitations. First, nasopharyngeal swabs were not performed on all suspected cases or contacts due to a lack of symptoms and cooperation, potentially underreporting cases. However, post-exposure prophylaxis and prevention measures were administered. Secondly, only 38 individuals underwent *Bordetella pertussis* PCR testing, which was lower than the required sample size, resulting in insufficient statistical power. Lastly, although the vaccination survey successfully included 84% of children aged 0–1 year, we missed eight children. This could lead to either an under- or over-estimation of the age-appropriate DTP coverage.

## Recommendations

The Division of Vaccine-Preventable Disease, Provincial Communicable Disease Committee, and District Health Board should enhance DTP coverage among children aged 0–1 year to over 90%. This can be achieved through local collaboration, post-immunization follow-up, and increased awareness. Further studies should assess whether DTaP is worth investing in compared to DTwP.

To prevent severe disease among children aged 0–1 year, DTP vaccination should start at 6 weeks of age with 4-week intervals.[23,24] Pregnant women should receive Tdap or aP at 27–36 weeks of gestation.

In low-vaccination areas, a modified pertussis definition should be established to enhance case detection sensitivity. Healthcare providers should prioritize pertussis in differential diagnoses, especially in cases of leukemoid reactions. Furthermore, distancing, mask-wearing, and hand-washing measures should be emphasized in crowded places to prevent future outbreaks.

### Conclusion

A pertussis outbreak in Muang Tia Subdistrict, Pattani Province, affected at least 11 confirmed and 4 suspected cases, including one hospitalized pneumonia case with no deaths. The attack rate in children under 1 year was 2.9%. Key factors included low vaccination coverage, with only 25.0% of children aged 0–1 years receiving age-appropriate DTP vaccine. High community transmission was also observed, with a pertussis positivity rate of 50%. A modified pertussis case definition demonstrated higher sensitivity (81.8%) compared to the national definition (9.1%). Increasing vaccine coverage to 90% and using a modified pertussis definition in low-vaccination areas are recommended.

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### Conflicts of Interest

The authors had no conflicts of interest.

### Declaration of AI and AI-assisted Technologies in the Writing Process

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## References

1. Havers FP, Moro PL, Hariri S, Skoff T. Chapter 16: pertussis [Internet]. Atlanta: Centers for Disease Control and Prevention (US); 2024 Apr 12 [cited 2025 Mar 25]. <https://www.cdc.gov/pinkbook/hcp/table-of-contents/chapter-16-pertussis.html?CDC_AAref_Val=https://www.cdc.gov/vaccines/pubs/pinkbook/pert.html>
2. Centers for Disease Control and Prevention (US). Symptoms of whooping cough [Internet]. Atlanta: Centers for Disease Control and Prevention; 2024 Apr 2 [cited 2025 Mar 25]. <https://www.cdc.gov/pertussis/signs-symptoms/index.html>
3. Lauria AM, Zabbo CP. Pertussis [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 [cited 2024 Jan 25]. <https://www.ncbi.nlm.nih.gov/books/NBK519008/>
4. Janewongwirot P, Anugulruengkitt S. Pertussis. In: Anugulruengkitt S, Jantarabenjakul W, Puthanakit T, Pancharoen C, editors. New faces of pediatric infectious diseases: epidemiology, diagnosis, treatment and prevention. 2nd ed. Bangkok: Active printing; 2022. p. 407–21.
5. Tiwari T, Murphy TV, Moran J; National Immunization Program, Centers for Disease Control and Prevention (US). Recommended antimicrobial agents for the treatment and postexposure prophylaxis of pertussis: 2005 CDC Guidelines [Internet]. MMWR Recomm Rep. 2005 Dec 9 [cited 2024 Jan 25];54(RR-14):1–16. <https://www.cdc.gov/mmwr/preview/mmwrhtml/rr5414a1.htm>
6. Bortolussi R, Miller B, Ledwith M, Halperin S. Clinical course of pertussis in immunized children. Pediatr Infect Dis J. 1995 Oct;14(10): 870-4. doi:10.1097/00006454-199510000-00010.
7. Centers for Disease Control and Prevention (US). Postexposure antimicrobial prophylaxis [Internet]. Atlanta: Centers for Disease Control and Prevention; 2024 Apr 2 [cited 2025 Mar 25]. <https://www.cdc.gov/pertussis/php/postexposure-prophylaxis/?CDC_AAref_Val=https://www.cdc.gov/pertussis/pep.html>
8. Pediatric Infectious Disease Society of Thailand. Thailand vaccination schedule for children in 2023 [Internet]. Bangkok: Pediatric Infectious Diseases Society of Thailand; [cited 2024 Jan 25]. <https://www.pidst.or.th/A1291.html>. Thai.
9. Division of Communicable Diseases, Department of Disease Control, Ministry of Public Health. Vaccination schedule of Ministry of Public Health Thailand, 2023 [Internet]. Nonthaburi: Division of Communicable Diseases, Department of Disease Control; [cited 2024 Jan 25]. 7 p. <https://ddc.moph.go.th/uploads/ckeditor2/dcd/files/1_Vaccine%20Schedule%202566_V3.pdf>
10. Alghounaim M, Alsaffar Z, Alfraij A, Bin-Hasan S, Hussain E. Whole-cell and acellular pertussis vaccine: reflections on efficacy. Med Princ Pract. 2022;31(4):313–21. doi:10.1159/000525468.
11. Hattasingh W. DTP vaccine. In: Pediatric Infectious Disease Society of Thailand, editor. Vaccine [Internet]. Bangkok: Pediatric Infectious Disease Society of Thailand; [cited 2024 Jan 25]. p. 165–72. <https://pidst.or.th/userfiles/15_%E0%B8%A7%E0%B8%B1%E0%B8%84%E0%B8%8B%E0%B8%B5%E0%B8%99%E0%B8%9B%E0%B989%E0%B8%AD%E0%B8%87%E0%B8%81%E0%B8%B1%E0%B8%99%E0%B9%82%E0%B8%A3%E0%B8%84%E0%B8%84%E0%B8%AD%E0%B8%95%E0%B8%B5%E0%B8%9A-%E0%B8%9A%E0%B8%B2%E0%B8%94%E0%B8%97%E0%B8%B0%E0%B8%A2%E0%B8%B1%E0%B8%81-%E0%B9%84%E0%B8%AD%E0%B8%81%E0%B8%A3%E0%B8%99.pdf>. Thai.
12. National Center for Immunization and Respiratory Diseases, Centers for Disease Control and Prevention (US). About diphtheria,

tetanus, and pertussis vaccines [Internet]. Atlanta: Centers for Disease Control and Prevention (US); 2022 Sep 6 [cited 2024 Feb 6]. <https://www.cdc.gov/vaccines/vpd/dtap-tdap-td/hcp/about-vaccine.html>

13. World Health Organization. 1 in 10 infants worldwide did not receive any vaccinations in 2016 [Internet]. Geneva: World Health Organization; 2017 Jul 17 [cited 2024 Feb 8]. <https://www.who.int/news/item/17-07-2017-1-in-10-infants-worldwide-did-not-receive-any-vaccinations-in-2016>

14. Jeharsae R, Hasamoh A, Takek M, Jehalee H, Tohpa H, Piriyasart J. Situation analysis of children in the Southern Border Provinces 2018–2019 [Internet]. Songkhla: Prince of Songkla University; 2019 [cited 2024 Jan 26]. 95 p. <https://nurmis-center.pn.psu.ac.th/covid19/displaypdf1.php?idpage=2>

15. Thailand Health Data Center Dashboard. Coverage of 1-year-old children receiving BCG, HBV1, DTP1, DTP3, HBV3, Hib3, Polio3, MMR1, IPV, and Rota vaccines by quarter. [Internet]. Nonthaburi: Ministry of Public Health; [cited 2023 Nov 16]. <https://hdc.moph.go.th/center/public/standard-report-detail/c88658f4d09acb8c76e6c06ffb58ebaf>. Thai.

16. Division of Epidemiology, Department of Disease Control (TH). Definitions and guidelines for disease prevention and control measures for close contacts of COVID-19 cases/infected individuals [Internet]. Nonthaburi: Division of Epidemiology, Department of Disease Control; 2022 May 21 [cited 2023 Oct 27]. 6 p. <https://ddc.moph.go.th/viralpneumonia/file/g_srrt/g_srrt_210565n.pdf>. Thai.

17. Division of Epidemiology, Department of Disease Control (TH). Case definition for communicable disease surveillance, Thailand, 2020 [Internet]. 1st ed. Bangkok: Division of Epidemiology; 2020 [cited 2023 Oct 26]. <http://klb.ddc.moph.go.th/dataentry/handbook/form/113>

18. Ghanaie RM, Karimi A, Sadeghi H, Esteghamti A, Falah F, Armin S, et al. Sensitivity and specificity of the World Health Organization pertussis clinical case definition. Int J Infect Dis. 2010 Dec;14(12):e1072–5. doi:10.1016/j.ijid.2010.07.005.

19. Decker MD, Edwards KM. Pertussis (whooping cough). J Infect Dis. 2021 Sep 30;224(Suppl 4):S310–20. doi:10.1093/infdis/jiaa469.

20. Berger JT, Carcillo JA, Shanley TP, Wessel DL, Clark A, Holubkov R, et al. Critical pertussis illness in children. Pediatr Crit Care Med. 2013;14(4):356–65. doi:10.1097/PCC.0b013e31828a70fe.

21. Quinn HE, Snelling TL, Macartney KK, McIntyre PB. Duration of protection after first dose of acellular pertussis vaccine in infants. Pediatrics. 2014 Mar;133(3):e513–9. doi:10.1542/peds.2013-3181.

22. Apiwachaneewong S, Thammapalo S, Phetchatree S, Musow A. Success factors on best practice performance of the immunization program of District Health Promotion Service in 3 Southern Border Provinces, Thailand. Journal of Health Science. 2019;28(2):263–72.

23. Division of Vaccine Preventable Diseases, Department of Disease Control, Ministry of Public Health (TH). Vaccination and immunization in 2019 [Internet]. Nonthaburi: Division of Vaccine Preventable Diseases; 2019 [cited 2024 Jan 25]. 370 p. <https://www.pidst.or.th/A771.html?action=download&file=887_%E0%B8%95%E0%B8%B3%E0%B8%A3%E0%B8%B2%E0%B8%A7%E0%B8%B1%E0%B8%84%E0%B8%8B%E0%B8%B5%E0%B8%99-62.pdf>

24. Division of Communicable Diseases, Department of Disease Control, Ministry of Public Health (TH). Pertussis immunization measures in the Deep South of Thailand [Internet]. Nonthaburi: Division of Communicable Diseases; 2023 [cited 2024 Feb 2]. 7 p. <https://ddc.moph.go.th/uploads/publish/1505620231204060610.pdf>

25. Division of Communicable Diseases, Department of Disease Control, Ministry of Public Health (TH). Vaccination and immunization in 2013 [Internet]. Nonthaburi: Division of Communicable Disease; 2013 [cited 2024 Feb 8]. p. 99–108. <http://data.nvi.go.th/vaccineknowledge/file_download/epi-program/dtp.pdf>

26. Drutz JE, Boom JA. Diphtheria, tetanus, and pertussis immunization in children 6 weeks through 6 years of age [Internet]. Massachusetts: UpToDate; 2023 [cited 2024 Jan 26]. <https://www.uptodate.com/contents/diphtheria-tetanus-and-pertussis-immunization-in-children-6-weeks-through-6-years-of-age/print>

27. Korkmaz HA, Aydin A, Unal B. Comparison of acellular pertussis-tetanus-diphtheria vaccines

and whole-cell pertussis-tetanus-diphtheria vaccines in infancy. Paediatr Int Child Health. 2014 Aug;34(3):198–202. doi:10.1179/2046905513Y.0000000110.

28. Public Health England. Guidelines for the public health management of pertussis in England. 1st ed. London: Public Health England; 2018.

29. Deen JL, Mink CM, Cherry JD, Christenson PD, Pineda EF, Lewis K, et al. Household contact study of bordetella pertussis infections. Clin Infect Dis. 1995 Nov;21(5):1211–9. doi:10.1093/clinids/21.5.1211.

30. Mortimer EA. Pertussis and its prevention: a family affair. J Infect Dis. 1990 Mar; 161(3): 473–9. doi:10.1093/infdis/161.3.473.

31. Britton P, Jones C. Pertussis prophylaxis. Ausst Prescr. 2012;35(3):82–4.

32. Immunization.org. Pertussis (whooping cough): questions and answers information about the diseases and vaccines [Internet]. Minnesota: Immunize.org; 2023 [cited 2024 Feb 2]. 4 p. <https://www.immunize.org/wp-content/uploads/catg.d/p4212.pdf>

33. Public Health Specialist. Pertussis [Internet]. Wellington: Health New Zealand; 2023 [cited 2024 Feb 2]. 19 p. <https://intel.cph.co.nz/media/47370/pertussis-protocol.pdf>

34. Cherry JD. Pertussis in young infants throughout the world. Clin Infect Dis. 2016 Dec 1;63(suppl 4):S119–22. doi:10.1093/cid/ciw550.

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Department of Disease Control, Ministry of Public Health, Thailand
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# Delayed Tuberculosis Detection in Healthcare Workers: Lessons from a Tuberculosis Outbreak in a Tertiary Care Hospital

Thanaphon Yisankhun[1]*, Saran Sujinpram[2], Phimruethai Chongkratok[3], Sattawat Sanmai[3], Vatcharapong Sungketkit[2], Khanuengnij Yueayai[3]

1 Field Epidemiology Training Program, Division of Epidemiology, Department of Disease Control, Ministry of Public Health, Thailand

2 Surin Provincial Health Office, Office of the Permanent Secretary, Ministry of Public Health, Thailand

3 Office of Disease Prevention and Control 9 Nakhon Ratchasima, Department of Disease Control, Ministry of Public Health, Thailand

*Corresponding author, email address: cocoedmetal@gmail.com

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**Abstract**

In March 2024, a healthcare worker (HCW) at a tertiary care hospital was confirmed with pre-extensively drug-resistant tuberculosis (pre-XDR-TB) after a delay of over 30 days following an abnormal chest X-ray (CXR). We investigated to verify the outbreak and diagnosis, describe its characteristics, review the HCW TB screening program, and identify factors associated with adequate CXR follow-up. We reviewed TB cases among HCWs in the hospital and conducted contact investigations via TB symptoms, CXR screening, and sputum GeneXpert tests. Confirmed cases were defined by positive bacteriological test, while probable cases were defined otherwise. We interviewed stakeholders to identify possible causes of delayed TB detection. We confirmed three HCWs with pulmonary TB (one pre-XDR-TB) and identified one probable case. There were three females and one male, all aged 30–39, and three had delayed detection. The attack rate among 90 contacts was 3.3%. In 2023, 32 out of 310 HCWs with abnormal CXRs (10%) completed CXR follow-up and 19 (6%) underwent sputum testing. The TB screening program faced challenges due to deviations from national guidelines, reliance on clinician judgment, and limited resources, contributing to delayed detection. A history of TB treatment and receiving sputum test for TB were significantly associated with adequate CXR follow-up, while good tuberculosis knowledge was probably associated with adequate CXR follow-up. This outbreak highlights the need to improve TB screening processes and education to reduce delayed detection in HCWs.

**Keywords:** tuberculosis, healthcare workers, outbreak, knowledge, delayed detection, screening

## Introduction

Pulmonary tuberculosis (PTB) is a contagious disease caused by *Mycobacterium tuberculosis* (MTB), spreading through the air.[1] Its incubation period ranges from weeks to years.[2] Symptoms include prolonged cough, chest pain, and hemoptysis. Drug-susceptible tuberculosis (DS-TB) is treatable with a 6-month standard regimen. Drug-resistant tuberculosis (DR-TB) arises from improper TB medication use (acquired drug resistance), or exposure to DR-TB strains (primary drug resistance).[3,4] Multidrug-resistant tuberculosis (MDR-TB) is resistant to rifampicin and isoniazid. Pre-extensively drug-resistant TB (pre-XDR-TB) is MDR/rifampicin-resistant TB with fluoroquinolone resistance, while extensively drug-resistant TB (XDR-TB) is additionally resistant to other Group A drugs.[5] MDR-TB treatment lasts at least 9 months with 75% success rate, while XDR-TB requires 20 months with 50% success rate.[6] Post-TB complications are more common in DR-TB cases.[3]

In 2022, there were approximately 400,000 MDR/rifampicin-resistant TB cases globally, including

170,000 in Southeast Asia.[7,8] In 2023, Thailand reported 948 DR-TB cases, including 56 pre-XDR-TB and 6 XDR-TB cases.[9]

Delayed detection, especially treatment delays exceeding 60 days, worsens disease progression.[10] Early detection and treatment are critical for control, with systematic screening of high-risk groups using chest X-rays (CXR) recommended.[11] A positive test result should trigger further investigation.[12] While increased screening identifies more presumptive cases, access to diagnostic services remains crucial.[13] Patient delay is the time from symptom onset to first consultation. Health system delay is from first consultation to diagnosis. In low- and middle-income countries, median delays are 27 days for patient delay, 18 days for health system delay, and 57 days for total delay.[14]

Healthcare workers (HCWs) have a threefold higher TB incidence than the general population.[15] Annual CXR screening is recommended, or biannual if working directly with TB patients. Abnormal CXR results warrant a sputum test and follow-up CXR in six months.[16,17] While TB prevalence in HCWs has been studied, challenges in HCW screening remain unexplored.

On 1 Mar 2024, a pre-XDR-TB case in an HCW at a tertiary care (Hospital A) was reported. During 5–29 Mar 2024, we investigated to verify the diagnosis, confirm the outbreak, identify contacts and possible source cases, and describe the epidemiological characteristics. The investigation also reviewed the HCW TB screening program at Hospital A, assessed factors influencing follow-up of abnormal CXRs, and provided recommendations.

## Methods

### Operational Definitions

An HCW is Hospital A employee. Front-line HCWs have patient contact, while back-office HCWs do not. TB contact, case, and outbreak definitions are as follows:

- Household contact: a person living with a probable/confirmed case from 1 Jan 2023 to 5 Mar 2024.
- Close contact: a person who was not a household contact but spent ≥8 hours per day or ≥120 hours per month with a probable/confirmed case from 1 Jan 2023 to 5 Mar 2024.
- Suspected case: index case or contact with one of following criteria: chronic cough, fever >2 weeks, hemoptysis, significant weight loss, abnormal CXR.
- Probable case: a suspected case with negative bacteriological test but TB diagnosed by physician.
- Confirmed case: a suspected case with bacteriologically confirmed TB.
- Confirmed pre-XDR-TB case: confirmed case with sputum drug sensitivity resistant to isoniazid, rifampicin, and fluoroquinolone.
- Tuberculosis outbreak: a cluster of ≥2 TB cases within three months with epidemiological linkage.
- Abnormal CXR: CXR showing active TB or other abnormalities.
- Delayed TB detection: a period >30 days between first abnormal CXR and TB diagnosis.
- Adequate CXR follow-up: repeat CXR within six months after abnormal CXR.

### Descriptive Study

We reviewed the National Tuberculosis Information Program and the paper-based HCW TB registry at Hospital A for TB cases diagnosed between 2019 and 2023. The index case was interviewed on symptoms, medical history, and previous TB contacts. DR-TB medical records in the index case's workplace from 2020-2023 were reviewed. Active case finding involved: (1) reviewing admission records to identify HCWs exposed to the index case; (2) symptom screening and CXR for all contacts; (3) sputum GeneXpert MTB/rifampicin testing for contacts with abnormal CXRs and selected contacts with normal CXRs based on hospital's risk and cost consideration such as increased time spent with the index case, absence of using protective equipment, or having health insurance from the civil service medical benefit scheme; (4) MTB culture for probable/confirmed TB cases. Data were collected via structured questionnaire including age, gender, occupation, symptoms, contact type, CXR, laboratory results, and treatment. Data were summarized by frequency, proportion, ratio, interquartile range (IQR), and median.

We reviewed the TB screening program at Hospital A and interviewed a physician, laboratory technician, nurse, and public health officer, regarding the HCW screening processes and staff roles. We described the HCW TB screening workflow, identifying potential gaps contributing to delayed TB detection, and screening results in 2023.

### Environmental Study

We surveyed the index case' s household and workplace to assess the TB transmission risk. Household assessment included location, housing type, ventilation, sun exposure, and living areas. Workplace assessment included reviewing ventilation assessment report, bed capacity, and active beds number.

### Analytical Study

A retrospective cohort study was conducted to analyze factors associated with adequate CXR follow-up after the 2023 CXR screening (January–March). Eligible HCWs had radiologist-reported lung abnormalities and responded to our questionnaire. We excluded active TB cases, follow-up CXR for comorbidities, and positive sputum test for TB. The questionnaire adapted from the World Health Organization guidelines, a previous study, and then reviewed by a TB medical epidemiologist.[18,19] The questionnaire covered socio-demographics, TB knowledge (34 questions on causes, symptoms, transmission, risk factors, diagnosis, treatment, and prevention). Correct answers scored 1, incorrect 0, with total scored from 0–34. Scores >20 (10% more than the reference) were categorized as "good" TB knowledge and "poor" otherwise.[19] The questionnaire' s reliability (Cronbach' s alpha) was 0.86. Other variables included age, gender, education, HCW type, comorbidities, TB treatment history, history of TB exposure, TB symptoms, and receiving a sputum test for TB.[14] Univariable analysis used chi-square tests, and multivariable analysis using Poisson regression with robust standard errors was calculated for an adjusted risk ratio (RR) for variables with $p$-value <0.2 in univariable analysis.[20] Statistical significance was defined as $p$-value <0.05, using STATA version 16.

### Ethics

This study was part of routine outbreak response and did not require ethics approval.

## Results

### Descriptive Study

Hospital A is a 914-bed regional hospital employing 2,935 HCWs. During 2019–2023, there were 718, 738, 615, 636, 476 new TB cases annually, respectively (total 3,183), of which 4, 7, 7, 6, 6 were HCWs, respectively (total 30) with the first pre-XDR-TB case reported in 2023.

The index case was a 31-year-old Thai female with mild anemia and no other comorbidities nor prior TB history, working as a patient care assistant at Hospital A since 2020. Her initial CXR was normal. In March 2023, she developed an intermittent cough with reticular opacities CXR, but sputum acid-fast bacillus (AFB) and polymerase chain reaction (PCR) tests were negative, and no follow-up CXR was done. By mid-January 2024, she experienced fever and fatigue and sought medical care on 1 February. After several visits, she was diagnosed with PTB on 8 Feb 2024 after miliary opacities appeared on her CXR. Initial sputum AFB and PCR tests were negative for TB, and she started standard TB treatment. A GeneXpert MTB/XDR test on 27 February confirmed pre-XDR-TB, and she was switched to a drug-resistant TB regimen on 10 Mar 2024. In May 2024, a sputum liquid culture grew nontuberculous mycobacteria, but no drug susceptibility testing was performed.

The index case had no known close TB contacts in the past two years but regularly interacted with TB patients at work, while wearing only a surgical mask. Between 2020 and 2023, two pre-XDR-TB patients (possible source cases) were admitted to the isolation room, where the index case worked. Her tasks included recording vital signs, feeding, and bathing these patients, spending 10–30 minutes per session, three times daily.

Contact investigation identified eight household contacts and 82 close contacts: 47 HCWs from the same ward as the index case and 35 HCWs from the wards where she was hospitalized. Among household contacts, one had an abnormal CXR but a negative sputum GeneXpert test. Among the close contacts, 77 underwent CXR with eight showing abnormalities, 49 underwent sputum GeneXpert MTB/rifampicin test with two having MTB detected (Table 1). One close contact with an abnormal CXR tested negative for MTB on sputum but was diagnosed with PTB based on a lung computed tomography scan (CT-scan). Therefore, among the 90 contacts, two confirmed TB cases, one probable case, and seven suspected cases were identified.

**Table 1. Active case finding results and tuberculosis case detection among household and close contacts**

| Type of contact | Number | CXR screening (abnormal/total) | GeneXpert (detected/total) | Tuberculosis cases identified |
|---|---|---|---|---|
| Household contact | 8 | 1/8 (13%) | 0/8 (0%)<br>(1 abnormal CXR, 7 normal CXR) | 1 suspected case |
| Close contact | 82 | 8/77 (10%) | 2/49 (4%)<br>(8 abnormal CXR, 41 normal CXR) | 2 confirmed cases<br>1 probable case<br>6 suspected cases |

*Among close contacts, 5 who had no CXR screening included 1 pregnant woman (4 could not be contacted). Among GeneXpert MTB detected, 1 had a normal CXR. CXR: chest X-ray. MTB: Mycobacterium tuberculosis.*

This outbreak included 11 PTB cases: one confirmed pre-XDR-TB, two confirmed TB cases, one probable case, and seven suspected cases. Among PTB cases, three were male (male-to-female ratio was 1:2.7), with a median age of 34 (IQR 30.0–42.5). Six were nurses, four were patient care assistants, and one was unemployed. Nine were asymptomatic and two had a chronic cough. Ten had abnormal CXRs. Among the confirmed TB cases, one had an abnormal CXR and MTB detected, while the other had a normal CXR and MTB detected. The probable case had an abnormal CXR and MTB was not detected (diagnosed by lung CT-scan). Among probable and confirmed cases, three had delayed TB detection. No phenotypic drug susceptibility testing was done because no MTB culture showed drug resistance (Table 2). Eight household contacts of confirmed TB cases were identified, all asymptomatic with normal CXRs.

**Table 2. Characteristics of probable and confirmed TB cases in a tertiary care hospital, 2024**

| Characteristic | Case 1 (index) | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|
| **Type of case** | Pre-XDR-TB | Confirmed TB | Confirmed TB | Probable |
| **Gender** | Female | Female | Female | Male |
| **Age (years)** | 31 | 30 | 34 | 39 |
| **Position** | Patient care assistant | Nurse | Nurse | Patient care assistant |
| **TB Symptom** | Chronic cough, dyspnea | Chronic cough | No symptom | No symptom |
| **Onset** | January 2024 | February 2024 | - | - |
| **Past CXR screening (lesion)** | Abnormal, March 2023 (Ground-glass and reticular opacities left lung) | Normal last, March 2023 | Abnormal, March 2023 (Reticular opacity right upper lung) | Abnormal, March 2023 (Reticulonodular left upper lung) |
| **Latest CXR result** | Abnormal | Abnormal | Normal | Abnormal |
| **GeneXpert MTB/RIF** | MTB detected/ RIF resistant | MTB detected/ RIF susceptible | MTB detected/ RIF intermediate resistant | MTB not detected |
| **GeneXpert MTB/XDR** | FLQ resistant | Not done | Not done | Not done |
| **Line probe assay** | INH resistant/ RIF resistant/ FLQ invalid | Not done | INH susceptible/ RIF susceptible | Not done |
| **CT scan** | Not done | Not done | Not done | Abnormal suggest TB |
| **Culture** | NTM | No growth | MTBC | No growth |
| **Phenotypic DST** | Not done | Not done | Not done | Not done |
| **Treatment regimen** | BPaL | IRZE | IRZE | IRZE |

*Pre-XDR-TB: pre-extensively drug-resistant tuberculosis. CXR: chest X-ray. MTB: Mycobacterium tuberculosis. MTBC: Mycobacterium tuberculosis complex. NTM: nontuberculous mycobacteria. RIF: rifampicin. INH: isoniazid. FLQ: fluoroquinolone. CT: computed tomography. DST: drug susceptibility test. BPal: bedaquiline, pretomanid, linezolid. IRZE: isoniazid, rifampicin, pyrazinamide, ethambutol.*

## Environmental Study

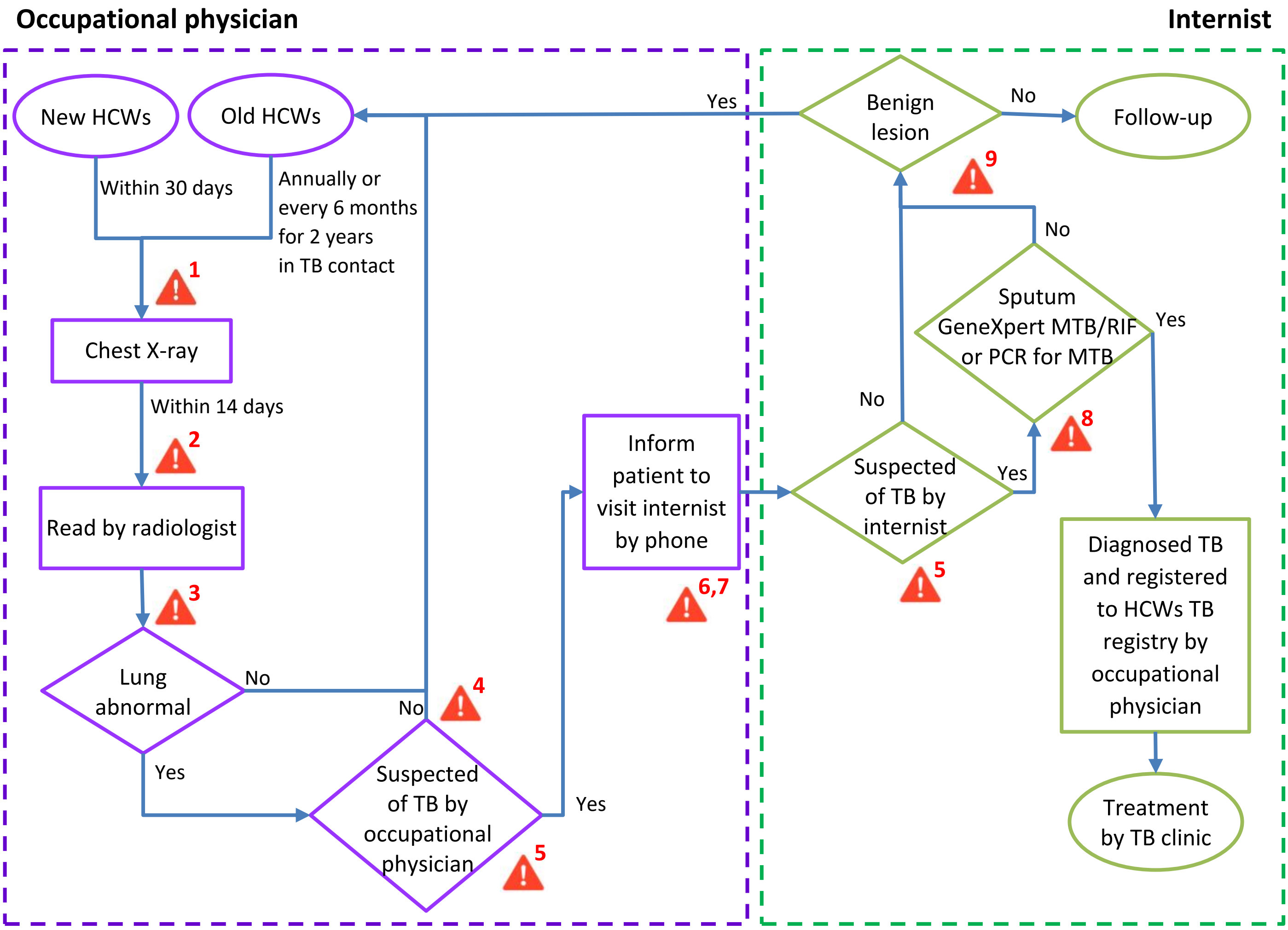
The index case lived in two one-story concrete houses in a low-density community with good ventilation and sun exposure. In the first house, she lived with five family members, sharing a room with her husband and son and rarely interacted with neighbors. In the second, she lived with three family members in a shared hall.

She worked in a 30-bed ward, operating as a 60-bed ward (200% occupancy rate), with two isolation rooms lacking anterooms, airflow control, or filtration. Air changes per hour (ACH) in the nurse' s station, general zone, semi-intensive care unit, general isolation room, and TB isolation room ranged from 0 to 4.2, and most exhaust fan were nonfunctional.

## TB screening for HCWs at Hospital A

In 2023, new HCWs were required to undergo CXR screening within 30 days of recruitment, while existing HCWs were required to have annual CXR, or biannually if their TB infection risk was high. Radiologists initially reported CXR results, and all abnormal reports were re-evaluated by an occupational physician. The occupational medicine department contacted HCWs with TB-compatible CXR results by phone, advising them to see an internist. The internist reinterpreted CXR and, if TB was suspected, ordered sputum investigations with GeneXpert or PCR, rarely using AFB. If TB was not suspected, HCW had no follow-up until the next CXR screening. HCWs diagnosed with TB were registered by the occupational medicine department and treated in the TB clinic. Possible deficiencies in these processes, such as no verbal screening, low use of sputum tests, and no mandatory repeat CXR for those with an abnormal result, may have led to delays in TB detection (Figure 1).

In 2023, out of 2,935 HCWs at Hospital A, 2,608 (88.9%) underwent CXR screening. Of these, radiologists reported lung abnormal findings in 310 cases (11.9%). Of these, 32 (10.3%) visited an internist or general physician, and 19 (6.1%) received a sputum test for TB, resulting in 6 (1.9%) confirmed TB cases.




*HCW: health care worker. TB: tuberculosis. MTB: Mycobacterium tuberculosis. RIF: rifampicin. PCR: polymerase chain reaction. CXR: chest X-ray.*

**Possible causes of delayed TB detection:**

1. CXR-based protocol, lack of verbal screening in the protocol.
2. Delayed CXR formal reporting due to lack of radiologists.
3. No alert system if the patient has an abnormal CXR.
4. Patients with abnormal lung lesions and not suspected of TB by occupational physician not receiving follow-up CXR within 6 months.
5. Suspected tuberculosis by occupational physician and internist based on clinical decisions, no specific criteria.
6. No formal appointment for suspected tuberculosis patients.
7. No screening result recorded in the medical record in the health information system.
8. GeneXpert or PCR tests were performed for suspected TB cases, but the laboratory capacity was insufficient due to dysfunctional machines and a shortage of test kits.
9. Individuals with an abnormal lung lesion defined as benign by the clinician, based on their judgment, will have no follow-up CXR.

**Figure 1. TB screening for HCWs in Hospital A in 2023 and possible causes of delayed TB detection**

### Analytical study

Among 310 HCWs with lung abnormal CXR, 248 (59.6%) answered our questionnaire (Figure 2). Among all participants, the median (IQR) age was 43 (36-48) years, the male-to-female ratio was 1:3.6, 187 (75.4%) were front-line workers, 185 (74.6%) demonstrated good TB knowledge, and 24 (9.7%) received adequate CXR follow-up. Among 63 HCWs with poor TB knowledge, 39 (61.9%) worked in back-office. They scored poorly (<25% correct) regarding TB risk factors and symptoms. Results of univariable and multivariable analyses are shown in Table 3. History of TB treatment and receiving a sputum test for TB were significantly associated with adequate CXR follow-up with RRs (95% CI) of 2.93 (1.31–6.54) and 4.14 (1.96–8.77), respectively. Good TB knowledge was associated with adequate CXR follow-up with a RR (95% CI) of 2.26 (0.75–6.83), however not statistically significant.

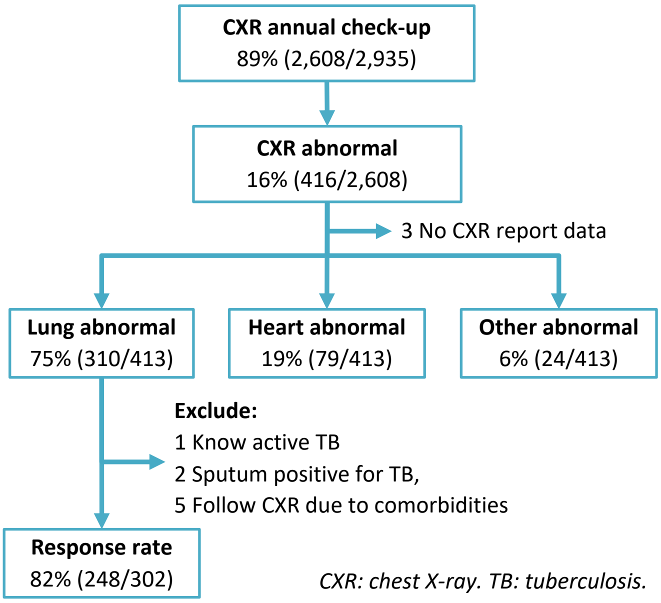



**Figure 2. Flowchart of eligible participants for the analytical study**

**Table 3. Factors associated with adequate chest X-ray follow-up among healthcare workers with abnormal chest X-ray in 2023 (n=248)**

| Characteristics | Adequate CXR follow-up (n=24) | Inadequate CXR follow-up (n=224) | Chi-square *p*-value | Adjusted risk ratio (95% CI) |
|---|---|---|---|---|
| **Age (years)** | | | | |
| ≤40 | 14 (14%) | 86 (86%) | Ref | |
| >40 | 10 (7%) | 138 (93%) | 0.06 | 0.67 (0.31–1.48) |
| **Gender** | | | | |
| Female | 20 (10%) | 174 (90%) | Ref | |
| Male | 4 (7%) | 50 (93%) | 0.52 | |
| **Education** | | | | |
| Below bachelor' s degree | 6 (8%) | 74 (92%) | Ref | |
| Bachelor' s degree or higher | 18 (11%) | 150 (89%) | 0.42 | |
| **Type of healthcare worker** | | | | |
| Front-line | 22 (12%) | 165 (88%) | Ref | |
| Back-office | 2 (3%) | 59 (97%) | 0.05 | 0.53 (0.12–2.25) |
| **Comorbidities** | | | | |
| No | 15 (10%) | 128 (90%) | Ref | |
| Yes | 9 (9%) | 96 (91%) | 0.61 | |
| **History of tuberculosis treatment** | | | | |
| No | 19 (8%) | 211 (92%) | Ref | |
| Yes | 5 (28%) | 13 (72%) | <0.01 | 2.93 (1.31–6.54)* |
| **History of tuberculosis in family, neighbor or workplace** | | | | |
| No | 9 (5%) | 158 (95%) | Ref | |
| Yes | 15 (19%) | 66 (81%) | <0.01 | 2.06 (0.90–4.69) |
| **Symptoms of tuberculosis** | | | | |
| No | 24 (10%) | 218 (90%) | Ref | |
| Yes | 0 (0%) | 6 (100%) | 0.42 | |
| **Receiving sputum test for tuberculosis** | | | | |
| No | 18 (8%) | 215 (92%) | Ref | |
| Yes | 6 (40%) | 9 (60%) | <0.01 | 4.14 (1.96–8.77)* |
| **Tuberculosis knowledge** | | | | |
| Poor | 3 (5%) | 60 (95%) | Ref | |
| Good | 21 (11%) | 164 (89%) | 0.13 | 2.26 (0.75–6.83) |

**Statistically significant. CI: confidence interval. Ref: reference.*

## Action Taken

The index case was treated with a DR-TB regimen in the isolation room until sputum conversion. Contact investigations and TB screening were conducted. Confirmed TB cases received treatment, and sputum samples were sent for MTB culture. Non-case contacts were scheduled for repeat CXRs every six months for two years, annually thereafter. Recommendations included improving ventilation, aligning TB screening guidelines with national guidelines and streamlining processes.

## Discussion

The index case, a 31-year-old woman, was confirmed as a primary pre-XDR-TB case, with resistance detected 19 days after initiating TB treatment, which is shorter than the median of 142 days to develop acquired drug resistance reported in another study.[21] She had mild symptoms and an abnormal CXR in March 2023, noticeable symptoms in January 2024, but was diagnosed in February 2024. Indicating an 11-months detection delay from her initial abnormal CXR and a 1-month delay from noticeable symptoms. A systematic review reported a median total delay in TB detection in low- and middle-income countries of 57 days.[14] Mild symptoms and good functional status may delay care-seeking, while multiple provider visits and protocol issues, contribute to health system delay.[22,23]

Confirmed TB cases had epidemiological links with the index case, suggesting that the outbreak occurred at Hospital A, although drug-resistance patterns varied. This may be due to multiple TB strains within a host or exposure to different TB sources in a high-risk setting.[24] Subclinical cases significantly contribute to transmission, especially in healthcare facilities with high exposure risks.

Among 90 contacts, the probable and confirmed TB rate was 3.7%, which is higher than other studies (1.4%–1.8%).[25,26] Two of the three confirmed TB cases were asymptomatic, aligning with findings that 56.4% of TB cases in Asia are subclinical.[27] Subclinical TB is concerning, contributing to an estimated 68% of global TB transmission.[28] MTB was detected in an HCW with a normal CXR, consistent with findings that 2–9% of PTB cases present with normal CXRs.[29–31] Intensive screening using symptoms, CXR and sputum AFB test in high-risk groups could support early detection and reduce subclinical TB transmission.

All workplace rooms showed substandard ACH, indicating poor ventilation. A minimum of 6 ACH is required to reduce TB transmission.[33] Inadequate ACH likely increased the risk of TB exposure in this setting. Hospital A' s TB screening program for HCWs showed deficiencies that likely contributed to delayed TB detection, including lack of verbal screening, radiologists shortage, informal appointment scheduling, absence of record in health information system, and limited sputum AFB testing, deviating from national guideline.[16] Decisions on further investigations require multiple clinician reviews, creating delays that could be minimized using standard guidelines and simplifying decision-making steps. We recommend that the screening program adhere closely to national guidelines, and streamline processes by reducing decision steps, and ensure consistent application at the operational level.

History of TB treatment and receiving sputum test for TB likely reflect a higher level of concern about TB infection or re-infection, which may motivate more CXR follow-up. Although TB knowledge was adjusted for in the analysis, these experiences might independently influence health-seeking behavior beyond knowledge alone.

HCWs with abnormal CXRs and good TB knowledge were more likely to receive adequate follow-up. Lack of TB knowledge is linked to delays in care-seeking and diagnosis, underscoring the importance of educating HCWs on TB.[14,23,32] Emphasis should be placed on TB symptoms and risk factors as knowledge in these areas was relatively low among those with poor TB knowledge overall, especially in back-office HCWs.

## Limitations

No specimens were available from possible source cases for genome sequencing to confirm a link with the index case. We, therefore, could not establish a connection between the index case and possible source cases, especially given the high TB risk in their workplace. We did not interview HCWs about the screening program so reasons for adequate follow-up were not elicited. The study period was insufficient for long-term active TB assessment in contacts.

## Recommendations

Hospital A should strengthen its TB screening program by adhering to national guideline, streamlining decision-making, and ensure consistent implementation through guideline dissemination and practice evaluations. Emphasis should be placed on conducting sputum testing for TB within two weeks and performing follow-up CXR after six months for individuals with abnormal CXRs to prevent diagnostic delays. To reduce TB transmission risks, ventilation in the wards should be improved by increasing ACH to at least 6.0.[33] Additionally, TB education should be provided, covering symptoms and TB risk factors, particularly for back-office HCWs.

HCWs in other hospitals should undergo annual screening for TB symptoms and CXR. Those working directly with TB patients should be screened biannually. Any abnormal CXR findings require diagnostic testing, such as sputum GeneXpert or AFB, within two weeks, followed by repeat CXR six months later. Hospitals should ensure at least annual TB screening and provide educational programs for HCWs. Clear protocols should be implemented to facilitate timely follow-up and minimize TB detection delays.

National and regional authorities for TB control and prevention programs, including the Division of Tuberculosis and the Offices of Disease Prevention and Control, should supervise and monitor the implementation of a national guideline for submitting laboratory tests to hospitals capable of detecting tuberculosis genetic material. The TB screening protocol should emphasize that individuals with lung abnormalities on CXR must undergo sputum testing and follow-up CXR.

## Conclusion

A front-line HCW was confirmed to have work-related primary pre-XDR-TB, likely contracted from pre-XDR-TB patients in her workplace. Ninety contacts were identified, of which 85 received a CXR. A TB outbreak occurred at Hospital A, involving one confirmed pre-XDR-TB case, two confirmed TB cases, one probable case, and seven suspected cases. Potential risk factors of the outbreak included inadequate TB patient isolation, overcrowded workplace, and poor ventilation. A history of TB treatment and receiving sputum test for TB were significantly associated with adequate follow-up while good TB knowledge HCWs were more likely to receive adequate follow-up after an abnormal CXR. Optimizing TB screening process, educating HCWs, and reinforcing national guidelines are essential steps toward timely TB detection and reducing transmission risks in high-exposure settings.

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### Conflicts of Interest

The authors declare no conflict of interest.

## Suggested Citation

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## References

1. World Health Organization. Tuberculosis [Internet]. Geneva: World Health Organization; 2024 [cited 2024 Oct 13]. <https://www.who.int/news-room/fact-sheets/detail/tuberculosis>
2. Ooi PL, Boudville I, Chan M, Tee N, editors. Communicable diseases control. Singapore: Singapore Field Epidemiology Training Programme; 2020.
3. Dheda K, Mirzayev F, Cirillo DM, Udwadia Z, Dooley KE, Chang KC, et al. Multidrug-resistant tuberculosis. Nat Rev Dis Primers. 2024 Mar 24;10(1):22. doi:10.1038/s41572-024-00504-2.
4. World Health Organization. Companion handbook to the WHO guidelines for the programmatic management of drug-resistant tuberculosis. Geneva: World Health Organization; 2014. 452 p.
5. World Health Organization. Meeting report of the WHO expert consultation on the definition of extensively drug-resistant tuberculosis, 27–29 October 2020. Geneva: World Health Organization; 2021. 40 p.
6. Bureau of Tuberculosis. Prevention and control of extensively drug-resistant tuberculosis guideline under Communicable Disease Act B.E. 2558. Bangkok: Department of Disease Control, Ministry of Public Health; 2018. Thai.
7. World Health Organization. Global tuberculosis report 2023. Geneva: World Health Organization; 2023.
8. World Health Organization. Tuberculosis [Internet]. Geneva: World Health Organization; [cited 2025 Jan 3]. <https://www.who.int/southeastasia/health-topics/tuberculosis>
9. Division of Tuberculosis. Thailand situation and result of tuberculosis control program report 2019–2023. Bangkok: Division of tuberculosis, Department of Disease Control; 2023. Thai.

10. Cheng S, Chen W, Yang Y, Chu P, Liu X, Zhao M, et al. Effect of diagnostic and treatment delay on the risk of tuberculosis transmission in Shenzhen, China: an observational cohort study, 1993–2010. PLoS One. 2013 Jun 27;8(6): e67516. doi:10.1371/journal.pone.0067516.

11. World Health Organization. The end TB strategy [Internet]. Geneva: World Health Organization; [cited 2025 Jan 3]. <https://www.who.int/teams/global-tuberculosis-programme/the-end-tb-strategy>

12. World Health Organization. Early detection of tuberculosis: an overview of approaches, guidelines, and tools. Geneva: World Health Organization; 2011.

13. van Wyk SS, Medley N, Young T, Oliver S. Repairing boundaries along pathways to tuberculosis case detection: a qualitative synthesis of intervention designs. Health Res Policy Syst. 2022 Jan 10;20(1):7. doi:10.1186/s12961-021-00811-0.

14. Getnet F, Demissie M, Assefa N, Mengistie B, Worku A. Delay in diagnosis of pulmonary tuberculosis in low-and middle-income settings: systematic review and meta-analysis. BMC Pulm Med. 2017 Dec 13;17(1):202. doi:10.1186/s12890-017-0551-y.

15. Division of Occupational and Environmental Diseases. Guideline for tuberculosis surveillance, prevention and control in healthcare workers. Nonthaburi: Division of Occupational and Environmental Diseases, Department of Disease Control; 2020. Thai.

16. Division of Tuberculosis. National tuberculosis control programme guideline, Thailand 2021. Bangkok: Division of Tuberculosis, Department of Disease Control; 2021. Thai.

17. Division of Tuberculosis. Risk assessment on Pre-XDR-TB case, Surin Province. In: Department of Disease Control subject matter experts conference; 2024 Mar 18; Nonthaburi, Thailand. Nonthaburi: Division of Tuberculosis; 2024. Thai.

18. World Health Organization; Stop TB Partnership Secretariat. Advocacy, communication and social mobilization for TB control: a guide to developing knowledge, attitude and practice surveys. Geneva. World Health Organization; 2008. 68 p.

19. Dorji T, Tshering T, Wangdi K. Assessment of knowledge, attitude and practice on tuberculosis among teacher trainees of Samtse College of Education, Bhutan. PLoS One. 2020 Nov 6;15 (11):e0241923. doi:10.1371/journal.pone.0241923.

20. Katz MH. Setting up a multivariable analysis. In: Katz MH, editor. Multivariable analysis: a practical guide for clinicians and public health researchers. 3rd ed. Cambridge: Cambridge University Press; 2011. p. 93–117.

21. Kempker RR, Kipiani M, Mirtskhulava V, Tukvadze N, Magee MJ, Blumberg HM. Acquired drug resistance in mycobacterium tuberculosis and poor outcomes among patients with multidrug-resistant tuberculosis. Emerg Infect Dis. 2015 Jun;21(6):992–1001. doi:10.3201/eid2106.141873.

22. Teo AKJ, Singh SR, Prem K, Hsu LY, Yi S. Duration and determinants of delayed tuberculosis diagnosis and treatment in high-burden countries: a mixed-methods systematic review and meta-analysis. Respir Res. 2021; 22(1):251. doi:10.1186/s12931-021-01841-6.

23. Bonadonna LV, Saunders MJ, Zegarra R, Evans C, Alegria-Flores K, Guio H. Why wait? The social determinants underlying tuberculosis diagnostic delay. PLoS One. 2017 Sep 25;12(9): e0185018. doi:10.1371/journal.pone.0185018.

24. Leung EC, Leung CC, Kam KM, Yew WW, Chang KC, Leung WM, et al. Transmission of multidrug-resistant and extensively drug-resistant tuberculosis in a metropolitan city. Eur Respir J. 2013 Apr;41(4):901–8. doi:10.1183/09031936.00071212.

25. Jiang Q, Lu L, Wu J, Yang C, Prakash R, Zuo T, et al. Assessment of tuberculosis contact investigation in Shanghai, China: An 8-year cohort study. Tuberculosis (Edinb). 2018 Jan;108:10–15. doi:10.1016/j.tube.2017.10.001.

26. Cavany SM, Sumner T, Vynnycky E, Flach C, White RG, Thomas HL, et al. An evaluation of tuberculosis contact investigations against national standards. Thorax. 2017 Aug;72(8): 736–45. doi:10.1136/thoraxjnl-2016-209677.

27. Frascella B, Richards AS, Sossen B, Emery JC, Odone A, Law I, et al. Subclinical tuberculosis disease-a review and analysis of prevalence surveys to inform definitions, burden, associations, and screening methodology. Clin Infect Dis. 2021 Aug 2;73(3):e830–41. doi:10.1093/cid/ciaa1402.

28. Emery JC, Dodd PJ, Banu S, Frascella B, Garden FL, Horton KC, et al. Estimating the contribution of subclinical tuberculosis disease to transmission: An individual patient data analysis from prevalence surveys. Elife. 2023 Dec 18;12:e82469. doi:10.7554/eLife.82469.

29. Morgan C, Barrett J, Brown A, Coughlan C, Subbarao S, Abbara A, et al. Respiratory samples to diagnose tuberculosis in the absence of chest x-ray abnormalities. Respir Med. 2021 Aug–Sep; 185:106488. doi:10.1016/j.rmed.2021.106488.

30. Pepper T, Joseph P, Mwenya C, McKee GS, Haushalter A, Carter A, et al. Normal chest radiography in pulmonary tuberculosis: implications for obtaining respiratory specimen cultures. Int J Tuberc Lung Dis. 2008 Apr;12(4):397–403.

31. Eini P, Owaysee Osquee H, Sajjadi Nasab M, Nasiroghli Khiyabani F, Rahighi AH. Chest radiological features among patients with smear positive pulmonary tuberculosis. Caspian J Intern Med. 2013 Fall;4(4):777–80.

32. Chimbatata NBW, Zhou CM, Chimbatata CM, Xu B. Post-2015, why delay to seek healthcare? Perceptions and field experiences from TB healthcare providers in northern Malawi: a qualitative study. Infect Dis Poverty. 2017 May 11;6(1):60. doi:10.1186/s40249-017-0279-1.

33. Niemeier T. Health hazard evaluation report: evaluation of ventilation controls for tuberculosis prevention at a hospital. Cincinnati (OH): U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health; 2013 Jul. 11 p.

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Field Epidemiology Training Program, Division of Epidemiology
Department of Disease Control, Ministry of Public Health, Thailand
Tel: +6625903894, Fax: +6625903845, Email: osireditor@osirjournal.net, https://he02.tci-thaijo.org/index.php/OSIR

# An Investigation of a Tour Bus's Side Collision with Roadside Trees on National Highway No. 41, Pa We Subdistrict, Chaiya District, Surat Thani Province, Thailand, 3–4 Jan 2025

Panuwat Naraart[1]*, Kantaphat Premtadasin[1], Kochrada Siriphon[1], Kowit Anurat[1], Vipawan Kuncharin[1], Jirawan Buachoei[1], Kritsada Lamsaeim[1], Thapanee Choolue[2], Narongsak Wutthipong[2], Sare Srirat[3], Suchittra Saengkhum[4], Wanee Loymai[4]

1 The Office of Disease Prevention and Control 11 Nakhon Si Thammarat, Department of Disease Control, Ministry of Public Health, Thailand

2 Surat Thani Provincial Public Health Office, Ministry of Public Health, Thailand

3 Surat Thani Disaster Prevention and Mitigation Office, Ministry of Interior, Thailand

4 Chaiya Hospital, Ministry of Public Health, Thailand

*Corresponding author, email address: praipanuwat@gmail.com

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**Abstract**

On 1 Jan 2025, at 7:25 PM, a tour bus driver lost control of his vehicle after overtaking a truck and had a side collision with roadside trees on National Highway No. 41 in Surat Thani Province, Thailand. The investigation was conducted to detail the accident's chronology and describe the epidemiology of the injuries and fatalities. Factors associated with the cause(s) of the accident, injuries, and deaths were identified. Road traffic injury countermeasures were consequently proposed. We reviewed medical records, post-mortem inquest reports, closed-circuit television footage and interviewed witnesses. We surveyed the collision site and interviewed rescuers, medical officers, and survivors, utilizing Haddon's matrix for the analysis of contributing factors from various perspectives. The tour bus, carrying 35 passengers and two drivers, was traveling on a round-trip journey from Nakhon Pathom Province to Pattani Province. During the return leg, the driver attempted to overtake a truck, and moved from the left lane to the right lane on a two-lane highway. The bus driver lost control of the bus and collided with roadside trees in the depressed median. All were injured and five (13.5%) were dead at the scene. There were 23 females and 14 males, with a median age of 60 years (range 9 to 75 years). The main causes of the accident were the driver's unfamiliarity with the route, a lack of lane markings and shoulder delineations, and poor visibility due to limited road lighting. We recommended that the road safety environment be improved, especially for roads under construction.

**Keywords:** tour bus, accident, investigation, roadside trees

## Introduction

Approximately 1.19 million lives are lost from road traffic accidents annually, and between 20 and 50 million have suffered from various forms of disability.[1] In response to this global crisis, the World Health Organization, as a secretariat for the United Nations Decade of Action for Road Safety 2021–2030, has committed to reducing road traffic deaths and injuries by at least 50% in 2030.[1] In 2021, Thailand had a road traffic death rate of 25.4 per 100,000 population, which was one of the highest in Asia and upper-middle-income countries. In addition, Thailand was ranked ninth out of 175 World Health Organization member states for road traffic deaths.[2] This resulted in economic loss from fatalities and severe injuries, estimated at 531,058 million Thai baht in 2022, equivalent to 3.1% of the nation's gross domestic product.[3] Tour buses do not rank among the top ten vehicle types with the highest accident rates; however, road traffic accidents involving tour buses often result in serious consequences with a significant number of injuries and deaths in a single event, and these accidents could have a profound negative impact on tourism, undermining public confidence and discouraging travel.

On 1 Jan 2025, the joint investigation team was notified of a tour bus that had lost control and crashed into roadside trees on National Highway No. 41 in Surat Thani Province, Thailand. The incident resulted in five deaths at the scene and 25 injuries. The joint investigation team from the Office of Disease Prevention and Control 11 Nakhon Si Thammarat, Surat Thani Provincial Public Health Office, Surat Thani Disaster Prevention and Mitigation Office, and Chaiya Hospital, investigated this event from 3–4 Jan 2025. The objectives of this investigation were to: 1) detail the event's chronology, 2) describe the epidemiological characteristics of injuries and deaths, 3) examine factors that contributed to the accident and the severity of injuries and fatalities, and 4) propose preventive measures for future road traffic accidents.

## Methods

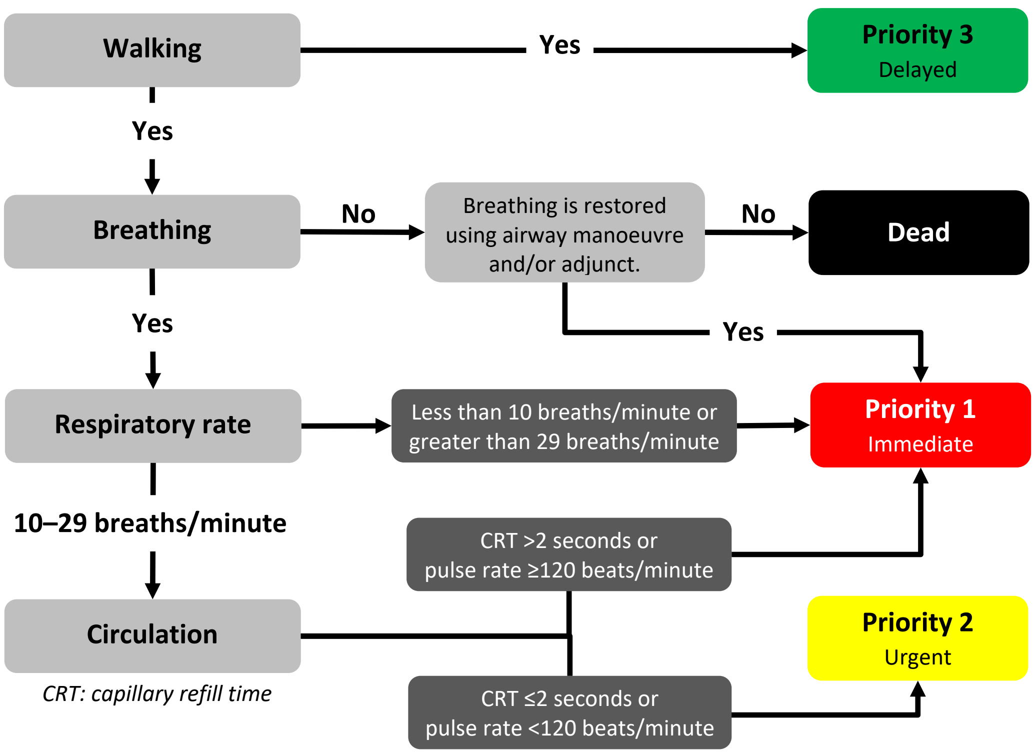
This descriptive study was conducted by utilizing the road traffic injury and fatality investigation form to assemble data from various approaches corresponding to the aims of the investigation, as follows:[4]

### Reconstructing the Incident's Chronology

All individuals related to this event were interviewed, including drivers, survivors, rescuers, healthcare workers at Chaiya Hospital and Tha Chang Hospital, and eyewitnesses at the scene. Closed-circuit television footage of pre-crash, crash, and post-crash events was observed.

### Descriptive Epidemiology of Injuries and Deaths

The medical records and post-mortem inquest report of two hospitals, Chaiya Hospital and Tha Chang Hospital, were reviewed. An accident victim was an individual involved in the tour bus accident on National Highway No. 41, Pa We Subdistrict, Chaiya District, Surat Thani Province, on 1 Jan 2025. Cases included those with any level of physical injuries and were categorized into four categories according to injury severities by triage sieve protocols, as shown in Figure 1.[5]




| Severity | Definition |
| --- | --- |
| Dead | Dead at the scene, dying, or euthanatized |
| Immediate | Requires immediate resuscitation to avoid death |
| Urgent | Requires surgery or treatment within 4 hours |
| Delayed | Ambulatory and can wait longer than 4 hours without treatment |

**Figure 1. Triage sieve algorithm and explanation of severity**

### Determinants Resulting in Incidence Occurrence and Factors Influencing Injuries and Fatalities

Haddon's Matrix was applied to define factors contributing to the accident and those that led to injuries and fatalities.[6] This approach was used to analyze the risk components of injuries in the aspects of human, vehicle, road, and environment during the pre-crash, crash, and post-crash periods as follows:

*A) Human factors*

Factors related to humans, including 1) the driver involved at the time of the incident was interviewed to assess driving behavior and experience, underlying medical conditions, and route familiarity. Other medical information was gathered from medical examinations, such as blood alcohol levels and urine tests for methamphetamine use, and 2) passengers were evaluated for their risk factors, such as seatbelt use and seat maps.

*B) Vehicular factors*

Factors associated with the vehicle were examined through interviews with the investigating police officer. The investigation included an assessment of the bus's condition from the wreckage and statements from police, especially concerning the conditions of the tires, and the availability of seatbelts, airbags, brake system, and other onboard equipment. The post-crash status of the speedometer was inspected. Reports from the Provincial Land Transport Office of Surat Thani were reviewed to obtain the vehicle's appearance, tax and inspection expiration date, tire production year, and driver's driving license. Data were collected on the bus's speed and location from the global positioning system (GPS).

*C) Environmental factors and related systems*

Road, environmental, social, and related system factors were examined. Data on the road and environment, including road type, number of lanes, and roadside objects, were collected. Tire marks between the bus and the trees were measured by the police. Social and related systems data were gathered through interviews with emergency response teams at the scene and medical staff from Chaiya Hospital and Tha Chang Hospital to define the time frame from activation time to arrival at the hospital.

### Ethics

This study was a part of the routine investigation and response activities of the Department of Disease Control, Ministry of Public Health, Thailand. Therefore, ethical approval was not required.

## Results

### Incident's Chronology

The tour bus was operated by two male drivers unfamiliar with the route and carried 35 passengers from Nakhon Pathom Province to Pattani Province on 28 Dec 2024. On the return leg on 1 Jan 2025, the bus departed Hat Yai District at 9:00 AM, arriving at Wat Phra Mahathat Woramahawihan in Mueang District, Nakhon Si Thammarat Province at 1:00 PM. By 3:00 PM, the bus reached Wat Chedi Ai Khai in Sichon District. The bus then proceeded to Surat Thani Province, arriving at a bus inspection station in Tha Chang District at 6:54 PM. Highway police assessed the vehicle's condition, engaged with the drivers, and instructed passengers to fasten their seatbelts.

The bus continued along a road that was under construction before the Chaiya Intersection, where southbound traffic was diverted to two northbound lanes for a two-way flow. Traffic congestion limited vehicle speeds. After this area, normal road flow resumed. GPS data showed that between 7:23 PM and 7:25 PM, the bus accelerated from 34 kilometers per hour (km/h) to 62 km/h and subsequently reached 81 km/h. At 7:25 PM, the vehicle, traveling in the left-hand lane behind a six-wheeled truck, attempted to overtake the truck on the right.

While the bus was overtaking the truck, the right front wheel of the bus moved onto the road's shoulder, which was 1–2 feet wide and covered with loose soil and grass. The driver, aware of the impending danger, accelerated the vehicle. An expert from the forensic police supported this supposition due to the existence of grass on the surface of the soil approximately 2–3 meters before the spot where the bus descended into the depressed median. After this distance, there was evidence of crushed grass made by tire marks of a vehicle travelling at high speed, suggesting that the speed of the bus during the collision was higher than 81 km/h. After the bus descended into the depressed median, which was sloped at an angle of approximately 40 degrees, it collided with three large trees (Figure 2).

The road was constructed of concrete and had been in use since June 2024. In this particular section of the road, there was a lack of lane markings, shoulder delineations, and street lighting. The incident occurred at night, during low visibility.

Nearby residents notified emergency services via the 1669 hotline, with the Narenthorn Center in Surat Thani Province receiving the report at 7:29 PM.

Response teams were immediately dispatched, with a foundation rescue vehicle arriving at the scene by 7:33 PM and an advanced life support (ALS) ambulance from Chaiya Hospital arriving at 7:53 PM.

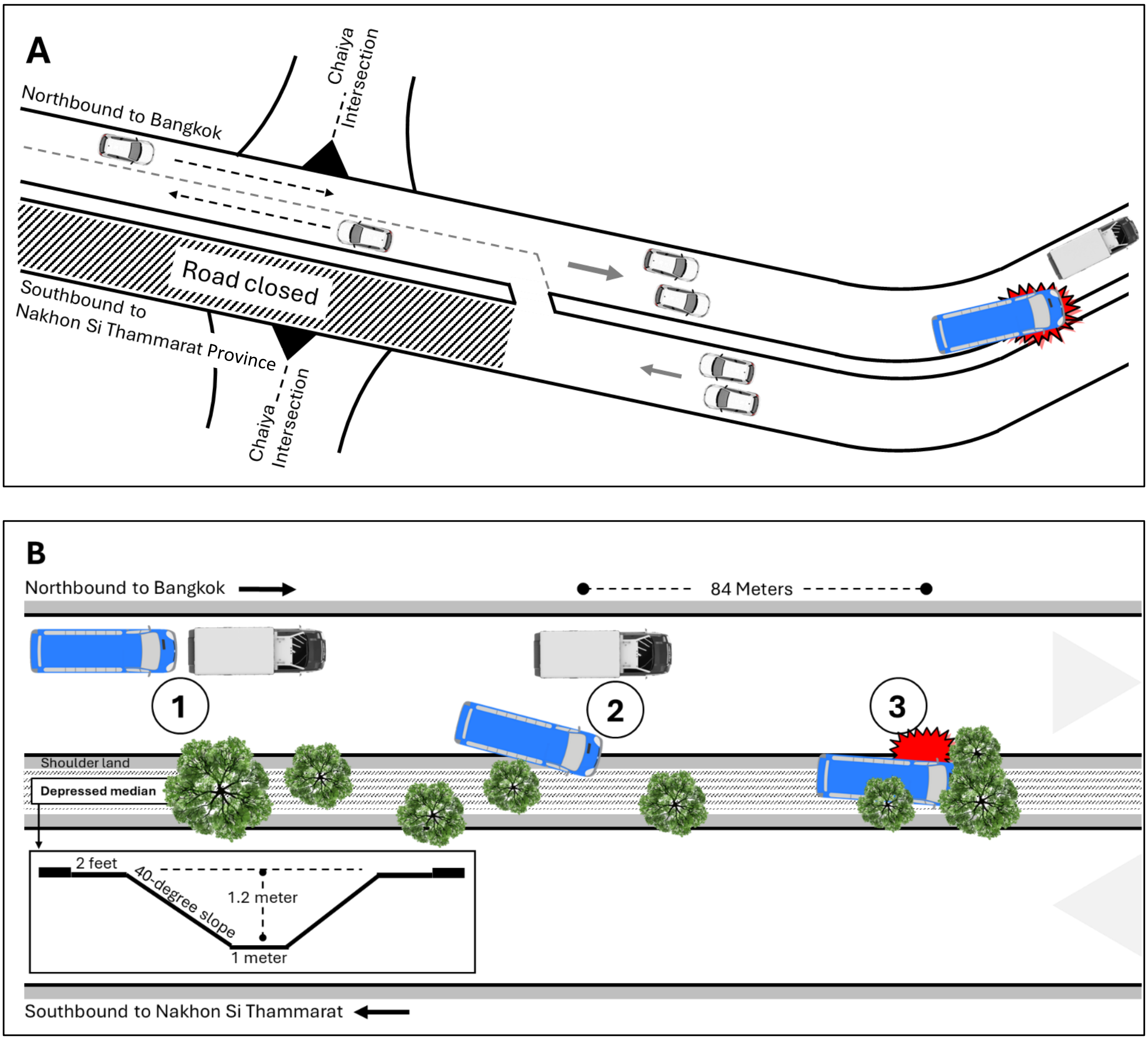



**Figure 2. A diagram of National Highway No. 41 with a 2-kilometer stretch of road before the accident site (A) and pictorial of events (B) of a tour bus before (1) and during (2) overtaking a truck, and after colliding with trees (3), Surat Thani Province, 1 Jan 2025**

### Descriptive Epidemiology of Injuries and Fatalities

The incident involved 37 individuals. All were injured and five (13.5%) were dead at the scene. There were 23 females and 14 males with a median age of 60 years (range 9 to 75 years). Among the 32 injured survivors, 22 (68.8%) were triaged as delayed, 8 (25.0%) as urgent, and 2 (6.2%) as immediate at the scene. Twenty-five injured individuals were hospitalized, while seven declined medical treatment for personal reasons.

Among the injured individuals or fatalities, multiple organ injuries were observed. The affected organs were classified through the injury severity score (ISS).[7] Out of the 25 individuals who were injured and hospitalized, 17 (68.0%) had extremity injuries, followed by 11 (44.0%) with injuries to the thoracic region and 7 (28.0%) with injuries to the head and neck (Figure 3A). Of the five who died at the scene, all had injuries on their extremities, and three had injuries to the head and neck (Figure 3B).

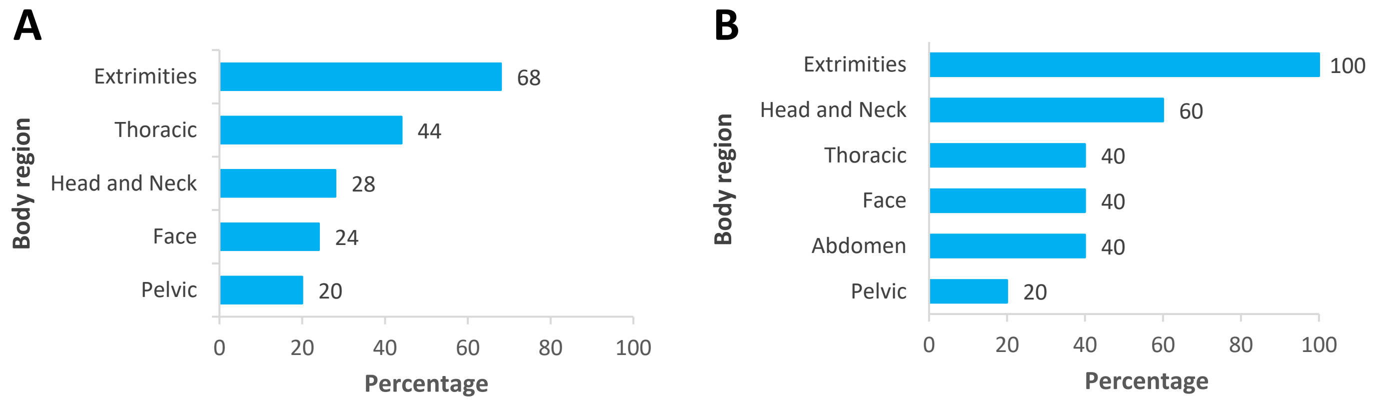



**Figure 3. Characteristics of the body regions injured from an accident on National Highway No. 41, Surat Thani Province, 1 Jan 2025, distinguishing those injured, n=25 (A) and died, n=5 (B)**

As shown in Table 1, livor mortis was a common finding in all deaths. The causes of death were massive intra-abdominal hemorrhage (n=2), cervical spine fracture with spinal cord injury (n=2), and severe head injury (n=1).

**Table 1. Characteristics of the injuries among the five fatalities and causes that led to death**

| No | Gender | Age | Injury manifestation and post-mortem inquest results | Cause of death |
|---|---|---|---|---|
| 1 | Female | 54 | - Lacerations on the right temple (5.0 x 1.0 cm, extending to the skull) and above the right eyebrow (2.0 x 1.0 cm).<br>- Abrasions on the right chest (5.0 x 0.5 cm) and the back of the right hand (2.0 x 1.0 cm).<br>- Postmortem lividity showed as a purplish-red discoloration, blanching when pressed. | Severe head injury |
| 2 | Female | 58 | - Lacerations on the lower lip (4.0 cm), chin (5.0 x 1.0 cm), and right thigh (7.0 x 1.0 cm), with an open fracture of the left forearm, nearly amputated.<br>- Postmortem lividity showed purplish-red discoloration, blanching when pressed.<br>- A positive hepatorenal finding in the supraumbilical region suggesting blood accumulation. | Massive intra-abdominal hemorrhage |
| 3 | Female | 58 | - Laceration on the right elbow (10.0 x 2.0 cm).<br>- Postmortem lividity on the back and hip showed purplish-red discoloration, blanching when pressed.<br>- Both eyes were closed with non-resilient corneas, and rigor mortis was present in the jaw, neck, fingers, wrists, and knees. | Cervical spine fracture with spinal cord injury |
| 4 | Male | 61 | - Abrasion on the right thigh (10 cm).<br>- Postmortem lividity on the back showed as purplish-red discoloration, blanching when pressed.<br>- Rigor mortis was present in the jaw, and a positive spleen-renal finding, suggesting blood accumulation. | Massive intra-abdominal hemorrhage |
| 5 | Male | 74 | - A scratch wound on the right neck, with ecchymosis on the forehead.<br>- Laceration on the right forehead (6.0 x 2.0 cm).<br>- Postmortem lividity on the back showed purplish-red discoloration, blanching when pressed.<br>- Rigor mortis was present in the jaw and neck. | Cervical spine fracture with spinal cord injury |

*cm: centimeters.*

Figure 4A illustrates the distribution of accident victims based on the location of their seats. Those who died at the scene sat closest to the points of collision with the trees. Victims who were triaged as immediate and urgent sat adjacent to those who died. After the collision, the bus came to rest in the position shown in Figure 4B. None of the passengers had their seatbelts fastened. Consequently, passengers who sat on the left side of the bus were thrown to the right, resulting in more severe injuries for those seated on the right side.

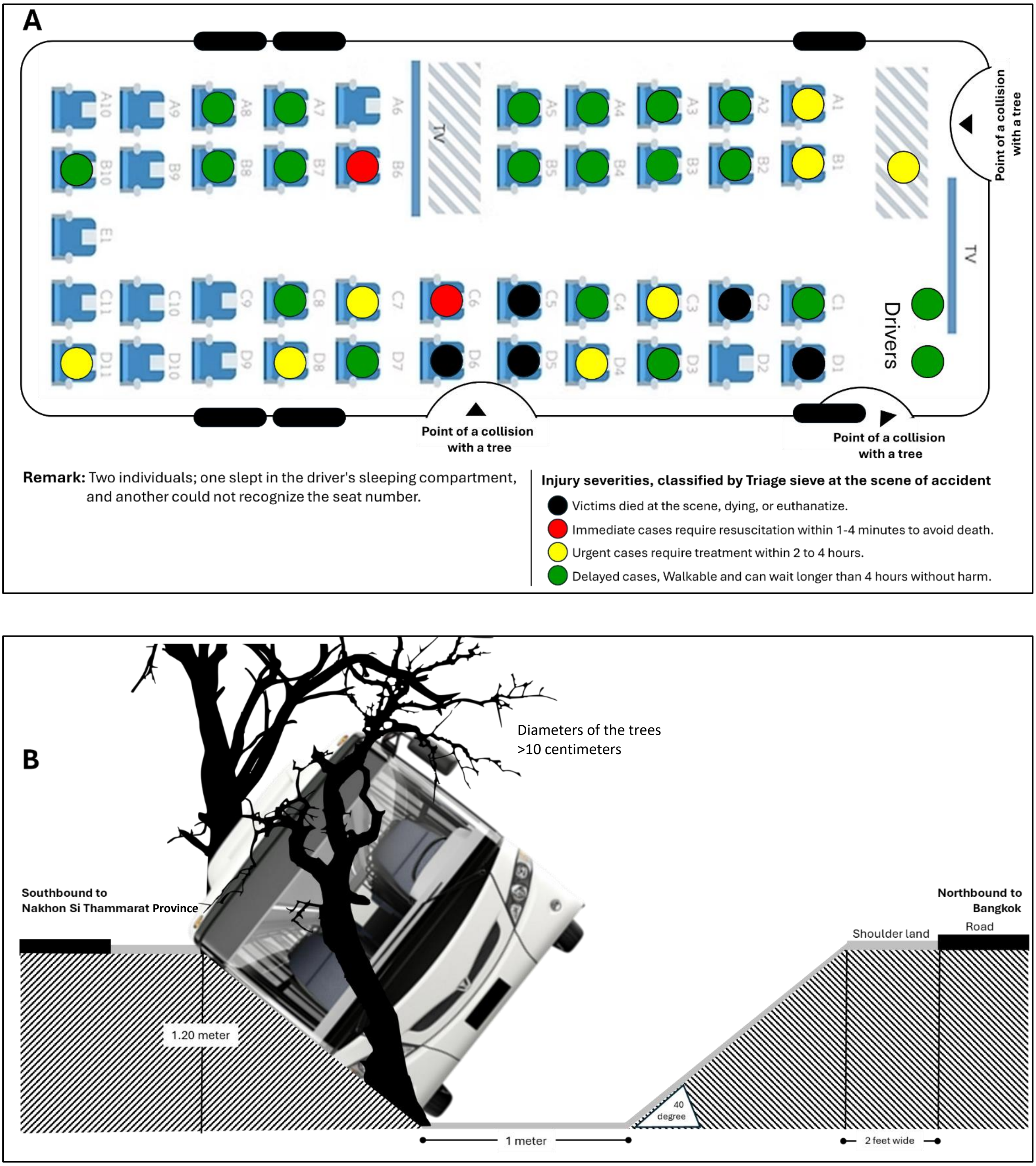



**Figure 4. Bus seat map showing the distribution of injury severities (A) and the bus's final position during the post-crash period in the depressed median (B), National Highway No. 41, Surat Thani Province, 1 Jan 2025**

## Contributing Factors of the Accident

### *A) Human factors*

A 46-year-old male driver, holding a vehicle driving license class 2, was involved in a crash. Blood alcohol and addictive substances were not detected. GPS data indicated that the driver drove at 81 km/h before impact and wore a seatbelt. The driver was from outside the area and may have been unfamiliar with the road as he had never operated along this specific route. None of the passengers wore seatbelts, causing them to be thrown from their seats and land on other passengers.

### *B) Vehicular factors*

The tour bus was manufactured in 1997. It was operated by two other companies before it was bought in 2024 by the current company, which has a valid license for operation. The latest inspection was conducted on 25 Dec 2024, and the results showed sufficient function for operation. The brake system and condition of the tires were in the normal range. The tires were produced in the 16$^{th}$ week of 2022. No modifications to the bus were observed, and all seats had seatbelts available (Table 2). After the crash, some parts of the bus were crumpled, particularly at the collision sites.

**Table 2. General information of the tour bus involved in the accident on National Highway No. 41, Surat Thani Province, 1 Jan 2025**

| Information | Details |
|---|---|
| **Brand and model** | Hino |
| **Type of vehicle** | Tour bus |
| **Tax expiration date** | 1 Jul 2029 |
| **Latest inspection date** | 25 Dec 2024 |
| **Color** | Mostly green, decorated with white, blue, and black |
| **Transmission type** | Manual |
| **Engine size** | Nissan 6-engine, 330 horsepower |
| **Dimensions** | 14,000 kilograms weight<br>Total weight: 16,200 kilograms |
| **Maximum number of passengers** | 38 |
| **Safety and protective system** | 100% availability of seatbelt, good condition of brake system |
| **Year of vehicle/tire production** | 1997/16$^{th}$ week of 2023 |
| **Any modifications** | Unobservable |

### *C) Environmental factors and related systems*

The incident occurred on National Highway No. 41, at marker 129+700 km, coordinates N 9.408897, E 99.164044, in Pa We Subdistrict, Chaiya District, Surat Thani Province. The road is a straight asphaltic concrete surface designed for mono-directional traffic. The northbound road to Bangkok was constructed to standard specifications and consists of two 3.50-meter lanes with 1.50-meter shoulders. It is separated from the southbound road to Nakhon Si Thammarat Province by a depressed median, as illustrated in Figure 4B. Although the highway has been operating since June 2024, compulsory components, including lane markings, shoulder delineations, and street lighting, were not presented. The accident occurred at night and at the end of a curve in the road. Many large roadside trees were present along the roadway with diameters exceeding 10 centimeters.

Residents reported the accident to Hotline 1669 at around 7:29 PM. Response teams were dispatched, and a foundation rescue vehicle arrived at 7:33 PM to perform vehicle extrication. Chaiya Hospital was notified at 7:43 PM, and ALS ambulances were dispatched at 7:44 PM, arriving at 7:53 PM.

Initial confusion regarding who was coordinating the situation, as there was no commander present at the scene, led to a delay in the evaluation of the accident and the number of victims. However, the arrival of the ALS ambulance team facilitated the resolution of these issues. Five black-tagged cases were referred by foundation rescue teams to Chaiya Hospital, while the ALS ambulance delivered the remaining injured individuals to Chaiya Hospital or Tha Chang Hospital. All cases were completely referred by 9:10 PM, and the last case arrived at the nearest hospital by 9:25 PM.

The application of Haddon's matrix to the tour bus accident is shown in Table 3, which presents contributing factors of the accident and potential determinants of the injuries and fatalities.

**Table 3. Haddon's matrix of an accident on National Highway No. 41, Surat Thani Province, 1 Jan 2025**

| Period | Factor | | |
|---|---|---|---|
| | Human | Vehicle | Road and environment |
| Pre-crash | **Drivers**<br>- Two males aged 45 and 46 years with valid vehicle driving license class 2.<br>- Were unfamiliar with the route.<br>- Average speed not more than 90 km/h throughout the journey.<br>- Attempting to overtake another vehicle ahead.<br>- Took breaks at checkpoints along the journey every two hours.<br>- Blood alcohol from breathalyzer was not detected.<br>**Passengers**<br>- None of the passengers fasten their seatbelts. | - Had been in use for 26 years.<br>- Tires, which were produced in the 16th week of 2022, were in good condition and proportionally used with the bus size.<br>- The latest inspection was conducted on 25 Dec 2024 and was checked at assigned points along the journey.<br>- The bus was equipped with a GPS, seatbelts, a fire extinguisher, and a window-breaking hammer. | **Road**<br>- Constructed with asphaltic concrete and re-opened in June 2024.<br>- Absence of lane markings, shoulder delineations, and street lighting.<br>- There were two lanes, separated by a depressed median.<br>**Environment**<br>- Many large roadside trees >10 cm in diameter were present along the roadway.<br>- Nighttime had low visibility. No recent precipitation. |
| Crash | **Driver**<br>- A 46-year-old male overtook a six-wheeled truck.<br>- Seatbelt was fastened.<br>- Blood alcohol and addictive substances were not detected.<br>**Passengers**<br>- None of the passengers fasten their seatbelts, resulting in being thrown to the right side of the bus.<br>- The five who died at the scene all sat nearest to the site of the collision with the trees. | - Airbags were not functional.<br>- Bus veered off to the right shoulder of the road, lost control, collided with a tree, and overturned onto its right side.<br>- The crash speed, recorded by the GPS, was 81 km/h. | **Environment**<br>- Three large trees >10 cm in diameter in the depressed median were struck, one of which broke. The impact caused a branch from one tree to penetrate the windshield, injuring passengers.<br>- At nighttime, the visibility was poor. No evidence of precipitation. |
| Post-crash | **Drivers and passengers**<br>- All were injured, including the drivers; five passengers were dead.<br>- Among the 32 injured survivors, 22 green-, 8 yellow-, and 2 red-tagged*. Seven green- tagged individuals declined medical treatment.<br>**Emergency team**<br>- ALS transported 25 injured individuals to the hospital while the deaths were delivered by rescue teams. | - The front frame on the right side of the driver's area was severely damaged, collapsing inward into the vehicle.<br>- The right side sustained significant damage, and the windows were shattered along the entire length.<br>- The front and rear wind-shields were shattered.<br>- Some passenger seats became detached from their bases. | - The foundation rescue team arrived within 4 minutes of the report and coordinated with additional hospital support teams.<br>- The ALS from Chaiya Hospital, which is approximately 7 km from the scene, arrived within 10 minutes.<br>- All cases were referred from the scene and arrived at the hospital by 9:25 PM, 2 hours after receiving notification. |

**Tagged colors: Red (immediate)—cannot survive without immediate treatment but has a chance of survival; Yellow (urgent)—requires observation. Condition is stable and not in immediate danger of death; Green (delayed)—the "walking wounded" who will need medical care after more critical injuries have been treated. ALS: Advanced life support. GPS: Global positioning system. km/h: kilometers/hour. cm: centimeters.*

## Action Taken

The relevant authorities convened to assess risks and propose countermeasures for improving road safety. They reached a consensus on accelerating safety improvement, including the installation of reflective signs and flashing lights before the accident site and marking lane lines between the Pa We District and Chaiya Intersection. Additionally, the Department of Highway, Tha Chang Office will present and propose road safety measures for the roads under construction to the national committee. As part of the immediate plan, this proposal includes installing a guardrail or barriers at the curve preceding the accident site. Furthermore, the Road Safety Operations Center Committee of Surat Thani Province invited related organizations to review and extract lessons learned from this mass casualty incident. A multidisciplinary approach will be a core function to enhance the incident command system and improve response strategies.

## Discussion

We investigated a tour bus accident on National Highway No. 41 in Surat Thani Province, Thailand, examining its causes and consequences, including injury severities and fatalities. Although motorcycle accidents are more common, accidents involving cars or buses can result in numerous injuries and deaths.[2]

Of the 37 accident victims, there were five deaths, and all died at the scene. The causes of death were massive intra-abdominal hemorrhage, cervical spine fracture, and severe head injuries. The fatalities were observed in passengers who sat closest to the collision points with the trees. It is well-documented that occupants seated on the side of impact in a vehicle exposed to a side collision with fixed objects such as massive trees are vulnerable due to limited space, increasing the severity of injury.[8] Moreover, the lack of seatbelt use worsened the outcomes, as passengers were thrown from their seats, increasing the force of impact. This finding is consistent with another study that found proper seatbelt use could reduce injury severity by half.[9,10] Among the survivors of this accident, the most common site of injury was the extremities, followed by the thorax, consistent with another study.[11]

Multiple factors contributed to this accident. A significant finding was the driver's unfamiliarity with the route. This is consistent with a report of drivers on unfamiliar roads and traffic crashes, which found that drivers unfamiliar with a road have an increased likelihood of a crash.[12] While driving under the influence of alcohol or addictive substances is often associated with accidents, neither alcohol nor addictive substances contributed to this accident, suggesting that environmental factors played a predominant role.[13]

The absence of lane markings, shoulder delineations, and road lighting were contributing factors for this accident, consistent with another study, the absence of these visual guides can result in driver confusion, loss of position recognition, reduced reaction times, and increased in the risk of run-off-road crashes.[14] Furthermore, the presence of fixed objects along the road, such as roadside trees, increased the severity of accidents. Many trees on this stretch of road had trunk diameters exceeding 10 centimeters. A study from Czechia found that for every increase in a tree's diameter by 10 centimeters, the probability of serious injury and death increased by 1.74 and 1.97 times, respectively.[15] Moreover, trees with trunks over 10 centimeters in diameter are roadside hazards and should not be planted within five meters of a road.[16,17]

Although all injured passengers were evacuated from the scene within two hours, initial delays in command, control, and coordination highlighted the need for a better-prepared response system during emergencies. Prompt command at the scene and coordination of multi-agency responses can potentially reduce fatalities.[18]

## Limitations

One significant limitation was the lack of complete data on the use of seatbelts among all passengers, as some individuals declined to participate in the interview due to the psychological trauma caused by the accident. Therefore, witnesses from medical records and rescue team interviews were combined to infer seatbelt use. This reliance on secondary data may have affected the accuracy of our results.

## Recommendations

The Surat Thani Disaster Prevention and Mitigation Office should conduct a functional exercise on scene management, particularly for mass casualty incidents. This training should involve key organizations such as the Emergency Medical Service Command and Control Center and the Surat Thani Provincial Public Health Office, with a focus on foundation rescue teams. Moreover, the Department of Highways may need to consider tree removal as there have been many studies suggesting that single vehicle collisions with trees exceeding 10 centimeters in diameter can increase the risk of fatality. The Department of Highways should consider installing delineation or guiding signals in areas considered at high-risk of crashes, such as roads under construction.

## Conclusion

A side-single collision between a tour bus and roadside trees on National Highway No. 41 in Surat Thani Province, caused by the driver losing control of the vehicle, resulted in five fatalities at the scene and 32 injured survivors. Key determinants were the driver's unfamiliarity with the route and unsafe road environment, including a lack of lane markings, shoulder delineations, and road lighting. Various factors contributed to the severity of the injuries and fatalities, including the passenger's non-use of seatbelts. The collision involved three large trees, each exceeding 10 centimeters in diameter, in the highway's depressed median, which was sloped at an angle of 40 degrees, causing the bus to tip over on its side, escalating the impact as gravitational force was combined with the bus's mass and velocity. We recommend that the road safety environment should be improved, especially on roads that are under construction. Roadside tree management should be included in the national plans. Exercises on emergency scene management involving command and coordination should be undertaken as a multi-disciplinary approach.

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## Conflicts of Interest

The authors declare no conflict of interest.

## Suggested Citation

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## References

1. World Health Organization. Road traffic injuries [Internet]. Geneva: World Health Organization; 2023 Dec 13 [cited 2025 Jan 6]. <https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries>
2. World Health Organization. The Global status report on road safety 2023. 1st ed. Geneva: Bloomberg Philanthropies; 2023.
3. World Health Organization in Thailand. Road Safety [Internet]. Nonthaburi: WHO Country Office for Thailand; 2025 [cited 2025 Jan 6]. <https://www.who.int/thailand/our-work/road-safety>
4. Division of Injury Prevention, Department of Disease Control (TH). *Documents and Related Official Directives* [Internet]. Nonthaburi: Division of Injury Prevention, Department of Disease Control; 2022 [cited 2025 Jan 2]. <http://ddc.moph.go.th/dip/pagecontent.php?page=795&dept=dip>
5. Department of Emergency Medicine, Khon Kaen Hospital. Medical management in disaster [Internet]. Khon Kaen (TH): Khon Kaen Hospital; 2020 [cited 2025 Jan 8]. <https://em.kkh.go.th/knowledge/diasater01.html>. Thai.
6. Haddon W Jr. A logical framework for categorizing highway safety phenomena and activity. J Trauma. 1972 Mar;12(3):193–207. doi:10.1097/00005373-197203000-00002.
7. Petridou ET, Antonopoulos CN. Injury Epidemiology. 2nd ed. In: Quah SR, editor. International Encyclopedia of Public Health. Oxford: ScienceDirect; 2017. p. 258–74.
8. Augenstein J, Perdeck E, Bowen J, Stratton J, Singer M, Horton T, et al. Injuries in Near-Side Collisions. Proceedings of the 43rd Association for the Advancement of Automative Medicine; 1999 Sep 20–21; Barcelona (Sitges), Spain. Chicago (IL): Association for the Advancement of Automotive Medicine; [1999]. p. 139–58.
9. Ogundele OJ, Ifesanya AO, Adeyanju SA, Ogunlade SO. The impact of seat-belts in limiting the severity of injuries in patients presenting to a university hospital in the developing world. Niger Med J. 2013 Jan;54(1): 17–21. doi:10.4103/0300-1652.108888.
10. Cummins JS, Koval KJ, Cantu RV, Spratt KF. Do seat belts and air bags reduce mortality and injury severity after car accidents? Am J Orthop (Belle Mead NJ). 2011 Mar;40(3):E26–9.

11. Bjornstig U, Bylund P, Albertsson P, Falkmer T, Bjornstig J. Injury events among bus and coach occupants: non-crash Injuries as Important as crash injuries. IATSS Research. 2005;29(1): 79–87. doi:10.1016/S0386-1112(14)60121-7.
12. Sivak M, Schoettle B. Drivers on unfamiliar roads and traffic crashes [Internet]. Ann Arbor (MI): University of Michigan; 2010 Dec [cited 2025 Jan 15]. <https://deepblue.lib.umich.edu/bitstream/handle/2027.42/78448/102704.pdf>
13. Lin H, Chan C, Wiratama BS, Chan PL, Wang MH, Chao CJ, et al. Evaluating the effect of drunk driving on fatal injuries among vulnerable road users in Taiwan: a population-based study. BMC Public Health. 2022 Nov 10;22(1):2059. doi:10.1186/s12889-022-14402-3.
14. Lopez G, Ona JD, Garach L, Baena L. Influence of deficiencies in traffic control devices in crashes on two-lane rural roads. Accid Anal Prev. 2016 Nov;96(5):130–9. doi:10.1016/j.aap.2016.08.008.
15. Bucsuhazy K, Zuvala R, Valentova V, Ambros J. Factors related to severe single-vehicle tree crashes: In-depth crash study. PLoS One. 2022;17(1):e0248171. doi:10.1371/journal.pone.0248171.
16. Central Asia Regional Economic Cooperation Program. CAREC road safety engineering manual: roadside hazard management [Internet]. Manila: Asian Development Bank; 2018 Apr [cited 2025 Mar 3]. <http://dx.doi.org/10.22617/TIM179174-2>
17. Chatngoen T, Saeaui P, Choosri N, Chattrawongwiwat T, Sangsawang C, Phiriyasart F, Jiraphongsa C. An investigation of double collisions of pickup trucks with multiple fatalities in Narathiwat Province, Thailand, October 2023. OSIR. 2024 Jun;17(2): 87–96. doi:10.59096/osir.v17i2.268926.
18. Cole D. The incident command system: a 25-year evaluation by California practitioners [Internet]. Hyattsville (MD); Federal Emergency Management Agency (US): 2000 [cited 2025 Jan 15]. 230 p. <https://apps.usfa.fema.gov/pdf/efop/efo31023.pdf>

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# Toward Optimizing Pertussis Detection During Outbreaks: A Comparison of National and High Epidemic Area Case Definitions in Narathiwat, Thailand, 2024

Farooq Phiriyasart[1,2]*, Noreeda Waeyusoh[1,3], Mahamad Mokmula[1,4], Sasikarn Nihok[1], Nungrutai Ninlakan[1], Peerawan Cheewaiya[1], Adul Binyusoh[1]

1 Narathiwat Provincial Public Health Office, Ministry of Public Health, Thailand

2 Sungai Kolok Hospital, Ministry of Public Health, Thailand

3 Bacho Hospital, Ministry of Public Health, Thailand

4 Cho-airong Hospital, Ministry of Public Health, Thailand

*Corresponding author, email address: farooqmedicine@gmail.com

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**Abstract**

Pertussis remains a significant public health challenge in low-vaccination areas. This study described the characteristics of cases meeting the Narathiwat and national definitions and cases confirmed by reverse transcription polymerase chain reaction (RT-PCR) during the epidemic. It also assessed diagnostic accuracy of the definitions. A cross-sectional analysis utilized data from the Narathiwat Emergency Operations Center during September 2023 to May 2024. For the Narathiwat definition, a suspected case was a person with a cough lasting ≥1 week plus at least one symptom (i.e., paroxysmal cough, post-tussive vomiting, inspiratory whooping, or apnea), while the national definition required cough lasting ≥2 weeks. Among 486 cases, 171 met the Narathiwat definition, 107 met the national definition, and 208 met neither. RT-PCR confirmed cases were 47.9%, 57.9% and 30.8% among cases meeting the Narathiwat, national, and neither definitions, respectively. Timeliness of pertussis detection had a median of 9 days (interquartile range (IQR) 7.8–10 days) for the Narathiwat definition and 16 days (IQR 15–21 days) for the national definition. Paroxysmal cough had the highest detection rate by RT-PCR (84.6%) and was more common among RT-PCR positive cases compared to RT-PCR negative cases. The Narathiwat definition had a sensitivity of 39.4% and a positive predictive value (PPV) of 48.0%. The national definition had a lower sensitivity, 29.8%, but a higher PPV, 57.9%. A proposed alternative definition (cough ≥1 week, accompanied by paroxysmal cough) achieved a sensitivity of 37.5% and a PPV of 49.1%. Modifying the definition improved early outbreak detection during epidemics.

**Keywords:** pertussis, case definition, sensitivity, PPV, outbreak, low vaccine coverage

## Introduction

Pertussis, also known as whooping cough, is a highly contagious bacterial infection caused by *Bordetella pertussis*. Despite widespread vaccination efforts, pertussis remains a significant global public health concern, particularly affecting infants who are incompletely vaccinated and lack sufficient herd immunity.[1] The disease typically manifests with catarrhal stage that can escalate to severe paroxysmal cough, marked by a characteristic "whoop" sound, and transmission primarily occurs through respiratory droplets expelled during coughing or sneezing.[2]

The World Health Organization (WHO) recommends clinical and laboratory case definitions for pertussis diagnosis. The clinical definition involves a prolonged cough (≥2 weeks) with characteristic symptoms, while the laboratory definition confirms the diagnosis through methods such as reverse transcription polymerase chain reaction (RT-PCR) or serology.[3] In Thailand, Narathiwat is a province with unique public health challenges, including a consistently low diphtheria-tetanus-pertussis (DTP) vaccine coverage rate, which has remained below 90% for years.[4,5] This low vaccination rate has contributed to the province's heightened vulnerability to pertussis outbreaks and rapid transmission, distinguishing it from other regions in Thailand. The most recent large pertussis outbreak occurred between September 2023 and May 2024. However, the Thailand national clinical case definition (national definition), which requires a cough lasting ≥2 weeks [6], posed limitations in this high-risk context by delaying case detection and hindering timely identification and containment of pertussis cases during the outbreak. In response to these challenges, the Narathiwat Provincial Public Health Office activated the Emergency Operations Center (EOC) on 25 Oct 2023, to strengthen outbreak response efforts. Unlike the routine outbreak response system, which is generally slower and may not fully mobilize resources in high-risk settings, the EOC facilitated a coordinated and rapid response to manage the potential epidemic.

One of the key responses was to modify the surveillance clinical case definition for suspected pertussis cases, adopting the Narathiwat definition to address the specific needs of the local outbreak. The Narathiwat definition, which includes clinical suspected cases with a cough lasting ≥1 week. Both factors were critical for effective outbreak management. During the outbreak, it was observed that some suspected cases met the national definition because they were detected during the period when they had a cough lasting ≥2 weeks. RT-PCR testing was conducted for all cases meeting either definition. Moreover, some individuals who did not meet any definition underwent RT-PCR testing due to physicians' suspicion or because they were identified as high-risk contacts (HRC) through contact tracing.

Thus, this study aimed to: (1) describe the characteristics of individuals meeting the Narathiwat definition, the national definition, and RT-PCR positive pertussis cases during the epidemic; (2) assess the clinical manifestations of RT-PCR positive and negative cases; and (3) evaluate the diagnostic accuracy of the Narathiwat, national, and alternative pertussis case definitions.

## Methods

This descriptive cross-sectional study was conducted using secondary data to examine characteristics, signs or symptoms, and diagnostic accuracy among individuals who underwent RT-PCR testing during the pertussis outbreak in Narathiwat Province, which occurred between September 2023 and May 2024. The RT-PCR testing database included individuals meeting the suspected pertussis case definition under one of the two definitions, and others who did not meet any definition, but were tested based on clinical suspicion by physicians or because they were identified as HRC through contact tracing. Cases meeting the Narathiwat definition were defined as individuals with a cough lasting ≥1 week (detected cases with a cough duration of 7 to 13 days) combined with at least one sign or symptom (paroxysmal cough, post-tussive vomiting, inspiratory whooping, or apnea). In contrast, cases meeting the national definition required a cough lasting ≥2 weeks (detected cases with 14 or more days of cough duration) combined with at least one of the same signs or symptoms. The cases meeting the two definitions in this analysis did not overlap each other, as cases were categorized based on the timing of detection, specifically the cough duration at diagnosis. The clinical data of the two groups were collected only at the time of case detection and were not followed up throughout the course of illness. Therefore, the Narathiwat and national definitions' cases were treated as independent groups. An RT-PCR positive case was defined as an individual who tested positive for *Bordetella pertussis* using RT-PCR, regardless of whether they met a clinical case definition.

Data were retrieved from line listings of pertussis cases recorded by the EOC using Microsoft Excel 2016.[7] Variables included gender, age group, case type, DTP vaccination status, clinical signs or symptoms, and RT-PCR test results. Case types included index cases, which were the initial cases identified in an outbreak; HRC, referring to individuals identified through contact tracing, such as household members or those in close contact with RT-PCR positive pertussis cases at a distance of less than one meter for at least five minutes without wearing a mask; and active case finding, involving cases identified through proactive surveillance. DTP vaccination status was categorized as completely vaccinated, incompletely vaccinated, or never vaccinated. Signs or symptoms recorded were paroxysmal cough, inspiratory whoop, post-tussive vomiting, and apnea. These symptoms were assessed at the time individuals met the definition (7–13 days of cough duration), but were not reassessed later when cases might meet the national definition (14 or more days of cough duration). RT-PCR testing was conducted using nasopharyngeal swabs collected with Dacron or rayon swabs, which were placed in sterile tubes. Samples were either sent immediately or stored at –10°C for no more than 48 hours before being transported within two hours in temperature-controlled containers to the Regional Medical Sciences Center 12, Songkhla Province, Thailand. RT-PCR test results were reported as positive, inconclusive, or negative for pertussis (no cycle threshold reported). Only cases with positive results were considered as RT-PCR positive pertussis cases.

The data were checked for completeness and accuracy, cleaned, and analyzed using R version 4.2.1.[8] The analysis addressed the following study objectives:

The first objective described demographic factors (gender, age group), case type, DTP vaccination status, and clinical signs or symptoms among the three groups: cases meeting the Narathiwat definition, cases meeting the national definition, and all RT-PCR positive cases (confirmed cases). Additionally, timeliness of pertussis detection, defined as the time from symptom onset to positive RT-PCR confirmation, was calculated separately for cases meeting the Narathiwat definition and the national definition. The results were presented as frequencies, percentages, median, and interquartile range (IQR). Chi-squared test or Fisher's exact test ($p$ <0.05) were used to compare the frequencies for between groups. The second objective involved assessing clinical manifestations of RT-PCR positive and negative cases. This analysis included pertussis related signs or symptoms, such as paroxysmal cough, post-tussive vomiting, inspiratory whooping, and apnea. The odds ratios (OR) and $p$-values were calculated to assess the association between those clinical symptoms and RT-PCR positivity. The third objective was to evaluate the diagnostic accuracy of the Narathiwat definition and the national definition for pertussis detection, using RT-PCR for pertussis results as the reference standard. Additionally, alternative definitions combining cough duration with statistically significant symptoms ($p$ <0.05), identified through univariable logistic regression analysis, were proposed and assessed using standard 2x2 table formulas to calculate sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and 95% confidence intervals (CI).[9]

| | | Reference standard (RT-PCR for pertussis) | |
|---|---|---|---|
| | | Positive | Negative |
| Meeting the case definition | Yes | A | B |
| | No | C | D |

Sensitivity = A/(A+C),
Specificity = D/(B+D),
Positive predictive value (PPV) = A/(A+B) ,
Negative predictive value (NPV) = D/(C+D)

From the 2x2 table, cases were categorized as follows: those meeting the case definition who tested positive (A: true positive) or negative (B: false positive), and those not meeting the case definition who tested positive (C: false negative) or negative (D: true negative). Cells C and D included individuals who underwent RT-PCR testing despite not meeting both clinical suspected case definitions. Those individuals were tested either based on physicians' suspicion of pertussis or identified as HRC through contact tracing.

### Ethics

Ethical clearance was omitted as this investigation was conducted under EOC outbreak management. Data collection was part of the investigation, with participants informed of objectives and benefits beforehand. Responses were recorded on forms without audio, ensuring anonymity by excluding full names and addresses. All documents were securely stored, and accessible only to the principal investigator, who oversaw data disposal post-publication.

## Results

A total of 486 cases were analyzed, including 171 cases that met the Narathiwat definition, 107 cases that met the national definition, and 208 cases that did not meet either definition. All 486 cases underwent RT-PCR testing. For the 208 cases who did not meet either definition, 171 were tested based on physicians' suspicion of pertussis (with a 27.8% positive rate), while 37 were identified as high-risk contacts through contact tracing (with a 59.5% positive rate). Following RT-PCR, confirmed cases were 47.9% (82/171), 57.9% (62/107) and 30.8% (64/208) among cases meeting the Narathiwat, national, and neither definitions, respectively. Timeliness of pertussis detection had a median of 9 days (IQR 7.8–10 days) for cases meeting the Narathiwat definition and a median of 16 days (IQR 15–21 days) for cases meeting the national definition. Of the RT-PCR positive cases, 53.4% were female and 46.6% male. Cases meeting the Narathiwat definition comprised 51.5% female and 48.5% male, while those under the national definition had 58.0% female and 42.0% male ($p$ 0.57). The majority of cases fell in the 0–1 year age group, accounting for 49.0% of RT-PCR positive cases, 46.8% of those meeting the Narathiwat definition, and 39.3% of those under the national definition ($p$ 0.15). Paroxysmal cough was present in 84.6% of RT-PCR positive cases, 93.0% under the Narathiwat definition, and 94.4% under the national definition ($p$ 0.01); inspiratory whoop in 30.8%, 42.1%, and 43.0%, respectively ($p$ 0.03); and post-tussive vomiting in 62.5%, 63.2%, and 72.9%, respectively ($p$ 0.15) (Table 1).

**Table 1. Characteristics of RT-PCR positive cases and cases meeting Narathiwat and national definitions**

| Variables | | Frequency, n (%) RT-PCR positive cases (n=208) | Cases meeting the Narathiwat definition (n=171) | Cases meeting the national definition (n=107) | *P*-value |
|---|---|---|---|---|---|
| **Gender** | | | | | |
| Female | | 111 (53.4) | 88 (51.5) | 62 (58.0) | 0.57 |
| Male | | 97 (46.6) | 83 (48.5) | 45 (42.0) | |
| **Age group (years)** | | | | | |
| 0–1 | | 102 (49.0) | 80 (46.8) | 42 (39.3) | 0.15 |
| 2–3 | | 49 (23.6) | 34 (19.9) | 35 (32.7) | |
| 4–5 | | 19 (9.1) | 25 (14.6) | 9 (8.4) | |
| ≥6 | | 38 (18.3) | 32 (18.7) | 21 (19.6) | |
| **Type of case** | | | | | |
| Index | | 179 (86.1) | 159 (93.0) | 101 (94.4) | 0.03 |
| Active case finding | | 8 (3.8) | 5 (2.9) | 2 (1.9) | |
| High-risk contact | | 21 (10.1) | 7 (4.1) | 4 (3.7) | |
| **DTP vaccination status** | | | | | |
| Never | | 153 (73.6) | 93 (54.4) | 77 (71.9) | 0.01 |
| Incomplete | | 36 (17.3) | 56 (32.8) | 20 (18.7) | |
| Complete | | 4 (1.9) | 11 (6.4) | 5 (4.7) | |
| Unknown | | 15 (7.2) | 11 (6.4) | 5 (4.7) | |
| **Sign or symptom** | | | | | |
| Paroxysmal cough | Yes | 176 (84.6) | 159 (93.0) | 101 (94.4) | 0.01 |
| | No | 32 (15.4) | 12 (7.0) | 6 (5.6) | |
| Inspiratory whooping | Yes | 64 (30.8) | 72 (42.1) | 46 (43.0) | 0.03 |
| | No | 144 (69.2) | 99 (57.9) | 61 (57.0) | |
| Post-tussive vomiting | Yes | 130 (62.5) | 108 (63.2) | 78 (72.9) | 0.15 |
| | No | 78 (37.5) | 63 (36.8) | 29 (27.1) | |

*P-values were calculated using the chi-squared test or Fisher's exact test, as appropriate.*

The distribution of RT-PCR positive cases based on various clinical case criteria showed distinct differences. Among RT-PCR positive cases (n=208) with cough lasting ≥1 week, 82 had combined at least one sign or symptom (OR 1.38, 95% CI 0.95–2.01, *p* 0.09), 78 had paroxysmal cough (OR 1.46, 95% CI 1.00–2.14, *p* 0.05), 54 had post-tussive vomiting (OR 1.45, 95% CI 0.95–2.23, *p* 0.09), and 30 had inspiratory whooping (OR 0.95, 95% CI 0.57–1.57, *p* 0.83). Among RT-PCR positive cases with cough lasting ≥2 weeks, 62 had combined at least one sign or symptom (OR 2.20, 95% CI 1.42–3.40, *p* ≤0.01), 60 had paroxysmal cough (OR 2.34, 95% CI 1.10–3.66, *p* <0.01), 48 had post-tussive vomiting (OR 2.48, 95% CI 1.51–4.10, *p* <0.01), and 24 had inspiratory whooping (OR 1.51, 95% CI 0.83–2.79, *p* 0.18). Paroxysmal cough was significantly more common among RT-PCR positive cases compared to RT-PCR negative cases for both cough duration categories (*p* 0.05 for ≥1 week, *p* <0.01 for ≥2 weeks (Table 2).

**Table 2. Distribution of RT-PCR positive cases based on various clinical case criteria**

| Cough duration* | Combine with sign or symptom | RT-PCR positive (n=208) | RT-PCR negative (n=278) | OR (95% CI) | *P*-value |
|---|---|---|---|---|---|
| Cough lasting ≥1 week | At least one sign or symptom | 82 | 89 | 1.38 (0.95–2.01) | 0.09 |
| | Paroxysmal cough | 78 | 81 | 1.46 (1.00–2.14) | 0.05 |
| | Post-tussive vomiting | 54 | 54 | 1.45 (0.95–2.23) | 0.09 |
| | Inspiratory whooping | 30 | 42 | 0.95 (0.57–1.57) | 0.83 |
| | Apnea | 2 | 2 | 1.33 (0.19–9.59) | 0.77 |
| Cough lasting ≥2 weeks | At least one sign or symptom | 62 | 45 | 2.20 (1.42–3.40) | <0.01 |
| | Paroxysmal cough | 60 | 41 | 2.34 (1.10–3.66) | <0.01 |
| | Post-tussive vomiting | 48 | 30 | 2.48 (1.51–4.10) | <0.01 |
| | Inspiratory whooping | 24 | 22 | 1.51 (0.83–2.79) | 0.18 |
| | Apnea | 1 | 0 | NA | 0.23 |

**Cough duration: 1) cough ≥1 week: detects cases with 7 to 13 days of cough duration, 2) cough ≥2 weeks: detects cases with 14 or more days of cough duration. P-values and odds ratios were calculated using univariable logistic regression analysis. NA: not applicable, OR: odds ratio, CI: confidence interval.*

The diagnostic accuracy of the Narathiwat and national definitions demonstrated key differences, particularly in sensitivity and PPV. The Narathiwat definition showed higher sensitivity (39.4%; 95% CI 32.7–46.4) compared to the national definition (29.8%; 95% CI 23.7–36.5). However, its PPV was lower at 48.0% (95% CI 40.3–55.7), compared to 57.9% (95% CI 48.0–67.4) for the national definition. Among alternative definitions, definition A (cough ≥1 week, accompanied by paroxysmal cough) demonstrated a sensitivity of 37.5% (95% CI 30.9–44.5) and a PPV of 49.1% (95% CI 41.1–57.1), which was comparable to the Narathiwat definition (Table 3).

**Table 3. Diagnostic accuracy of clinical case definitions for pertussis compared to RT-PCR testing results as the reference standard**

| Clinical case definitions* | TP | FP | FN | TN | Sensitivity (%) (95% CI) | Specificity (%) (95% CI) | PPV (%) (95% CI) | NPV (%) (95% CI) |
|---|---|---|---|---|---|---|---|---|
| Narathiwat definition: Cough ≥1 week +at least one sign or symptom† | 82 | 89 | 126 | 189 | 39.4 (32.7–46.4) | 68.0 (62.2–73.4) | 48.0 (40.3–55.7) | 60.0 (54.4-65.5) |
| National definition: Cough ≥2 weeks +at least one sign or symptom† | 62 | 45 | 146 | 233 | 29.8 (23.7–36.5) | 83.8 (78.9–87.9) | 57.9 (48.0–67.4) | 61.5 (56.4-66.4) |
| **Alternative definition** | | | | | | | | |
| (A) cough ≥1 week +paroxysmal cough | 78 | 81 | 130 | 197 | 37.5 (30.9–44.5) | 70.9 (65.1–76.1) | 49.1 (41.1–57.1) | 60.2 (54.7-65.6) |
| (B) cough ≥2 weeks +paroxysmal cough | 60 | 41 | 148 | 237 | 28.8 (22.8–35.5) | 85.3 (80.5–89.2) | 59.4 (49.2–69.1) | 61.6 (56.4-66.4) |
| (C) cough ≥1 week +post-tussive vomiting | 54 | 54 | 154 | 224 | 26.0 (20.1–32.5) | 80.6 (75.4–85.1) | 50.0 (40.2–59.8) | 59.3 (54.1-64.3) |
| (D) cough ≥2 weeks +post-tussive vomiting | 18 | 10 | 190 | 268 | 8.7 (5.2–47.3) | 96.4 (93.5–98.3) | 64.3 (44.1–81.4) | 58.5 (53.9-63.1) |
| (E) cough ≥1 week +inspiratory whooping | 30 | 42 | 178 | 236 | 14.4 (9.9–19.9) | 84.9 (80.1–88.9) | 41.7 (30.2–53.9) | 57.0 (52.1-61.8) |
| (F) cough ≥2 weeks +inspiratory whooping | 12 | 5 | 196 | 273 | 5.8 (3.0–9.9) | 98.2 (95.9–99.4) | 70.6 (44.0–89.7) | 58.2 (53.6-62.7) |

**Cough duration in clinical case definitions: 1) cough ≥1 week: detects cases with 7 to 13 days of cough duration, 2) cough ≥2 weeks: detects cases with 14 or more days of cough duration. †The signs and symptoms include paroxysmal cough, post-tussive vomiting, inspiratory whooping, and apnea. (A)–(F) represent the alternative case definitions assessed for diagnostic accuracy. TP: true positive. FP: false positive. FN: false negative. TN: true negative. PPV: positive predictive value, NPV: negative predictive value.*

## Discussion

This study assessed the diagnostic performance of pertussis case definitions in a low-vaccination setting, comparing the Narathiwat and national definitions in detecting RT-PCR confirmed cases. The findings have highlighted differences in sensitivity and PPV between the two definitions, with alternative criteria also evaluated to improve detection. Notably, a significant proportion of cases did not meet either definition, emphasizing the challenges in clinical diagnosis. The results underscore the importance of standardized case definitions in outbreak settings and suggest the need for optimized criteria to enhance early detection and intervention.

Paroxysmal cough had the highest positive detection rate by RT-PCR (84.6%) and was significantly more common among RT-PCR positive cases compared to RT-PCR negative cases for both cough duration categories. This finding has reinforced paroxysmal cough's diagnostic value as recommended by the WHO and the US Centers for Disease Control and Prevention.[10] Studies have consistently emphasized the high prevalence of paroxysmal cough in confirmed pertussis cases, supporting its inclusion in case definitions.[11–13]

Post-tussive vomiting was more commonly observed in cases with a longer cough duration (≥2 weeks) (OR 2.48, 95% CI 1.51–4.10, $p$ <0.01) compared to those with a shorter cough duration (≥1 week) (OR 1.45, 95% CI 0.95–2.23, $p$ 0.09). Similarly, inspiratory whooping was more frequently observed in cases with a longer cough duration (OR 1.51, 95% CI 0.83–2.79, $p$ 0.18) compared to a shorter cough duration (OR 0.95, 95% CI 0.57–1.57, $p$ 0.83). These findings may reflect differences in cough duration and symptom reporting. They have aligned with evidence suggesting that symptoms such as post-tussive vomiting and inspiratory whooping often intensify after two weeks of coughing.[14–16] In contrast, apnea showed no significant association with any clinical case criteria, reflecting its limited diagnostic value in this context. However, previous research has highlighted that, although inspiratory whooping and apnea are less commonly observed, they can still aid in confirming the diagnosis in certain cases.[17]

The diagnostic performance of pertussis case definitions have highlighted their strengths and limitations in the contexts of outbreak detection versus routine surveillance. The Narathiwat definition, requiring ≥1 week of cough with at least one sign or symptom, achieved higher sensitivity (39.4%) than the national definition, which requires ≥2 weeks of cough with at least one sign or symptom (29.8%). This higher sensitivity allows for earlier detection, which has been supported by previous studies.[13] Additionally, the median time for pertussis detection according to the Narathiwat definition was nine days (IQR 7.8–10 days), which aligned with research on the optimal timing of specimen collection, suggesting that modified case definitions could help detect cases earlier and allow for more timely interventions.[18] However, the national definition demonstrated superior specificity (83.8% versus 68.0%) and PPV (57.9% versus 48.0%), making it more effective for identifying true cases while minimizing false positives in routine surveillance.[12] Alternative definitions, such as cough ≥1 week combined with paroxysmal cough, can increase specificity and PPV while still maintaining similar sensitivity compared to the definition of >1 weeks of cough with at least one sign or symptom. This aligned with studies which have suggested that including paroxysmal cough as a criterion can improve the balance of diagnostic accuracy by enhancing specificity, and PPV. Such an approach provides a more effective way to identify true pertussis cases while minimizing false positives and negatives.[19]

The relatively low RT-PCR positive rate of 27.8% among cases identified based solely on physicians' suspicion without meeting any case definition highlights the limitations of relying on clinical judgment alone, especially in outbreak settings where escalating laboratory costs pose additional challenges. However, the WHO and European Union consider physicians' suspicion as a valid component of case definitions.[3,10] This approach may be less effective in high-prevalence settings like Narathiwat. To address this during the epidemic, the EOC implemented regular clinician training and follow-ups to ensure consistent application of the Narathiwat definition across hospitals and community settings, improving diagnostic accuracy and outbreak management.

## Limitations

During the outbreak, case definitions were based on patients visiting the hospital or being identified through investigations. Symptom data were recorded only at the time of investigation, preventing tracking of new or changing symptoms. This study relied on secondary data, and the completeness and accuracy of certain variables, especially clinical symptoms, could not be fully verified. Variability in symptom reporting may have affected case classification. Therefore, cases meeting the Narathiwat definition (7–13 days of cough) and the national definition (≥14 days of cough) were analyzed separately

## Recommendations

To improve pertussis detection and response, case definitions with high sensitivity, such as the Narathiwat definition (≥1 week of cough with one sign or symptom), should be prioritized during outbreaks in high-prevalence and widespread epidemic areas to enable early detection and timely intervention. Alternative definitions, such as cough ≥1 week combined with paroxysmal cough, offer a better balance of sensitivity (37.5%) and PPV (49.1%), enhancing diagnostic accuracy while minimizing false positives. For routine surveillance in non-outbreak settings, the national definition (≥2 weeks of cough with one sign or symptom) is more appropriate due to its higher specificity (83.8%). Regular clinician training and consistent follow-up measures are vital to ensure the standardized application of case definitions, thereby reducing unnecessary laboratory testing costs and maintaining efficiency.

## Conclusion

This study compared the characteristics of cases meeting the Narathiwat definition, national definition, and RT-PCR positive pertussis cases, focusing on demographics, vaccination status, and clinical signs. Paroxysmal cough, present in 84.6% of RT-PCR positive cases, was significantly more common among RT-PCR positive cases compared to RT-PCR negative cases, reinforcing its diagnostic value. The Narathiwat definition, with higher sensitivity (39.4%), detected earlier cases (≥1 week of cough), than the national definition, with higher specificity (83.8%). Additionally, the median time for pertussis detection was nine days (IQR 7.8–10 days) according to the Narathiwat definition, suggesting that modified case definitions could help to detect cases earlier and allow for more timely interventions. Alternative definitions, like cough ≥1 week plus paroxysmal cough, offered a balanced sensitivity (37.5%) and PPV (49.1%). Periodic reviews of case definitions, clinician training, and consistent application are crucial for improving pertussis detection, resource allocation, and outbreak response.

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## Conflicts of Interests

The author declares no conflicts of interest related to this work.

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## References

1. Centers for Disease Control and Prevention (US). Pertussis cases by country [Internet]. Atlanta (GA): Centers for Disease Control and Prevention; 2023 May [cited 2024 Feb 5]. <https://www.cdc.gov/pertussis/countries/index.html>
2. World Health Organization. Pertussis [Internet]. Geneva: World Health Organization; [cited 2024 Feb 5]. <https://www.who.int/health-topics/pertussis#tab=tab_1>
3. World Health Organization. Recommended case classifications of pertussis [Internet]. Cairo: Regional Office for the Eastern Mediterranean, World Health Organization; 2024 [cited 2024 May 25]. <https://www.emro.who.int/health-topics/pertussis/disease-surveillance.html>
4. World Health Organization. Thailand case study: school vaccination checks [Internet]. Geneva: World Health Organization; [cited 2024 Feb 7]. 11 p. <https://cdn.who.int/media/docs/default-source/immunization/school-vaccination/case_study_report-school_vaccination_checks-thailand_final.pdf?sfvrsn=ac97da26_3>
5. Division of Epidemiology, Department of Disease Control, Ministry of Public Health (TH). Annual epidemiological surveillance report 2019 [Internet]. Nonthaburi: Department of Disease Control, Ministry of Public Health; [cited 2024 Feb 12]. <https://apps-doe.moph.go.th/boeeng/download/MIX_AESR_2562.pdf>
6. Division of Epidemiology, Department of Disease Control. Case definition for communicable diseases surveillance, Thailand, 2020 [Internet]. Nonthaburi: Division of Epidemiology, Department of Disease Control; 2020 [cited

2024 Aug 10]. <http://klb.ddc.moph.go.th/data entry/handbook/form/113>

7. Microsoft Corporation. Microsoft excel. Redmond (WA): Microsoft Corporation; 2016.

8. R Development Core Team. R Project for statistical computing. Version 4.2.1. Vienna: R Foundation; 2022.

9. Shreffler J, Huecker MR. Diagnostic testing accuracy: Sensitivity, specificity, predictive values and likelihood ratios [Internet]. In: StatPearls. Treasure Island (FL): StatPearls Publishing; [updated 2023 Mar 6; cited 2024 Apr 21]. <https://www.ncbi.nlm.nih.gov/books/NBK557491/>

10. Cherry JD, Tan T, Wirsing von Konig CH, Forsyth KD, Thisyakorn U, Greenberg D, et al. Clinical definitions of pertussis: summary of a global pertussis initiative roundtable meeting. Clin Infect Dis. 2012 Jun;54(12):1756–64. doi:10.1093/cid/cis302.

11. Ghanaie RM, Karimi A, Sadeghi H, Esteghamti A, Falah F, Armin S, et al. Sensitivity and specificity of the World Health Organization pertussis clinical case definition. Int J Infect Dis. 2010 Dec;14(12):e1072–5. doi:10.1016/j.ijid.2010.07.005.

12. Wu DX, Chen Q, Yao KH, Li L, Shi W, Ke JW, et al. Pertussis detection in children with cough of any duration. BMC Pediatr. 2019 Jul 12;19(1):236. doi: 10.1186/s12887-019-1615-3.

13. Muloiwa R, Nicol MP, Hussey GD, Zar HJ. Diagnostic limitations of clinical case definitions of pertussis in infants and children with severe lower respiratory tract infection. PLoS One. 2020 Jul 17;15(7):e0235703. doi:10.1371/journal.pone.0235703.

14. Fry NK, Campbell H, Amirthalingam G. JMM Profile: Bordetella pertussis and whooping cough (pertussis): still a significant cause of infant morbidity and mortality, but vaccine-preventable. J Med Microbiol. 2021 Oct;70(10):001442. doi:10.1099/jmm.0.001442.

15. Teng MS, Wang NE. Whooping cough: management and diagnosis of pertussis [Internet]. Morrisville (NC): Relias Media; 2011 May 1 [cited 2024 May 30]. <https://www.reliasmedia.com/articles/130291-whooping-cough-management-and-diagnosis-of-pertussis>

16. Centers for Disease Control and Prevention (US). Clinical Features of pertussis [Internet]. Atlanta (GA): Centers for Disease Control and Prevention; 2024 Apr 2 [cited 2024 May 5]. <https://www.cdc.gov/pertussis/hcp/clinical-signs/index.html>

17. Ristic M, Radosavljevie B, Stojanovic VD, Dilas M, Petrovic V. Performance of the new clinical case definitions of pertussis in pertussis suspected infection and other diagnoses similar to pertussis. PLoS One. 2018 Sep 20;13(9): e0204103. doi:10.1371/journal.pone.0204103.

18. Lee AD, Cassiday PK, Pawloski LC, Tatti KM, Martin MD, et al. Clinical evaluation and validation of laboratory methods for the diagnosis of Bordetella pertussis infection: Culture, polymerase chain reaction (PCR) and anti-pertussis toxin IgG serology (IgG-PT). PLoS One. 2018 Apr 13;13(4):e0195979. doi:10.1371/journal.pone.0195979.

19. Patriarca PA, Biellik RJ, Sanden G, Burstyn DG, Mitchell PD, Silverman PR, et al. Sensitivity and specificity of clinical case definitions for pertussis. Am J Public Health. 1988 Jul; 78(7):833–6. doi:10.2105/ajph.78.7.833.

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# Mascot Magic or Sporting Spectacle: An Interrupted Time Series Analysis with Social Listening Tools to Assess the Effect of "Butterbear" Mania and the 2024 European Football Championship on the Mental Well-being of Thai Residents

Suphanat Wongsanuphat[1*], Charuttaporn Jitpeera[1], Rapeepong Suphanchaimat[1,2], Naruttha Norphun[3], Bhornpimon Na-on[4], Panithee Thammawijaya[5]

1 Division of Epidemiology, Department of Disease Control, Ministry of Public Health, Thailand

2 International Health Policy Program, Ministry of Public Health, Thailand

3 Songkhla Rajanagarindra Psychiatric Hospital, Department of Mental Health, Ministry of Public Health, Thailand

4 Bureau of Mental Health Service Administration, Department of Mental Health, Ministry of Public Health, Thailand

5 Office of Senior Expert Committee, Department of Disease Control, Ministry of Public Health, Thailand

*Corresponding author, email address: suphanat.wong@gmail.com

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**Abstract**

Mental health is a major public health issue in Thailand. In June and July 2024, a commercial mascot called "Butterbear" and the Euro-2024 football tournament were trending on social media. This study assessed gender, age, and geographic-specific exposure to these trends and their association with mental well-being in Thailand. We applied an interrupted time series analysis to compare mental well-being across gender, age, and region. Data from the Mental Health Check-in, from January 2020–July 2024, were used to estimate the levels of stress and depression, and the risk of suicide. Google Trends and social media analytics provided engagement data. Seasonal autoregressive integrated moving average models with exogenous regressors incorporating socioeconomic indicators were used. Totally, 5,499,170 responses were recorded, with stress, depression, and suicide risk levels at 7.8%, 5.2%, and 9.1%, respectively. "Butterbear" and "Euro-2024" were searched 631,414 and 1,975,759 times, respectively. Significant female engagement for "Butterbear" and male engagement for "Euro-2024" in the 18–34-year age group were observed. Improvements in mental well-being were found among females in Bangkok aged 18–34 years in terms of stress (−18.0%), depression (−22.8%), and suicide risk (−18.0%) compared to predicted levels. Males and females outside Bangkok, had smaller differences, with changes in stress levels ranging from −4.2% to 5.7%. The study's trends suggest a mental health relationship with these global events, influenced by media marketing. Leveraging popular phenomena such as Butterbear and global sporting events such as Euro-2024 can enhance mental well-being and could be utilized as part of health promotion campaigns.

**Keywords:** mental health, marketing, social listening tools, interrupted time series analysis, social media consumption

## Introduction

Mental health problems have become increasingly prevalent in Thailand, particularly among those in early to middle adulthood who face a range of socioeconomic pressures.[1,2] In 2020, Thailand had 13,000 outpatient mental health visits per 100,000 population with 0.94 psychiatrists per 100,000 population.[3]

Rapid socio-economic changes and educational pressures can exacerbate mental health, making those in their early to middle adulthood particularly vulnerable.

Additionally, various forms of social events and digital entertainment, including sports tournaments, and entertainment videos via online resources and social media, have a profound impact on an individual's mental health, either as a source of stress relief as a "therapeutic effect of entertainment" or as a trigger for mental health issues. Therapeutic effects of entertainment have been described as a coping strategy to deal with stress, for example, entertainment videos for stress coping among undergraduate students, or the use of animal mascots to help soldiers combat or adjust to the stress associated with their military duties. The effect of the media could produce positive emotions toward their psychological well-being.[4–6]

Social media has become a major platform allowing individuals to follow social events and digital entertainment. It provides a valuable source of data for understanding population-level entertainment exposure via social listening tools. Social media usage in Thailand is pervasive, particularly among adolescents and young to middle-aged adults. Social media platforms such as Facebook, TikTok, Instagram, and X (formerly twitter) are integral to the daily lives of many Thais with 49.0, 44.3, 18.7, and 14.6 million users, respectively.[7] These platforms provide a space for social interaction and entertainment dissemination.

Butterbear, a cuddly mascot created by the owner of a popular Thai bakery located in Bangkok, was introduced in December 2023 and went viral through social media in June 2024.[8] Her character is designed to exude warmth, comfort, friendliness, politeness, accessibility, and happiness. People on social media interact with Butterbear not as a mascot with someone inside, but as if she was a little girl, an internet idol with a personality.[8] Many say that Butterbear helps alleviate stress and enhance emotional well-being.[9] From 1 Jun 2024 to 10 Jul 2024, Butterbear was engaged more than 82 million times, with three million views on YouTube for her first music video within two weeks.[10,11]

Major sporting tournaments have the potential to impact population-level mental health, either positively through increased community engagement and emotional involvement or negatively through heightened anxiety, disappointment, and gambling.[12,13] The 2024 European Football Championship (Euro-2024), a globally-watched sporting event, began in June 2024 at the same time as Butterbear fever was becoming a global phenomenon. These global events can have significant mental health implications in Thailand, fostering community spirit and enhancing social bonds through shared experiences. However, it also poses challenges, particularly for vulnerable young adults, who may face increased stress and feelings of isolation.[14,15]

During June 2024 and July 2024, "Butterbear" and "Euro-2024" were the top monthly searched and mentioned keywords in Thailand), prompting discussions on their emotional impact on the Thai population.[16] However, the influence of social media engagement with Butterbear and Euro-2024 on mental well-being has not been thoroughly examined. This study aimed to utilize social listening tools to analyze the online entertainment target audience, assessing the gender, age, and geographic-specific exposure of Butterbear and Euro-2024, and to evaluate their relationships on short-term mental well-being in Thailand.

## Methods

### Study Design

This was an interrupted time series (ITSA) study.

### Data Collection and Descriptive Analysis

Mental well-being data were extracted from the Mental Health Check-in (MHCI), a voluntary preliminary online mental health assessment and screening tool for mental health problems under the responsibilities of the Department of Mental Health, Ministry of Public Health, Thailand. The MHCI is accessible to all individuals nationwide. Individuals can choose to participate anonymously, allowing for widespread engagement. This approach enables the collection of mental health data across various demographics and regions. The online assessment includes measures of stress (5 four-frequency-choices questions: ST-5), severity of depression (9 four-frequency-choices questions: 9Q), and suicide risk (8 yes-no questions: 8Q). These measures were tested for validity and reliability and are standard measures for use in stress and suicidal risk assessments.[17,18] Aggregated data on number of responses, high stress (ST-5 ≥5), suicide risk (8Q ≥1), and severe depression (9Q ≥7) were collected for the period between 1 Jan 2020 and 15 Jul 2024.[19] Data were stratified by gender, age group, and geographic region (Bangkok metropolitan or others). Monthly percentages of stress, depression, and suicide risk were calculated.

To measure the magnitude of engagement, daily search data on Google and YouTube, covering 1 Jan 2024 to 15 Jul 2024, were obtained from Google Trends with Google Trends Supercharged Chrome extension.[20] Keywords used included "Butterbear" and "หมีเนย" (Butterbear in Thai) for Butterbear and "Euro-2024" and "ยูโร 2024" (Euro-2024 in Thai) for Euro-2024. Searches were summarized weekly and visualized to identify patterns and trends over time.

Bi-weekly engagement data, including the number and percentage of messages, were extracted from social media analytics provided by Wisesight Trend, an open-source real-time social media monitoring platform.[21] Social media included Facebook, TikTok, Instagram, X (formerly Twitter), and YouTube. The entertainment media were categorized into nine categories by Wisesight Trend, namely restaurant (which Butterbear was classified), sport (which Euro-2024 was classified), actor/actress, gaming and e-sport, V-tuber, variety, film and literature, beauty and fashion, and cooking and chef. Gender and age-specific distributions were also analyzed to understand the demographic reach of Butterbear and Euro-2024.

Monthly key socioeconomic indicators, including unemployment rate and household debt, were extracted from the labor force survey report, National Statistical Office, and Society and Bank of Thailand.[22–24]

### Interrupted Time Series Analysis

ITS analysis is a quasi-experimental design that assesses the effect of an intervention by analyzing data collected at multiple time points before and during the intervention.[25] In this study, ITS analysis was used to assess the impact of Butterbear and Euro-2024 on mental well-being indicators. We first identified the intervention period based on search trends from the descriptive analysis. The beginning of the intervention period was identified by the time that cumulative searches reached 5% of total searches and onward. Secondly, time series components were identified by visualization and component decompositioning of the monthly percentage of stress, depression, and suicide risk. Due to appearances of trends and seasonality, seasonal autoregressive integrated moving average with exogenous regressor (SARIMAX) models were selected, incorporating socioeconomic indicators as exogenous variables to address socioeconomic confounders. Different parameters were fit to the data. For model validation, data during the pre-intervention period were split into a training set and a testing set (last six months), and the best model was selected based on the mean absolute error (MAE) and mean absolute percentage error (MAPE) criterion during the six-month testing phase. MAE measures the average magnitude of errors between predicted and actual values, without considering their direction, by calculating the average absolute differences between them. MAPE expresses this accuracy as a percentage by calculating the average absolute percentage difference between predicted and actual values.[26] The selected model was used to perform the ITS analysis on the mental health indicators, together with monthly key socioeconomic indicators. Changes in monthly percentages of stress, depression, and suicide risk between observed data (as-is) and predicted data (pre-intervention trend continued) during intervention periods (until August 2024) were calculated. The analysis was stratified by subpopulation based on social listening data (gender, age group, and geographic region). Mean estimates of predicted data with 95% prediction interval (PI) were calculated.

### Ethics

Ethics approval was not required for this work as it is part of the routine mission of the Intelligence and Non-communicable Diseases Unit at the Division of Epidemiology. This study did not collect individual data.

## Results

### Descriptive Analysis

From 1 Jan 2020 to 15 Jul 2024, there were totally 5,499,170 responses in the MHCI. High stress levels were reported in 7.8% of responses, suicide risk in 5.2%, and severe depression in 9.1%. Most responses were female (62.5%) and 6.9% were from Bangkok.

Between 1 Jan and 15 Jul 2024, Butterbear was searched 631,414 times (32.5% Google Search, 67.5% YouTube), while Euro-2024 garnered 1,975,759 searches (49.6% Google Search, 50.4% YouTube). As shown in Figure 1, most searches (96.3%) occurred between 1 Jun 2024 and 15 Jul 2024.

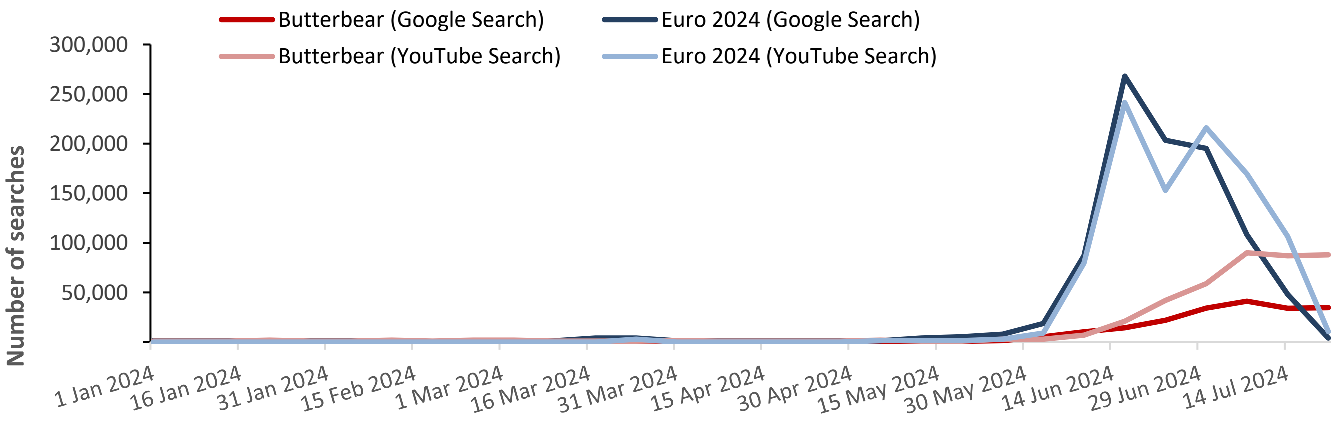



**Figure 1. Number of Butterbear and Euro-2024 keyword searches between 1 Jan 2024 and 15 Jul 2024 stratified by platform (Google Search and YouTube)**

For hashtags mentioned on social media, Butterbear and Euro-2024 significantly outpaced other entertainment categories, with 31.6% and 29.9% of the total entertainment hashtags, respectively. This positioned Butterbear and Euro-2024 as the top two entertainment topics during that timeframe. Butterbear accounted for 82.0% of the overall restaurant hashtag, and Euro-2024 comprised 75.2% of the overall sport hashtag. Both showed a consistent upward trend, with Butterbear's hashtag rising from 2,151 to 8,209 and Euro-2024's from 3,154 to 5,795 from early June to early July. Figure 2 shows that 50,193 messages mentioned Butterbear and 130,148 mentioned Euro-2024. For Butterbear, the 25–34 age group accounted for 49.1% of messages, with 79.3% female representation, and the 18–24 age group made up 37.9% of messages, with 66.8% females. For Euro-2024, the 18–24 age group accounted for 45.3% of messages, with 81.8% male representation, and the 25–34 age group made up 34.6% of messages, with 80.5% males (Table 1).

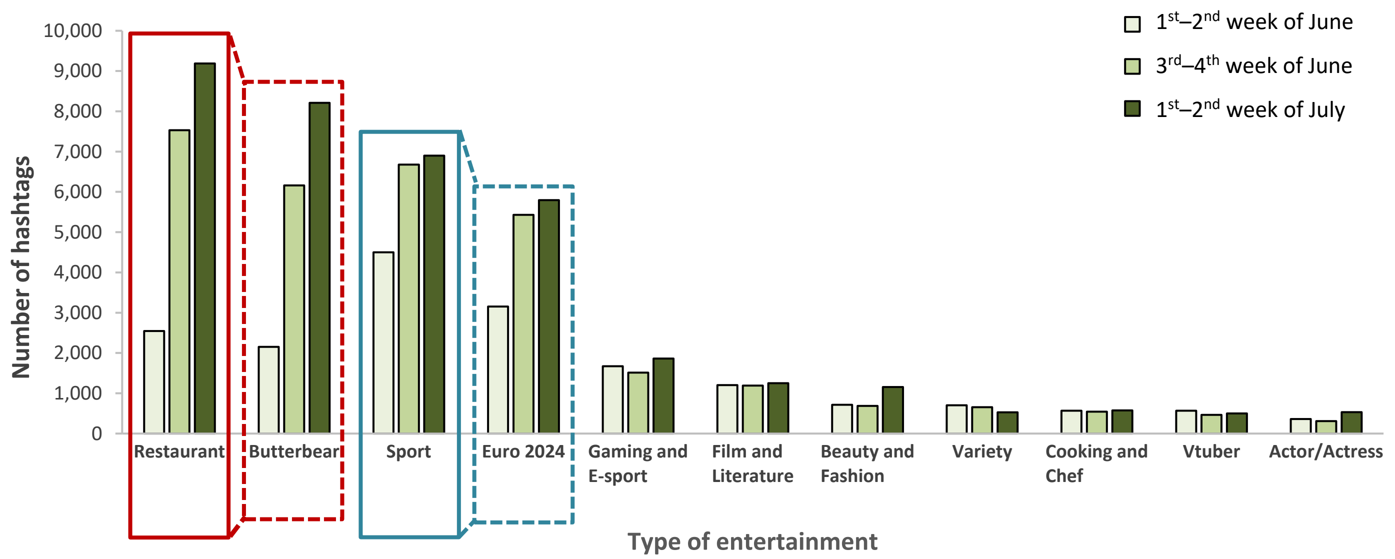



**Figure 2. Number of Butterbear and Euro-2024 messages mentioned between 1 Jan 2024 and 15 Jul 2024 compared with other types of entertainment**

**Table 1. Number and percentage of messages mentioning Butterbear and Euro-2024 on social media by age group and gender between 1 Jun 2024 and 15 Jul 2024**

| Age group (years) | Butterbear | | | Euro-2024 | | |
|---|---|---|---|---|---|---|
| | Total n (%) | Females n (%) | Males n (%) | Total n (%) | Females n (%) | Males n (%) |
| <18 | 3,046 (6.1) | 1,354 (44.4) | 1,692 (55.6) | 10,157 (7.8) | 2,576 (25.4) | 7,581 (74.6) |
| 18–24 | 19,039 (37.9) | 12,707 (66.8) | 6,332 (33.3) | 58,939 (45.3) | 10,748 (18.1) | 48,191 (81.9) |
| 25–34 | 24,647 (49.1) | 19,557 (79.3) | 5,090 (20.7) | 45,025 (34.6) | 8,796 (19.6) | 36,229 (80.4) |
| 35–44 | 2,534 (5.0) | 1,448 (57.1) | 1,086 (42.9) | 10,959 (8.4) | 1,309 (12.0) | 9,650 (88.0) |
| ≥45 | 944 (1.9) | 363 (38.5) | 581 (61.5) | 5,068 (3.9) | 655 (12.9) | 4,413 (87.1) |
| **Total** | **50,193 (100)** | **35,429 (70.6)** | **14,764 (29.4)** | **130,148 (100)** | **24,084 (18.5)** | **106,064 (81.5)** |

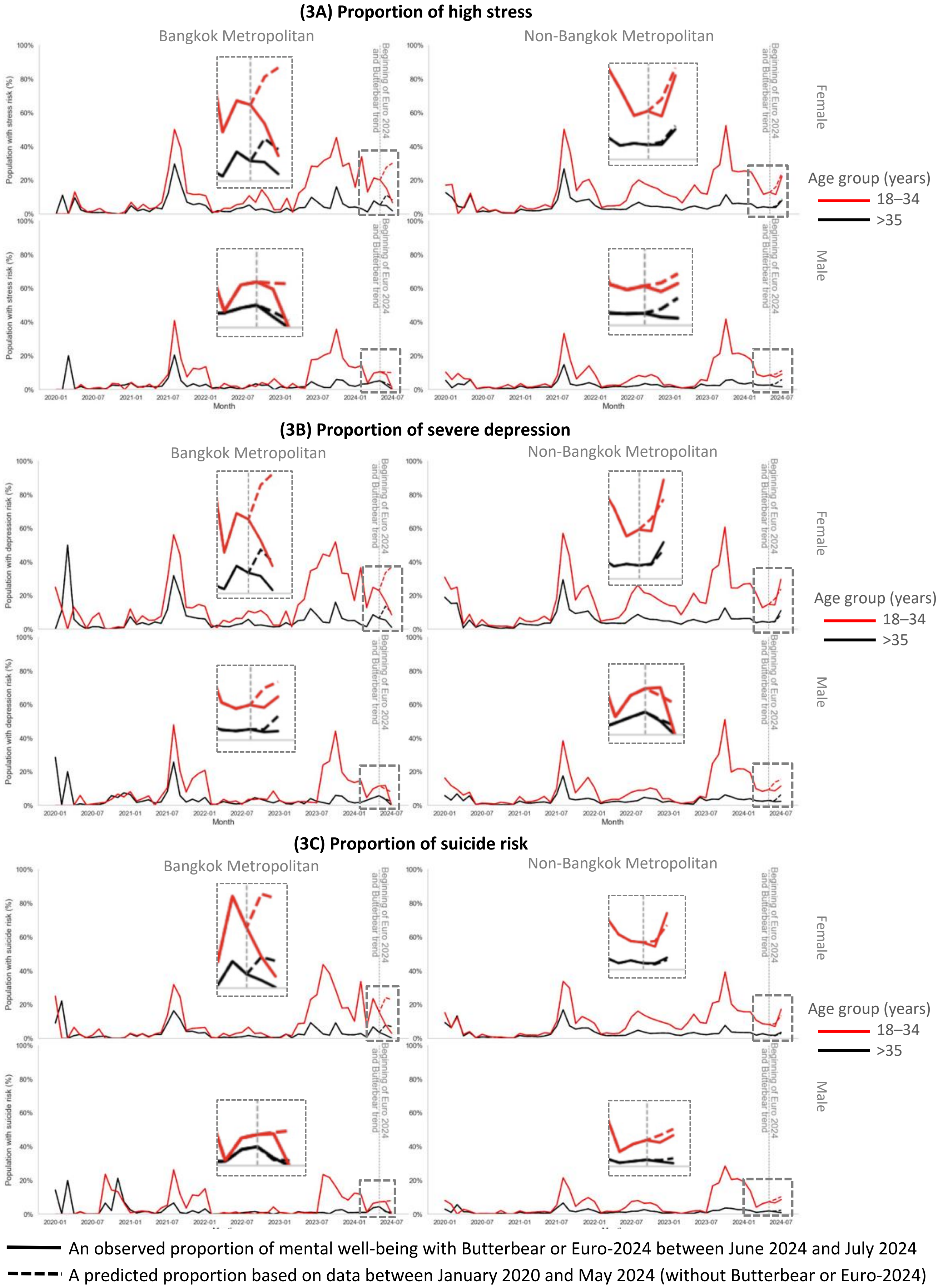
### Interrupted Time Series Analysis

From the aforementioned searching trends, 1 Jun 2024 and 15 Jul 2024 were identified to be the intervention period. The analysis revealed high MAPE in the "under 18 years" age group, with an average 724.1%, leading to its exclusion due to low model accuracy. For ages 18–34, the overall average MAPE was 65.0%, and for ages over 35, it was 61.9%. Overall, except for respondents under 18 years of age, the average MAPE increased to 63.5% (Table 2). The model parameters, coefficients, standard errors, and *p*-values are illustrated in Supplementary Table 1.

**Table 2. Mean absolute error (MAE) and mean absolute percentage Error (MAPE) of SARIMAX model for predicting monthly percentage of high stress, severe depression, and suicide risk during model validation phase (December 2023–May 2024) stratified by age group, gender, and region**

| Age group (years) | Gender | Region | MAE | MAPE (%) |
|---|---|---|---|---|
| **Under 18 years old** | Female | Bangkok Metropolitan | 36.27 | 1,077.1 |
| | | Non-Bangkok Metropolitan | 9.33 | 311.0 |
| | Male | Bangkok Metropolitan | 20.23 | 700.7 |
| | | Non-Bangkok Metropolitan | 30.66 | 807.6 |
| | Overall | Overall | 24.12 | 724.1 |
| **18–34 years old** | Female | Bangkok Metropolitan | 10.89 | 73.3 |
| | | Non-Bangkok Metropolitan | 3.47 | 23.4 |
| | Male | Bangkok Metropolitan | 3.24 | 54.8 |
| | | Non-Bangkok Metropolitan | 8.11 | 108.6 |
| | Overall | Overall | 6.43 | 65.0 |
| **Over 35 years old** | Female | Bangkok Metropolitan | 1.66 | 76.5 |
| | | Non-Bangkok Metropolitan | 1.17 | 37.1 |
| | Male | Bangkok Metropolitan | 1.90 | 115.4 |
| | | Non-Bangkok Metropolitan | 0.43 | 18.8 |
| | Overall | Overall | 1.29 | 61.9 |
| **Overall** | Females | Overall | 10.47 | 266.4 |
| | Males | Overall | 10.76 | 301.0 |
| | Overall | Bangkok Metropolitan | 12.37 | 349.6 |
| | | Non-Bangkok Metropolitan | 8.86 | 217.8 |
| | | Overall | 10.61 | 283.7 |
| **Overall except for respondents under 18 years of age** | Females | Overall | 4.30 | 55.6 |
| | Males | Overall | 3.42 | 74.4 |
| | Overall | Bangkok Metropolitan | 4.42 | 80.0 |
| | | Non-Bangkok Metropolitan | 3.30 | 47.0 |
| | | Overall | 3.86 | 63.5 |

The ITS analysis, depicted in Figure 3, evaluates the impact of Butterbear and Euro-2024 on mental well-being indicators, adjusted for key socioeconomic variables. The analysis covered three indicators: stress (Figure 3A), severe depression (Figure 3B), and suicide risk (Figure 3C) across different regions and genders. High stress levels, severe depression, and suicide risk showed higher proportions in the 18–34 age group compared to the 35 and older age group, with noticeable peaks during June and August 2021 and 2023. Between June and July 2024, however, the proportion decreased in all subgroups in Bangkok, while it increased in females outside Bangkok. In contrast, marked predicted spikes were observed among females, but not in males, during the same period.




*Vertical dashed line illustrates the starting point of the intervention period.*

**Figure 3. Interrupted time series analysis illustrated the impact of Butterbear and Euro-2024 on mental well-being indicators after adjusting for key socioeconomic indicators by (3A) proportion of high stress, (3B) proportion of severe depression, and (3C) proportion of suicide risk**

Further examination revealed significant differences between observed and predicted mental well-being proportions between June and July 2024. For females aged 18–34 in Bangkok, the observed proportion for high stress was 10.9% versus a predicted proportion of 28.9% (95% PI 3.9%, 53.9%), resulting in a difference of −18.0% (95% PI −43.0%, 7.0%). The difference for severe depression was −22.8% (−50.9%, 5.4%), and −18.0% (−33.0%, −3.0%) for suicide risk. For females aged 35 and older in Bangkok, the observed differences were smaller: −6.4% (−23.9%, 3.4%) for stress, −8.5% (−32.5%, 3.3%) for depression, and −6.4% (−17.0%, 1.0%) for suicide risk. In contrast, females aged 18–34 outside Bangkok had much smaller discrepancies: −3.3% (−24.4%, 16.9%) for stress, 1.1% (−25.8%, 22.0%) for depression, and 1.0% (−14.5%, 12.1%) for suicide risk. For males aged 18–34 in Bangkok, the difference for stress was −5.7% (−20.8%, 4.4%), −2.9% (−23.2%, 5.9%) for depression, and −4.2% (−15.3%, 3.7%) for suicide risk. These variations highlighted regional and demographic disparities in observed and predicted mental well-being trends, particularly among young females in Bangkok, where observed rates were significantly lower than expected. (Table 3)

**Table 3. Differences between observed and predicted monthly percentage of high stress with 95% prediction interval (PI), severe depression and suicide risk from SARIMA model between June and July 2024 stratified by age group, gender and region**

| Mental well-being | Age group (years) | Gender | Region | Mean observed proportion (%) | Mean predicted proportion (95% PI) | Different from predicted (%) |
|---|---|---|---|---|---|---|
| **High stress** | 18–34 | Female | Bangkok Metropolitan | 10.92 | 28.91 (3.88, 53.93) | -17.99 (-43.01, 7.04) |
| | | | Non-Bangkok Metropolitan | 16.90 | 20.16 (0.00, 41.26) | -3.26 (-24.36, 16.90) |
| | | Male | Bangkok Metropolitan | 4.42 | 10.15 (0.00, 25.20) | -5.73 (-20.78, 4.42) |
| | | | Non-Bangkok Metropolitan | 8.22 | 10.22 (0.00, 26.11) | -2.00 (-17.89, 8.22) |
| | ≥35 | Female | Bangkok Metropolitan | 3.37 | 9.79 (0.00, 27.26) | -6.42 (-23.89, 3.37) |
| | | | Non-Bangkok Metropolitan | 5.93 | 6.75 (0.00, 14.24) | -0.82 (-8.31, 5.93) |
| | | Male | Bangkok Metropolitan | 1.26 | 2.69 (0.00, 34.92) | -1.43 (-33.66, 1.26) |
| | | | Non-Bangkok Metropolitan | 1.72 | 4.76 (0.26, 9.27) | -3.04 (-7.55, 1.46) |
| **Severe depression** | 18–34 | Female | Bangkok Metropolitan | 12.54 | 35.30 (7.10, 63.49) | -22.76 (-50.95, 5.44) |
| | | | Non-Bangkok Metropolitan | 22.04 | 20.99 (0.00, 47.81) | 1.05 (-25.77, 22.04) |
| | | Male | Bangkok Metropolitan | 5.90 | 8.76 (0.00, 29.05) | -2.86 (-23.15, 5.90) |
| | | | Non-Bangkok Metropolitan | 10.04 | 14.54 (0.00, 33.77) | -4.50 (-23.73, 10.04) |
| | ≥35 | Female | Bangkok Metropolitan | 3.33 | 11.78 (0.00, 35.79) | -8.45 (-32.46, 3.33) |
| | | | Non-Bangkok Metropolitan | 7.87 | 6.58 (0.00, 16.55) | 1.29 (-8.68, 7.87) |
| | | Male | Bangkok Metropolitan | 1.73 | 3.04 (0.00, 36.48) | -1.31 (-34.75, 1.73) |
| | | | Non-Bangkok Metropolitan | 2.29 | 4.60 (0.00, 10.11) | -2.31 (-7.82, 2.29) |
| **Suicide risk** | 18–34 | | | | | |
| | | Female | Bangkok Metropolitan | 5.48 | 23.52 (8.52, 38.52) | -18.04 (-33.04, -3.04) |
| | | | Non-Bangkok Metropolitan | 12.13 | 11.10 (0.00, 26.64) | 1.03 (-14.51, 12.13) |
| | | Male | Bangkok Metropolitan | 3.69 | 7.86 (0.00, 19.01) | -4.17 (-15.32, 3.69) |
| | | | Non-Bangkok Metropolitan | 7.64 | 9.51 (0.00, 21.59) | -1.87 (-13.95, 7.64) |
| | ≥35 | Female | Bangkok Metropolitan | 1.04 | 7.41 (0.00, 18.06) | -6.37 (-17.02, 1.04) |
| | | | Non-Bangkok Metropolitan | 2.72 | 2.21 (0.00, 9.31) | 0.51 (-6.59, 2.72) |
| | | Male | Bangkok Metropolitan | 0.90 | 1.30 (0.00, 32.73) | -0.40 (-31.83, 0.90) |
| | | | Non-Bangkok Metropolitan | 1.16 | 2.04 (0.00, 5.21) | -0.88 (-4.05, 1.16) |

## Discussion

The findings from this study underscore the importance of considering demographic and geographic factors when assessing the mental health impacts of social events. Notably, the significant engagement with Butterbear and Euro-2024 among young adults reflects a broader trend of digital and social media influence on mental health.

The analysis of the Mental Health Check-in data from January 2020 to July 2024 revealed significant findings, with high stress levels reported in 7.8% of responses, severe depression in 9.1%, and suicide risk in 5.2%. Gender-specific trends showed higher levels of mental health issues among females. These findings are consistent with other studies, such as the Global Burden of Disease study, which also highlighted higher rates of mental health disorders among younger adults and females.[3,27] The consistency with other research indicates that the patterns observed in this study are reflective of broader global trends, possibly due to shared socioeconomic and cultural factors influencing mental health.

The Butterbear phenomenon and Euro-2024 had significant engagement in search trends, with millions of searches, and their hashtags dominated the entertainment and sports categories on social media. The gender-specific trends, with Butterbear engaging more females and Euro-2024 engaging more males, align with general patterns in media consumption where females tend to engage more with entertainment content and males with sports content.[28] Comparatively, studies on media events and mental health, such as those on the FIFA World Cup, have shown similar trends where major events significantly influence social media activity and further public mental health.[29] This similarity suggests that large-scale digital entertainment universally captures public attention and can affect mental health through heightened media exposure and social engagement.

The greater impact on mental well-being for females compared to males can be attributed to differences in emotional engagement, regardless of age group and region. Males might engage with Euro-2024 in a way that is less emotionally charged, for example, heightened anxiety, disappointment, and gambling, than females' engagement with Butterbear, leading to a less pronounced impact on their mental health.[12,13] Additionally, females may be more susceptible to the emotional and social content associated with Butterbear, leading to a more significant impact on their mental well-being.[28] The age-specific trends, with young adults (18–34-year-olds) being more affected, align with findings from other studies that indicate younger people are more vulnerable to the mental health effects of social media and major events due to their higher levels of engagement and emotional investment.[14,15,30]

For geographical consideration, females in the Bangkok metropolitan area experienced a higher impact compared to those outside Bangkok. Urban areas such as Bangkok typically have higher media exposure and more intense social pressures, which can exacerbate baseline mental health issues.[31] Rural and suburban areas might have less intense media coverage and different social environments, mitigating the effects of these events on mental well-being.[32] These trends align with other findings, suggesting that the mental health impact of global events is a global phenomenon influenced by media consumption patterns and social dynamics.

Mascots have been used by several countries, including the United States of America, Taiwan, and Japan, to promote disease prevention and health promotion.[33–35] Our findings suggest critical policy and practical implications, particularly the need for tailored mental health support services for different demographic groups. Leveraging popular cultural phenomena like Butterbear and Euro-2024 could enhance mental health and other health promotion campaigns, such as disease prevention and control. For example, Butterbear could promote mental health interventions related to females aged 18–34 who have depression.[36] Additionally, the differences in impact across age, gender, and region suggest that a one-size-fits-all approach to social media promotion for public health policy may not be effective. Instead, tailored strategies that consider media exposure, social context, and individual engagement are crucial for mitigating the mental health effects of major social events.

## Limitations

This study's limitations include reliance on self-reported data, mostly during critical periods, which may introduce overestimation of mental health risks from reporting biases, as similar studies have noted that such data can be affected by stigma and reporting biases.[37] Moreover, the trending of search terms can be performed multiple times by the same individual. Second, focusing on only two social events may overlook other influential factors, though these two events contributed to more than two-thirds of entertainment engagement during that period, with models already adjusted for several key social indicators mentioned above. Third, the impacts of global phenomena/events are influenced by a complex interplay of media exposure, social context, and individual engagement. Therefore, the interpretation of individual relationships should be done with caution to avoid the "ecological fallacy". Addressing these limitations in future research by incorporating diverse data sources and robust methodologies will enhance the accuracy and reliability of findings.

## Recommendations

To maximize the public health benefits of global phenomena and events, public health campaigns should incorporate them into health promotion strategies for mental health and disease prevention. By linking health messages with well-recognized characters or events, campaigns can enhance their appeal and effectiveness, particularly for specific audiences who are more engaged with these trends. Additionally, campaigns should be tailored to reflect the distinct social and media landscapes of both urban and rural settings, improving their relevance and effectiveness across different demographics. Future research should investigate these dynamics, particularly individual effects, further to support the development of more targeted, evidence-based health promotion campaigns that address mental health needs during significant national and global events.

## Conclusion

In conclusion, engagement with Butterbear and Euro-2024 among young adults was significantly correlated with improved mental well-being. Our findings align with other research demonstrating that major events can have a profound influence on mental health via media consumption patterns and social dynamics. Future research should explore these factors and develop targeted interventions to support the mental health of vulnerable populations during significant events.

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## Conflicts of Interests

The author declares that there are no conflicts of interest.

## Suggested Citation

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## References

1. Office of the National Economic and Social Development Council. Thailand’s social outlook of Q3/2024 [Internet]. Bangkok: Office of the National Economic and Social Development Council; [cited 2024 Jul 16]. 8 p. <https://www.nesdc.go.th/ewt_dl_link.php?nid=5492>
2. World Health Organization. Mental health atlas 2020 member state profile, Thailand [Internet]. Geneva: World Health Organization; 2021 Oct 8 [cited 2024 Jul 16]. 136 p. <https://www.who.int/publications-detail-redirect/9789240036703>
3. Suwannasin P. Mental health and employment status: evidence from Thailand [dissertation]. Bangkok: Chulalongkorn University; 2019 [cited 2024 Jul 28]. 122 p. <https://digital.car.chula.ac.th/chulaetd/8655>
4. Pang H. Exploring the beneficial effects of social networking site use on Chinese students’ perceptions of social capital and psychological well-being in Germany. International Journal of Intercultural Relations. 2018 Nov;67:1–11. doi:10.1016/j.ijintrel.2018.08.002
5. Prestin A, Nabi R. Media prescriptions: exploring the therapeutic effects of entertainment media on stress relief, illness symptoms, and goal attainment. Journal of Communication. 2020;70(2):145–70. doi:10.1093/joc/jqaa001.
6. Xiao Y, Liu Z, Wang B, Zheng Y. The entertainment videos pushed by WeChat promote the mental health of undergraduate students. Heliyon. 2023 Mar;9(3):e13776. doi:10.1016/j.heliyon.2023.e13776.
7. Leesa-Nguansuk S. Thais among top social media users [Internet]. Bangkok: Bangkok Post; 2024 Feb 1 [cited 2024 Jul 28]. <https://www.bangkokpost.com/business/general/2734744/thais-among-top-social-media-users>
8. Chantan V. Who is Butterbear, Thailand’s new viral mascot? The story of internet sensation and viral mascot [Internet]. Kuala Lumpur: Lifestyle Asia; 2024 Jul 16 [cited 2024 Jul 16]. <https://www.lifestyleasia.com/kl/entertainment/who-is-butterbear-the-story-of-internet-sensation-and-viral-mascot/>
9. Wongwooth P. ‘Little Butterbear’, a symbol of ‘healing the heart’, an idea from a teddy bear that every childhood home should have [Internet]. Bangkok: The People; 2024 Jun 29 [cited 2024 Jul 27]. <https://www.thepeople.co/business/game-changer/53719>. Thai.
10. Pigabyte. Social listening: Labubu and Butterbear [Internet]. Bangkok: Marketing Oops; 2024 Jul 10 [cited 2024 Jul 16]. <https://www.marketingoops.com/marketing-tech/social-listening-labubu-and-butterbear/>. Thai.

11. Daradaily. The hottest female idol "Nong Neoy" has brought the MV "Nak Rak Mai Mai Ru" to over 2 million views [Internet]. Bangkok: Line Today; 2024 Jul 8 [cited 2024 Jul 16]. <https://today.line.me/th/v2/article/aGjR97n>. Thai.

12. Inoue Y, Wann DL, Lock D, Sato M, Moore C, Funk DC. Enhancing older adults' sense of belonging and subjective well-being through sport game attendance, team identification, and emotional support. J Aging Health. 2019 Mar 15;32(7–8):530–42. doi:10.1177/08982643 19835654.

13. Lopez-Gonzalez H, Griffiths MD, Estevez A. In-play betting, sport broadcasts, and gambling severity: A survey study of Spanish sports bettors on the risks of betting on sport while watching it. Communication & Sport. 2018 Dec 19;8(1):50–71. doi:10.1177/2167479518816338.

14. MGR Online. Euro-2024 football "watch football, have fun, no gambling required" Thai Health Promotion Foundation, Stop Gambling Foundation, National Sports University join hands to raise awareness of gambling harm [Internet]. Bangkok: MGR Online; 2024 May 21 [cited 2024 Jul 16]. <https://mgronline.com/qol/detail/9670000043961>. Thai.

15. ThaiPBS. How to watch "Euro football" for fun "without losing 4 S" [Internet]. Bangkok: Thai PBS; 2024 Jun 24 [cited 2024 Jul 16]. <https://www.thaipbs.or.th/now/content/1320>. Thai.

16. Google Trends. Real-Time search trends [Internet]. Mountain View (CA): Google; [cited 2024 Jul 16]. <https://trends.google.co.th/trends/trendingsearches/daily?geo=TH&hl=en-AU>

17. Depression screening/assessment form and suicide assessment form (2Q 9Q 8Q) [Internet]. Lampang (TH): Vejjarak Lampang Hospital; [cited 2024 Jul 16]. 3 p. <https://vjlh.go.th/booking/upload_file2/2450661385f86a43f9e92d.pdf>. Thai.

18. Department of Mental Health. Manual of mental health check-in [Internet]. Nonthaburi: Department of Mental Health, Ministry of Public Health; [cited 2024 Jul 16]. <https://checkin.dmh.go.th/manual/content/index.php?page_name=chapter_person>. Thai.

19. Department of Mental Health. Mental health check-in dashboards [Internet]. Nonthaburi: Department of Mental Health, Ministry of Public Health; [cited 2024 Jul 16]. <https://checkin.dmh.go.th/dashboards>. Thai.

20. Glimps. How to see absolute search volume in Google Trends [Internet]. New York; Glimps; [cited 2024 Jul 16]. <https://meetglimpse.com/insights/google-trends-search-volume/>

21. Real Time Monitor social trend in Thailand [Internet]. Bangkok: Wisesight; [cited 2024 Jul 28]. <https://trend.wisesight.com/login/trend>

22. Bank of Thailand. EC_RL_015_S2 Number of unemployed persons classified by type of business previously engaged in (ISIC Rev.4) [Internet]. Bangkok: Bank of Thailand; [cited 2024 Jul 16]. < https://app.bot.or.th/BTWS_STAT/statistics/BOTWEBSTAT.aspx?reportID=637&language=TH>. Thai.

23. Office of the National Economic and Social Development Council. Social development report [Internet]. Bangkok: Office of the National Economic and Social Development Council; [cited 2024 Jul 16]. <https://www.nesdc.go.th/nesdb_en/main.php?filename=social_dev_report>

24. Bank of Thailand. EC_MB_039 Loans to household 1/ [Internet]. Bangkok: Bank of Thailand; [cited 2024 Jul 16]. <https://app.bot.or.th/BTWS_STAT/statistics/BOTWEBSTAT.aspx?reportID=775&language=eng>

25. Turner SL, Karahalios A, Forbes AB, Taljaard M, Grimshaw JM, McKenzie JE. Comparison of six statistical methods for interrupted time series studies: Empirical evaluation of 190 published series. BMC Med Res Methodol. 2021 Jun 26;21(1):134. doi:10.1186/s12874-021-01306-w.

26. Myttenaere A, Golden B, Le Grand B, Rossi F. Mean absolute percentage error for regression models. Neurocomputing. 2016 Jun;192:38–48. doi:10.1016/j.neucom.2015.12.114.

27. Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2019 (GBD 2019) Results. Seattle (WA): Institute for Health Metrics and Evaluation; 2020.

28. Valkenburg PM, Peter J. Online communication among adolescents: An integrated model of its attraction, opportunities, and risks. J Adolesc Health. 2011;48(2):121–7. doi:10.1016/j.jadohealth.2010.08.020.

29. Schallhorn C. "The land of football": an analysis of media coverage of the 2014 FIFA World Cup and its effects on people's

perceptions of Brazil. International Journal of Intercultural Relations. 2019 Sep;72:25–35. doi:10.1016/j.ijintrel.2019.06.002

30. Keles B, McCrae N, Grealish A. A systematic review: The influence of social media on depression, anxiety, and psychological distress in adolescents. Int J Adolesc Youth. 2020;25(1): 79–93. doi:10.1080/02673843.2019.1590851.

31. Verheij RA, Maas J, Groenewegen PP. Urban-rural health differences and the availability of green space. Eur Urban Reg Stud. 2008;15(4): 307–16. doi:10.1177/0969776408095107.

32. Patel V, Saxena S, Lund C, Thornicroft G, Baingana F, Bolton P, et al. The Lancet Commission on global mental health and sustainable development. Lancet. 2018;392 (10157):1553–98. doi:10.1016/S0140-6736(18)31612-X.

33. Taiwan Centers for Disease Control. Taiwan CDC mascot and Cartoon character Shimajiro come together to teach children proper handwashing techniques to ward off enterovirus [Internet]. Teipei City: Taiwan Centers for Disease Control; 2018 May 16 [cited 2024 Sep 16]. <https://www.cdc.gov.tw/En/Bulletin/Detail/vskSazAlExG39kSRun80vw?typeid=158>

34. Ellison K. Could Kalo become the Smokey Bear-type mascot for pandemic hygiene? [Internet]. Washington: Washington Post; 2021 Nov 13 [cited 2024 Sep 16]. <https://www.washingtonpost.com/health/covid-mascot-kids-vaccination/2021/11/12/e484df08-3cc0-11ec-8ee9-4f14a26749d1_story.html>

35. Hoeller SC. Japan has an adorable new anti-coronavirus cat mascot that's handing out free masks around Tokyo and reminding people to social distance [Internet]. New York: Business Insider; 2020 Nov 18 [cited 2024 Sep 16]. <https://www.businessinsider.com/koronon-anti-coronavirus-cat-japan-mascot-2020-11>

36. National Center for Immunization and Respiratory Diseases. HPV vaccination recommendations [Internet]. Atlanta: Centers for Disease Control and Prevention (US); 2021 Nov 16 [cited 2024 Jul 28]. <https://www.cdc.gov/vaccines/vpd/hpv/hcp/recommendations.html>

37. Tourangeau R, Yan T. Sensitive questions in surveys. Psychol Bull. 2007;133(5):859–83. doi:10.1037/0033-2909.133.5.859.

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Field Epidemiology Training Program, Division of Epidemiology
Department of Disease Control, Ministry of Public Health, Thailand
Tel: +6625903894, Fax: +6625903845, Email: osireditor@osirjournal.net, https://he02.tci-thaijo.org/index.php/OSIR

# Enhancing Digital Disease Surveillance in Thailand Using Information Technology, Data Engineering, Data Science, and Artificial Intelligence

Suphanat Wongsanuphat*, Jaruwan Malaikham, Supansa Suriya, Jiraporn Prommongkhol, Narawadee Khampha, Thapanee Khempetch

Division of Epidemiology, Department of Disease Control, Ministry of Public Health, Thailand

*Corresponding author, email address: suphanat.wong@gmail.com

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**Abstract**

Recent advancements in data engineering, data science, and artificial intelligence have revolutionized disease surveillance systems globally. This study examines the implementation of these advancements in Thailand. We integrated these advancements to enhance the four key steps of public health surveillance: data collection, data analysis, data interpretation, and data dissemination. We expanded data collection to include data environment and integration, designing systems to manage multiple sources and facilitating seamless integration. To support analysis and interpretation, we adopted a design thinking approach and developed intuitive tools for exploring disease situations. We identified target users and described the data distribution mechanism. We integrated three major databases: digital disease surveillance, syndromic surveillance, and event-based surveillance, all managed by the Department of Disease Control. Data environments were divided into clusters for extraction, integration, and a data mart for specific use cases. Automated hourly extract-transform-load processes using Apache Airflow facilitated real-time data integration, ensuring seamless data management and timely updates. Data analysis solutions, including automated validation algorithms and business intelligence tools with user-friendly interfaces, were developed according to findings from the design thinking workshop. We developed open data published on dashboards and closed data managed through the Digital Export System. Artificial intelligence-enhanced early warning systems provided notifications of an outbreak to public health authorities via the instant messaging application LINE. In conclusion, the integration of information technology, data engineering, and data science has significantly enhanced Thailand's disease surveillance system, improving data collection, analysis, interpretation, and dissemination of results, leading to more efficient public health responses.

**Keywords:** disease surveillance, information technology, data engineering, data science, artificial intelligence

## Introduction

Public health surveillance is defined as "the ongoing, systematic collection, analysis, and interpretation of health-related data essential to planning, implementation, and evaluation of public health practice".[1] In recent years, the convergence of information technology, data engineering, and data science has revolutionized various sectors, including healthcare and public health.

Specifically, the application of these advancements has significantly enhanced disease surveillance systems, enabling quicker detection, more accurate prediction, and more effective responses to public health threats.[2] Real-time data collection from hospitals, clinics, laboratories, and wearable devices ensures immediate availability of health data, facilitating faster identification of potential outbreaks.[3] Automated reporting reduces delays associated with manual data entry, keeping information up-to-date and readily accessible.[4] With the advent of advanced analytical techniques, including machine learning and statistical modeling, vast amounts of health data can now be analyzed to help researchers identify patterns and trends, predicting disease outbreaks by considering factors such as population density, climate conditions, travel patterns, and historical data.[3,5] This integration of technology, data science, and artificial intelligence has transformed traditional surveillance methods, allowing for early detection of emerging threats and enabling data-driven decision-making for efficient public health responses.[6–9]

In the context of Thailand, a country that faces diverse health challenges ranging from infectious diseases to chronic conditions, leveraging digital tools for disease surveillance holds immense potential for improving public health outcomes. Thailand, known for its robust healthcare infrastructure and proactive approach to public health, has recognized the importance of integrating information technology and data science into its disease surveillance system. By harnessing the power of digital platforms, real-time data collection, and advanced analytics, Thailand aims to strengthen its ability to monitor, analyze, and respond to disease outbreaks promptly and efficiently.

Disease surveillance in Thailand is primarily facilitated through the R506 reporting system, in accordance with the Communicable Diseases Act B.E. 2558 (2015), using a comprehensive framework for collecting and analyzing notifiable diseases under the surveillance system across the country.[10] This system enables healthcare providers to report cases of notifiable diseases, according to their case definition, facilitating timely responses to potential outbreaks.[11] The R506 reporting system is complemented by digital tools that enhance data accuracy and accessibility, further supporting public health initiatives. A notable example of Thailand's efforts to enhance its disease surveillance system was the implementation of information technology during the coronavirus disease 2019 (COVID-19) pandemic.[12,13]

This study aims to explore the landscape of digital disease surveillance (DDS) in Thailand, highlighting the key strategies, technologies, and initiatives employed to enhance public health monitoring and response capabilities. It delves into the role of information technology and data science in transforming traditional surveillance methods, facilitating the early detection of emerging threats, and enabling data-driven decision-making at local, regional, and national levels.

## Methods

Public health surveillance consists of four crucial steps: data collection, data analysis, data interpretation, and data dissemination.[1] In this study, we integrated information technology, data engineering, and data science to enhance these steps in the surveillance system. The research questions and methods to enhance digital disease surveillance using information technology, data engineering, and data science for each step are described in Table 1. We also describe recent implementations, challenges, and suggest opportunities for improvement.

**Table 1. Summary of surveillance steps, research questions, and methods to enhance digital disease surveillance in Thailand using information technology, data engineering, and data science**

| Surveillance step | Research question | Method |
|---|---|---|
| **Data collection, data environment, and data integration** | What are the data sources that the user needs for disease surveillance? | Describing the current surveillance system. |
| | How to design and implement a multiple data source integration system? | Designing a data environment and automating data management pipeline. |
| **Data analysis and interpretation** | What are the needs of users for disease surveillance data analysis? | Developing a user-friendly surveillance data analysis system. |
| **Data dissemination** | How to design an effective and timely data dissemination system? | Identifying target data users.<br>Designing data dissemination pathways. |

### Definitions

*Information Technology*

The use of computers, networks, and software to manage and process information, enabling data storage, retrieval, and communication.[14]

*Data Engineering*

The practice of designing and building systems for collecting, storing, and analyzing data at scale, including creating data pipelines and infrastructure.[15]

*Data Science*

Data science combines statistics, mathematics, and computer science to extract meaningful insights from data using algorithms, machine learning, and visualization.[16]

*Artificial Intelligence (AI)*

Artificial intelligence is a system capable of performing tasks that typically require human intelligence, such as learning, decision-making, and language understanding.[17]

### Data Collection, Data Environment, and Data Integration

We identified diverse data sources related to disease surveillance by describing current surveillance systems in the Thai Department of Disease Control. We designed data environments to manage data from multiple sources, facilitating seamless integration and aggregation into a centralized surveillance system. We integrated these diverse data sources using real-time data pipeline automation (Figure 1).

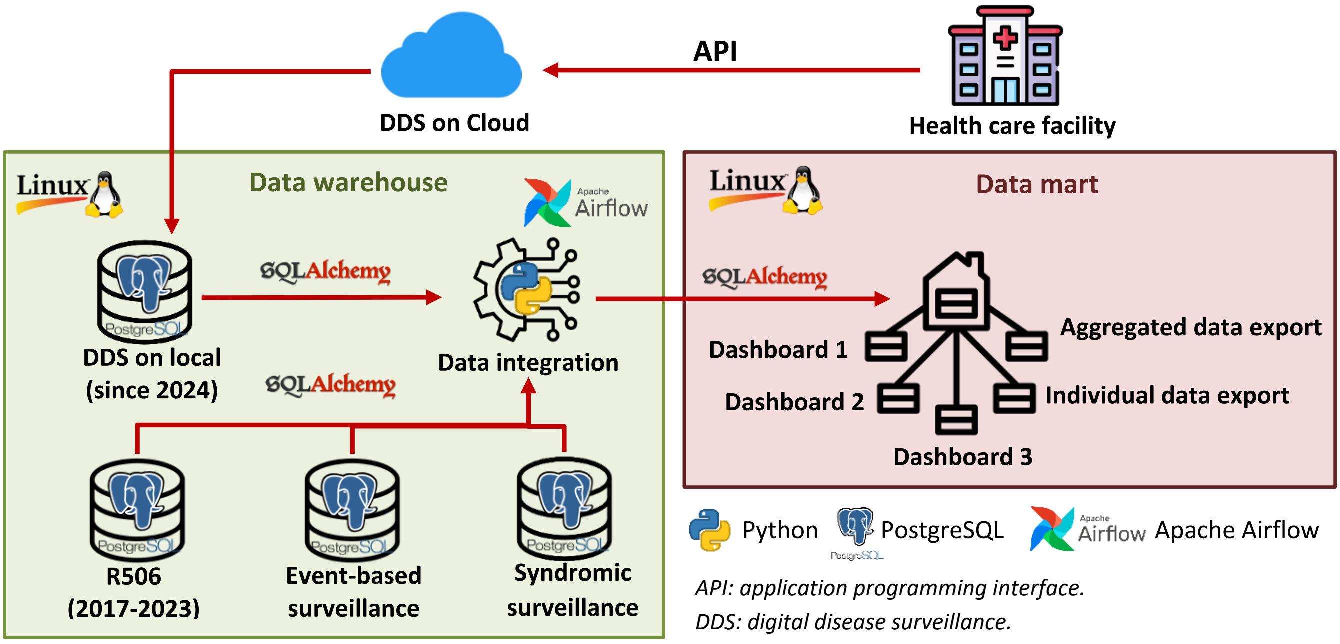


**Figure 1. Data collection, data environment, and data integration pipeline of the digital disease surveillance system**

### Data Analysis and Interpretation

In our previous study, we applied a design thinking approach to gather data analysis requirements for 50 epidemiological staff, 10 executives, and 10 frontline staff at the national office, regional health office, provincial health office, hospital, and sub-district hospital levels in Chiang Mai, Uthai-Thani, and Nakhon Sawan provinces.[18] In this step, our goal was to create user-friendly tools to support the analysis and interpretation of surveillance data based on user requirements mentioned in our previous study.[18] We identified the potential of information technology, data engineering, and data science techniques based on our previous study.[18] These tools are designed to enable public health officials, executives, and frontline staff to explore data trends, disease clusters, and hotspots intuitively. Additionally, we designed tools for user-friendly data interpretation to generate hypotheses based on the findings of the data analysis.

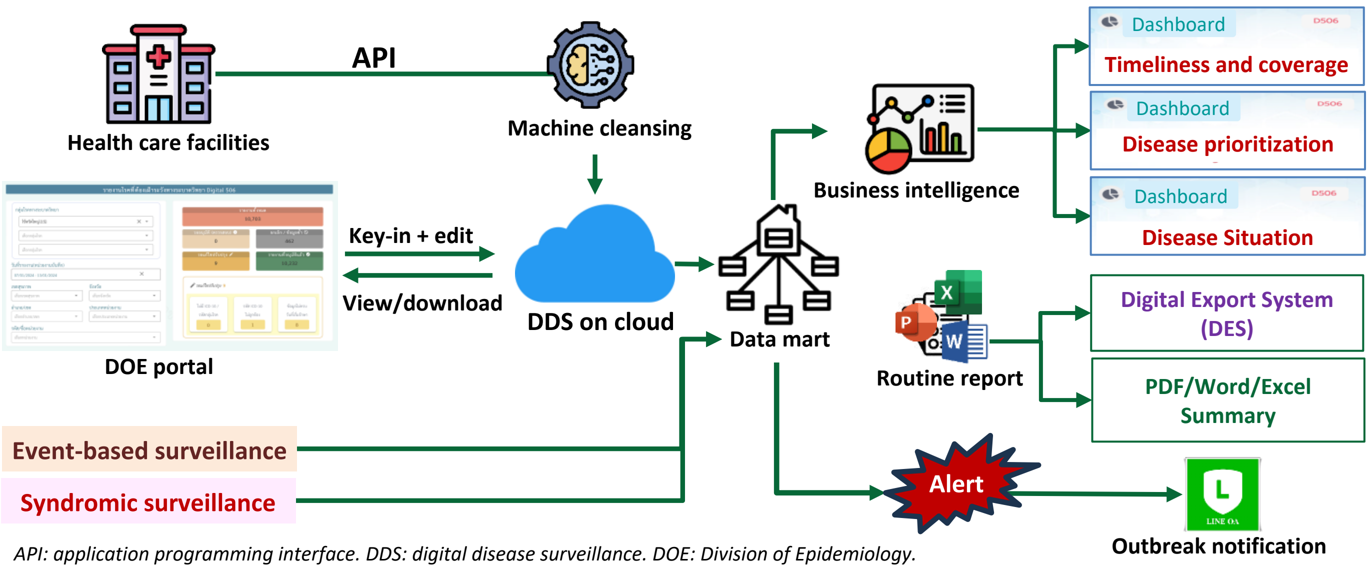


**Figure 2. Data analysis, interpretation, and dissemination pipeline of digital disease surveillance**

**Data Dissemination and Response**

Potential data users under data dissemination were identified and classified. Data dissemination pathways were described. We also established early warning systems by identifying appropriate algorithms that generate early warning signals based on predictive analytics and artificial intelligence. We evaluated reporting performance using data from the DDS system (2024) and the R506 system (2023). Reporting coverage was defined as the proportion of hospitals submitting data and timeliness as the percentage of records reported within seven days of diagnosis. Data from 1,409 eligible hospitals were analyzed using consistent criteria for both systems to compare reporting coverage and timeliness.

**Ethics**

Ethics approval was not required for this work as it is part of the routine mission of the Division of Epidemiology. This study did not collect individual data nor involve any personal sensitive data.

## Results

In Thailand, data engineering, data science, and artificial intelligence were integrated into data collection platforms, data integration, data analysis, data interpretation, and data dissemination of public health surveillance.

**Data Collection, Data Environment, and Data Integration**

We reviewed three current disease surveillance systems: a case-based surveillance system, a syndromic surveillance system, and an event-based surveillance system. The case-based disease surveillance system collects individual data from hospitals across the country. Data from this system is divided into two phases: 1) R506 (before 2024) and 2) the DDS system (2024 and after). This surveillance system is a major method in Thailand, which seamlessly connects individual data from 1,409 healthcare facilities, including public and private hospitals. R506 contains weekly offline disease surveillance data sent by provincial health offices, while the DDS contains real-time disease surveillance data sent directly from hospitals via an application programming interface (API).[19] Fifty-seven notifiable diseases were reported to the DDS consisting of 2,159,925 records as of December 2024. The syndromic surveillance system contains seven groups of symptoms, including influenza-like illnesses, fever, viral conjunctivitis, viral exanthem, acute diarrhea, acute flaccid paralysis, and adverse events following immunization. Data from this surveillance system was aggregated daily at the hospital level. Data from all three surveillance systems are managed by the Thai Department of Disease Control, Ministry of Public Health. Additionally, data from the Thai Health Data Center, which includes demographic data, underlying clinical data, treatment data, and immunization data, were incorporated. There were opportunities to enhance the surveillance systems by including various data sources such as animal health data, vector data, environmental data, and social media feeds. Here, we included three major data sources, namely the DDS, the syndromic surveillance system, and the event-based surveillance system.

For data environment, initially, we set up local environments (on premises) using the Linux operating system. The local environments were divided into three clusters: 1) data warehouse for data extraction and ingestion, 2) data warehouse for data source integration, and 3) data mart for specific use cases such as creating a dashboard. All three local environments were seamlessly interconnected under the Linux operating system. A PostgreSQL database was installed on these local environments.

For data integration, we integrated three data sources using automated hourly batch procedures. Data engineering techniques, specifically extract, transform, and load (ETL), were implemented. First, DDS on a cloud using NoSQL were extracted and transformed to SQL structures using the pymongo and pandas packages in Python. Data were loaded into the DDS on the local environment. Second, data from R506 and the DDS system were extracted using the SQLAlchemy package and then over 10 million rows of surveillance data spanning six years were manipulated and transformed using Python.[37] In this step, data were transformed into multiple data structures based on their specific purposes. Some of the data were integrated with syndromic and event-based surveillance data. Finally, data were loaded back into the data mart using SQLAlchemy. The ETL process was scheduled as an hourly batch using Apache Airflow. A summary of all of these steps is shown in Table 2.

**Data Analysis and Interpretation**

We designed a wireframe of business intelligence for disease surveillance data analysis based on the aforementioned data analysis requirements using Microsoft PowerPoint, which entails a human-centric approach and data visualization best practices. We prototyped user-friendly interfaces of business intelligence using Tableau.[38] Data were automatically transferred to the Tableau Server using the Tableau Server REST API and Apache Airflow (Table 2). To validate the performance of our tools, we tested our prototypes with the same stakeholders as described in our previous study.[18]

### Data Dissemination and Response

We separated data dissemination into two types, namely open data and closed data. To facilitate open data dissemination, user-friendly business intelligence interfaces were developed and integrated into the dashboard section of https://ddsdoe.ddc.moph.go.th/ddss/, as illustrated in Figure 2. Our open data dissemination consisted of 1) timeliness and coverage monitoring business intelligence, 2) disease prioritization business intelligence, and 3) disease situation business intelligence. For closed data, we developed a Digital Export System (DES). First, we indicated data accessibility among different users. Second, we designed and developed a data mart for data dissemination. The data were anonymized to protect personal data privacy. Data anonymization procedures included data deletion, data encryption, and data aggregation. For data encryption and deletion, we deleted or encrypted identifiers such as first name, surname, and citizen identification number. The choice between deletion or encryption depended on the data accessibility level of users. Additionally, we established an "outbreak notification" feature by identifying appropriate algorithms to generate early warning signals with artificial intelligence-enhanced time-series forecasting using the autogluon.timeseries package in Python. This includes developing an outbreak early warning system that automatically flags unusual deviations from predicted trends in surveillance data, e.g., higher than 80, 90, or 95% of the upper prediction interval, with alert mechanisms implemented to notify public health authorities of potential outbreaks or emerging threats in real-time via LINE (Table 2). As of December 2024, the reporting coverage of the DDS system stands at 1,356/1,409 hospitals (96.24%), compared to the coverage of the R506 system in 2023, which had a coverage of 1,239/1,409 hospitals (88.12%). Additionally, the timeliness of reporting to the surveillance system within seven days of the diagnosis date for the DDS system was 83.91%, compared to the performance of R506 in 2023 (74.97%).

**Table 2. Summary of the use case of information technology, data engineering, data science, and artificial intelligence in the surveillance steps of data collection, analysis, and dissemination**

| Surveillance steps | Technology | How the technology is used |
|---|---|---|
| **Data collection, data environment, and data integration** | Information technology | APIs were used to collect real-time data (DDS) and set up local Linux-based environments with PostgreSQL for storage and integration. |
| | Data engineering | ETL processes such as Python, SQLAlchemy, and Apache Airflow were used for automated data extraction, transformation, and integration of DDS, syndromic, and event-based surveillance data. |
| | Data science | Data manipulation and transformation using Python packages (e.g., pandas, numpy, pyspark) to harmonize and structure large datasets for analysis. |
| **Data analysis and interpretation** | Data engineering | Automated data transfers to Tableau Server via REST APIs and Airflow for visualization prototyping and stakeholder feedback. |
| | Data science | Prototyping and designing user-friendly data visualization interfaces for disease surveillance using Tableau, focusing on actionable insights. |
| | Artificial intelligence | Developing early warning systems using AI-based time-series forecasting (e.g., autogluon.timeseries) to predict and flag unusual surveillance trends. |
| **Data dissemination and response** | Information technology | Developed open and closed data dissemination systems via dashboards and secure Digital Export Systems with data privacy protocols (e.g., PDPA-compliant anonymization). |
| | Artificial intelligence | Integrated AI to detect outbreak signals by analyzing trends and deviations, with alert mechanisms through platforms like LINE for real-time public health response. |

*AI: artificial intelligence. API: application programming interface. DDS: digital disease surveillance. ETL: extract, transform, and load. PDPA: Personal Data Protection Act.*

## Discussion

Our study established a data integration pipeline of three major disease surveillance systems in Thailand, integrating data from 1,409 healthcare facilities. Together, these three systems facilitated a comprehensive and centralized surveillance system, enhancing real-time data management and integration. Similar initiatives have been implemented globally, such as the BioSense platform in the United States, which also integrates multiple data sources for public health surveillance.[20] However, our study included diverse data types, such as syndromic and event-based data, which provided a broader context for disease monitoring. This comprehensive approach allows for more holistic surveillance but also presents challenges in data harmonization and privacy protection, underscoring the importance of a robust data governance framework.

Combining data engineering and data science has been a significant step forward in real-time disease surveillance systems by enabling automated data pipelines. Data engineering involves multiple steps, including data collection, establishing a data environment, and data integration. Surveillance data from the data warehouse were extracted, transformed, and loaded into a data mart automatically. Data engineering techniques have also been applied to other public health fields, including cancer clinical genomic analysis and women's imaging.[21,22] With a data science approach, large amounts of data can be managed quickly and efficiently. This approach is important when dealing with large-scale epidemics such as COVID-19.[23]

The design thinking approach that we adopted involved epidemiological staff and executives gathering user requirements, resulting in the development of automated validation algorithms and user-friendly interfaces. This human-centric method ensured that the tools met the actual needs of the end-users, improving the efficiency and accuracy of data analysis.[24,25] Studies also emphasized the importance of a user-centric design in public health informatics, highlighting the fact that stakeholder engagement leads to better tool adoption and satisfaction.[26,27] In addition, a previous literature review on developing data visualization for hospital-based surveillance highlighted key issues for tool development, including 1) clear objectives of tools and use case, 2) report content, and 3) interactive use on the screen.[28] Our results align with these findings, demonstrating that gathering comprehensive requirements from users, iterative development, and testing with end-users are critical for successful implementation. The engagement process facilitated the identification of practical challenges and the development of tailored solutions, reinforcing the value of design thinking in public health technology projects.

Our AI approach was embedded in an early warning system resulting in timely alerts for potential outbreaks. Various studies on AI-enhanced early warning systems illustrated promise for their development in the context of disease outbreaks.[29–32] While advanced models such as deep learning provide high accuracy, they pose challenges in interpretability and resource demands. However, AI-based early warning systems must address challenges related to data quality, model explainability, bias mitigation, adaptability, and continuous monitoring, as well as data volume, velocity, variety, availability, and granularity.[33]

Our integration of real-time alert mechanisms via the LINE application is relatively accessible and addresses the need for rapid communication in public health emergencies as implemented in other countries such as Australia.[34,35] Consistent with a study from Canada, a COVID-19 alert application showed high ratios of averted cases and deaths.[36] The successful implementation of these systems in Thailand demonstrates that tailored and context-specific solutions can significantly enhance disease surveillance and response, aligning with global best practices while addressing local needs and challenges.

## Limitations

This surveillance system development has some limitations. First, we primarily focused on integrating data from existing surveillance systems, which may not account for gaps in community-level data or non-traditional sources such as social media and environmental data, limiting the system's comprehensiveness. Second, the user requirements for tool design were gathered from a relatively small sample of stakeholders in specific provinces, which may reduce the generalizability of the findings to other regions or levels of the healthcare system. Lastly, while we incorporated predictive algorithms, we did not include a robust validation framework to assess their performance under varying conditions, potentially limiting their reliability in diverse scenarios.

## Public Health Recommendations

To optimize real-time disease surveillance, organizations seeking to enhance their systems, similar to the Department of Disease Control, can adopt a structured, step-by-step approach. First, investing in robust IT infrastructure is critical, including scalable cloud-based databases such as PostgreSQL or NoSQL for data storage and processing, and APIs to ensure seamless real-time data exchange between hospitals and central surveillance systems. Next, targeted capacity-building programs should be implemented to train personnel in learning essential skills, such as data engineering techniques (e.g., ETL processes for data integration), data science methods for statistical analysis, visualization using tools such as Tableau and Python, and AI techniques for deploying predictive algorithms to improve outbreak detection. Automated ETL pipelines should then be developed to integrate syndromic, event-based, and case-based surveillance data, with tools such as Apache Airflow enabling frequent updates to maintain data timeliness and accuracy. To enhance analytical capabilities, organizations should design user-friendly dashboards using platforms such as Tableau, incorporating AI-driven early warning systems to flag anomalies and provide predictive insights on disease trends. Real-time communication mechanisms, such as instant messaging applications or platforms such as LINE, should be integrated to immediately notify public health authorities of potential outbreaks. Additionally, organizations must prioritize data privacy by implementing secure dissemination systems that anonymize sensitive information in compliance with existing regulations.

Future studies should integrate additional data sources, such as animal health, vector, environmental, and social media data, to enhance predictive models for emerging health threats. Comparative research on AI algorithms can identify the most effective tools for real-time disease forecasting. In addition, surveillance evaluation should be conducted to monitor performance of enhanced surveillance system.

## Conclusion

We have established an integrated data pipeline for disease surveillance in Thailand, combining data from three surveillance systems. This centralized approach enhances real-time data management, providing a comprehensive view of public health monitoring. By employing a design thinking approach, we ensured the system met user needs, improving data accuracy and operational efficiency. The inclusion of AI-driven early warning systems and real-time alerts strengthened outbreak response, aligning with global best practices while addressing local challenges. Our findings underscore the value of robust data governance, user-centered design, and context-specific solutions to enhance public health surveillance and response.

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## Conflict of Interest

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## References

1. Centers for Disease Control and Prevention (US). Principles of epidemiology in public health practice; an introduction to applied epidemiology and biostatistics [Internet]. 3rd edition. [cited 2024 Nov 4]. <https://archive.cdc.gov/#/details?url=https://www.cdc.gov/csels/dsepd/ss1978/lesson1/section1.html>

2. Wang L, Liu Y, Chen H, Qiu S, Liu Y, Yang M, et al. Search-engine-based surveillance using artificial intelligence for early detection of coronavirus disease outbreak. J Big Data. 2023 Nov 11;10:169. doi:10.1186/s40537-023-00847-9.

3. Obe OO, Sarumi OA, Adebayo A. Enhancing epidemiological surveillance systems using dynamic modeling: a scoping review. Proceedings of the 13th International Conference on Soft Computing and Pattern Recognition; 2021 Dec 15–17; Seattle (WA), United States. Cham (CH): Springer; 2022. p. 512–23. doi:10.1007/978-3-030-96302-6_48.

4. Anjaria P, Asediya V, Bhavsar P, Pathak A, Desai D, Patil V. Artificial intelligence in public health: revolutionizing epidemiological surveillance for pandemic preparedness and equitable vaccine access. Vaccines. 2023 Jun 26;11(7):1154. doi:10.3390/vaccines11071154.

5. European Centre for Disease Prevention and Control. Digital technologies for the surveillance, prevention and control of infectious diseases - a scoping review of the research literature [Internet]. Stockholm: European Centre for Disease Prevention and Control; 2021 [cited 2024 Jul 30]. <https://www.ecdc.europa.eu/en/publications-data/digital-technologies-surveillance-prevention-and-control-infectious-diseases>

6. Fisher S, Rosella LC. Priorities for successful use of artificial intelligence by public health organizations: a literature review. BMC Public Health. 2022;22(1):2146. doi:10.1186/s12889-022-14422-z.

7. Centers for Disease Control and Prevention (US). Artificial Intelligence and Machine Learning: Technologies. [Internet]. Atlanta: Centers for Disease Control and Prevention; 2023 [cited 2025 Jan 15]. <https://www.cdc.gov/surveillance/technologies/index.html>

8. Zhang L, Guo W, Lv C. Modern technologies and solutions to enhance surveillance and response systems for emerging zoonotic diseases. Sci One Health. 2024;3:100061. doi:10.1016/j.soh.2023.100061

9. Zahlan A, Ranjan R, Hayes D. Artificial intelligence innovation in healthcare: literature review, exploratory analysis, and future research. Technology in Society. 2023;74: 102321. doi:10.1016/j.techsoc.2023.102321.

10. Division of Epidemiology, Department of Disease Control. Guidelines for reporting communicable diseases under surveillance: Digital format in accordance with the Communicable Disease Act B.E. 2558. Paper presented at: Meeting of the guidelines for submitting epidemiological surveillance data in digital format (D506); 2023 Sep 21; Bangkok, Thailand. Thai.

11. Division of Epidemiology, Department of Disease Control. Case definition for Communicable Diseases Surveillance, Thailand, 2020. Nonthaburi: Division of Epidemiology, Department of Control (TH); 2020. Thai.

12. Wongsanuphat S, Sangwanloy S, Sopha P, Buangsuang W, Denduang S, Thongplean A, et al. Enhancingcoronavirus disease (COVID-19) surveillance system through information technology, Thailand, 2020. OSIR. 2020 Sep;13(3):90–100.

13. Wongsanuphat S, Jitpeera C, Iamsirithaworn S, Laosiritaworn Y, Thammawijaya P. An Evaluation of the Enhanced Information System for COVID-19 Surveillance in Thailand, 2020: A Pre-Post Intervention Comparison. OSIR. 2020 Sep;13(3):101–9. doi:10.59096/osir.v13i3.262806.

14. Laudon KC, Laudon JP. Management information systems: managing the digital firm. 16th ed. London: Pearson; 2021.

15. Gorton I. Essential software architecture. 2nd ed. Heidelberg: Springer; 2011.

16. Provost F, Fawcett T. Data science for business. Sebastopol (CA): O'Reilly Media; 2013.

17. Russell S, Norvig P. Artificial intelligence: a modern approach. 4th ed. London: Pearson; 2021.

18. Malaikham J, Suriya S, Prommongkhol J, Wongsuwanphon S, Wongsanuphat S. Development of innovations for analyzing surveillance situations of communicable diseases in Thailand using the design thinking process. Weekly Epidemiological Surveillance Report. 2025;56(3): 1–15. doi:10.59096/wesr.v56i3.3571.

19. Yotwattana P, Tepsittha K. The development of a digital epidemiological surveillance reporting platform. Weekly Epidemiological Surveillance Report. 2023;54:717–30.

20. Centers for Disease Control and Prevention (US). BioSense platform [Internet]. Atlanta: Centers for Disease Control and Prevenion: 2024 Apr 22 [cited 2024 Nov 4]. <https://www.cdc.gov/nssp/php/about/about-nssp-and-the-biosense-platform.html>

21. Doig K, Papenfuss AT, Fox S. Clinical cancer genomic analysis: data engineering required. Lancet Oncol 2015 Sep;16(9):1015–7. doi:10.1016/s1470-2045(15)00195-3.

22. Cui C, Chou SS, Brattain L, Lehman CD, Samir AE. Data engineering for machine learning in women's imaging and beyond. AJR Am J Roentgenol. 2019 Jul;213(1):216–26. doi:10.2214/ajr.18.20464.

23. Zhang Q. Data science approaches to infectious disease surveillance. Philos Trans A Math Phys Eng Sci. 2021 Nov 22;380(2214): 20210115. doi:10.1098/rsta.2021.0115.

24. Hanan M, Galal GEH. Design thinking using qualitative data analysis and machine learning. Proceedings of the 2023 13th International Conference on Information Communication and Management. 2023 Nov 7; Cairo, Egypt. New York: Association for Computing Machinery; 2024. p. 40–7. doi:10.1145/3640429.3640437.

25. Nguyen AH, Hoang TG, Nguyen LQ, Thi Pham HM. Design thinking-based data analytic lifecycle for improving management control in Banks. Technology Analysis & Strategic Management. 2022 Jul 14;36(7):1508–23. doi:10.1080/09537325.2022.2100754.

26. Drzyzga G, Harder T. User-centered design and iterative refinement: Promoting student learning with an interactive dashboard. Proceedings of the 19th International Conference on Web Information Systems and Technologies. 2023 Nov 15–17; Rome, Italy. Setubal (PT): Science and Technology; p. 340–6. doi:10.5220/0012191300003584

27. Lennox-Chhugani N. A user-centred design approach to integrated information systems – a perspective. Int J Integr Care. 2018;18(2):15. doi:10.5334/ijic.4182.

28. Areechokchai D, Sayumpurujinan S. Developing data visualization for hospital-based surveillance under the Communicable Disease Act B.E. 2558. Weekly Epidemiological Surveillance Report. 2023;55(9):1–12. doi:10.59096/wesr.v55i9.3247.

29. Althomsons SP, Winglee K, Heilig CM, Talarico S, Silk B, Wortham J, et al. Using machine learning techniques and national tuberculosis surveillance data to predict excess growth in genotyped tuberculosis clusters. Am J Epidemiol. 2022;191(11):1936–43. doi:10.1093/aje/kwac117.

30. Panja M, Chakraborty T, Kumar U, Liu N. Epicasting: an ensemble wavelet neural network for forecasting epidemics. Neural Netw. 2023; 165:185–212. doi:10.1016/j.neunet.2023.05.049.

31. Didi Y, Walha A, Wali A. Data-driven model for influenza prediction incorporating environmental effects. Proceedings of the 5th International Conference on Internet of Things, Big Data and Security; 2020 May 7–9; Prague, Czech Republic. Setubal (PT): Science and Technology; 2022. p. 15–24. doi:10.5220/0009325500150024.

32. Shinde S, Yadav S, Somvanshi A. Epidemic outbreak prediction using machine learning model. Proceedings of the 5th International Conference on Advances in Science and Technology (ICAST); 2022 Dec 2-3, Mumbai, India. New York: IEEE; 2023. p. 127–32. doi:10.1109/ICAST55766.2022.10039594.

33. El Morr C, Ozdemir D, Asdaah Y, Saab A, El-Lahib Y, Sokhn ES. Ai-based epidemic and pandemic early warning systems: a systematic scoping review. Health Informatics J. 2024 Jul-Sep;30(3):14604582 241275844. doi:10.1177/14604582241275844.

34. Ahn E, Liu N, Parekh T, Patel R, Baldacchino T, Mullavey T, et al. A mobile app and dashboard for early detection of infectious disease outbreaks: development study. JMIR Public Health Surveill 2021;7(3):e14837. doi:10.2196/14837.

35. Mohanty B, Chughtai A, Rabhi F. Use of mobile apps for epidemic surveillance and response – availability and gaps. Global Biosecurity. 2019 Sep 11;1(2):37. doi:10.31646/gbio.39.

36. Sun S, Shaw M, Moodie EEM, Ruths D. The epidemiological impact of the Canadian covid alert app. Can J Public Health. 2022;113(4):519–27. doi:10.17269/s41997-022-00632-w.

37. Python Software Foundation. Python: a programming language [Internet]. Version 3.13.2. Beaverton (OR): Python Software Foundation; [cited 2025 Mar 16]. <https://www.python.org/>

38. Tableau Software. Tableau Desktop [Internet]. Version 2024.3.4. Seattle (WA): Salesforce; [cited 2025 Mar 16]. <https://www.tableau.com/>

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Field Epidemiology Training Program, Division of Epidemiology
Department of Disease Control, Ministry of Public Health, Thailand
Tel: +6625903894, Fax: +6625903845, Email: osireditor@osirjournal.net, https://he02.tci-thaijo.org/index.php/OSIR

# The Grammar of Science: Bar, Pie, Line, and Lie

Jaranit Kaewkungwal*

Mahidol University, Thailand

*Corresponding author email: jaranitk@biophics.org

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We are now in the world of "Big Data" which can be turned into actionable information. We thus need tools to analyze the data and present the data-driven information to convey our message for making decisions. Data visualization is a dominant tool to turn data into useful information and present it in a form that is easy to understand. Data visualization is defined as the graphical representation of information and data.[1] We can say that data visualization is a form of visual art that grabs our interest on the intended message as our eyes are drawn to colors and patterns, trends and outliers.[1] General types of data visualization include such as: tables, charts, graphs, geospatial, maps, infographics, dashboards, etc. Let's focus on the three most commonly used in data visualization: bar charts, pie charts and line charts.

## Bar, Pie, Line Chart

Many people use the words "chart" and "graph" interchangeably. Both terms are ways of displaying data visually. For graphical typology, fundamental concepts behind the terms are defined. The chart is a table and/or diagram with the purpose to depict and compare multiple sets of large quantitative datasets which is the best option to analyze the data in detail. Graph can be considered as a subtype of charts but illustrates data in a more picture-like format which is often used to show more complex relationships and mathematical manipulations without impeding the readers with details allowing faster understanding.[2,3]

### Bar Chart

A bar chart shows numeric values of a variable plotted as bars on one chart axis, for levels of another categorical (discrete) variable plotted on the other axis. The length of each bar corresponds to the bar's value. The numeric values may be a simple frequency count, proportion, average, total, or some other summary measures computed separately for each category.[4] For example, bars represent numbers (count) of infected persons in four risk groups (A–D), mean pain scores of four groups of cancer patients (A–D), or means of percentage change of healthcare expenditure from baseline survey among people classified in four socioeconomic levels (A–D) (Figure 1(a)–(c)). A bar chart can be used to compare discrete data or show trends over time.[5,6] Other commonly found bar chart types include: clustered or grouped bars, proportional (stacked) bars, and histograms.

*Clustered bar chart*

A clustered bar chart, multi-set bar chart, or grouped column chart is a group of bar graphs that is used to show a distribution of data points or perform a comparison of numeric values across multiple categories (subgroups).[6] For example, bars represent the numbers (count) of study participants in three age groups within each of the three risk groups (A–C) (Figure 1(d)).

*Stacked bar chart*

A stacked bar chart is an extended bar chart when a second categorical variable is added to divide each of the groups in the original categorical variable, making subgroups within a bar. It is useful for comparing proportional contributions within a category.[6] For example, bars represent numbers (count) of deaths by three causes (unintended injuries, homicide, suicide) among three risk groups (A–C) (Figure 1(e)).

*Histogram*

A histogram can be considered as a type of bar chart that depicts frequency values. It is different from the standard bar chart in which its primary variable is categorical in nature, whereas a histogram's primary variable is continuous and numeric.[4,7] By counting and grouping the values in a dataset into bins (intervals) based on the frequency with which they occur, a histogram then shows a distribution of the values of data within that dataset.[7,8] For example, a histogram represents the distribution of knowledge scores among students in a school (Figure 1(f)). Some have said that a histogram is not exactly a bar chart. A histogram shows the frequency of numerical data as intervals in the form of bars while a bar chart shows the numerical values of different categorical entities. The bars of a histogram cannot be reordered but the bars in a bar chart can be reordered.[5,7,9]

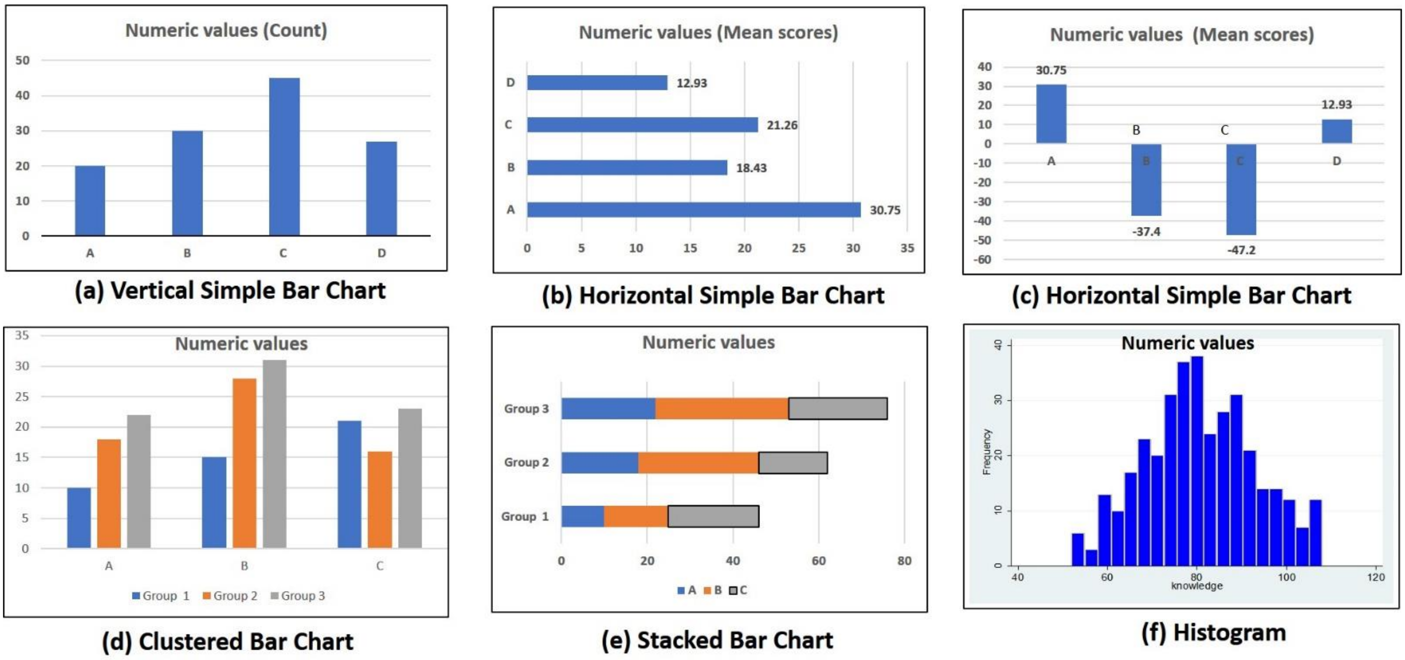



**Figure 1. Different types of bar charts**

## Pie Chart

A pie chart shows the total amount divided into separate categories as radial slides of a circle (pie), in which the size of each slide represents a proportion of a category of the total (100%). The pie chart is effective in presenting the idea of a part-to-whole comparison. The pie chart is sometimes presented in a "donut" form. For example, a pie chart depicts percentages of seven types of food consumption (A–F) among people in a community (Figure 2). There are shortcomings of the pie chart. It is different from the bar chart, because a single pie chart is not good for comparison purposes. It is difficult to comprehensively interpret the pie slices, particularly when there are too many slices or too many similarly-sized slices.[10] When slices are too small, it is difficult to read and color distinctly.[5]

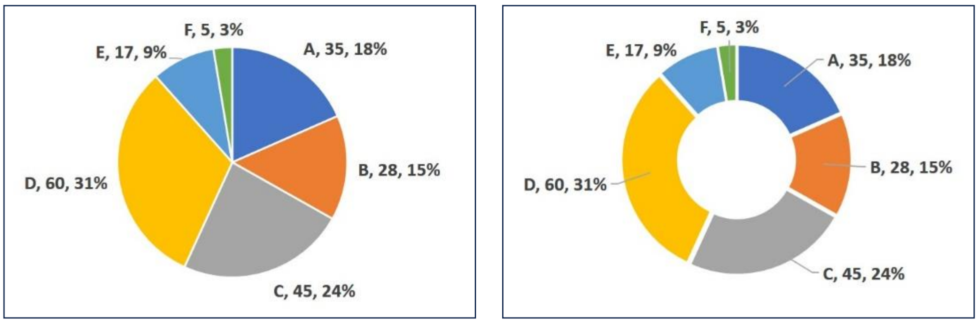



**Figure 2. Different types of pie charts**

## Line Chart

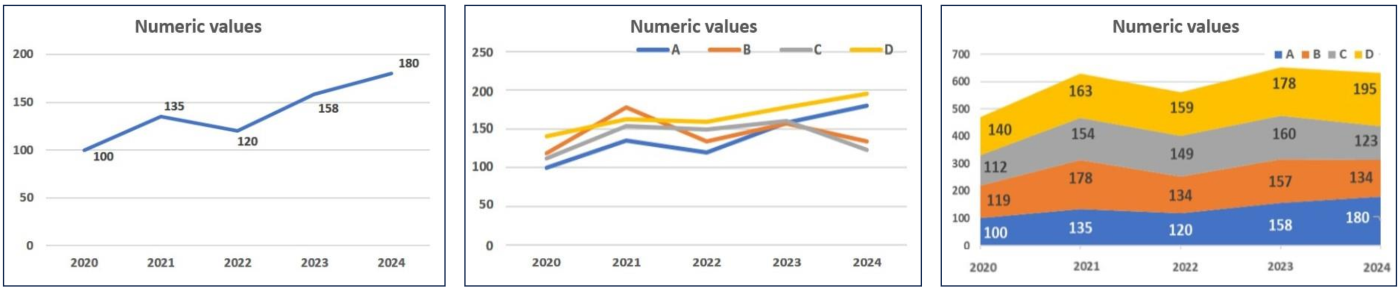
A line chart, also called a line graph, presents a series of data points connected by straight-line segments. The line chart is commonly used to show trends over time and compare several data sets.[6] The line chart is commonly used due to its simplicity which make it universally understandable. For example, a line chart shows the number of emergency department visits at a hospital during 2020–2024 (Figure 3(a)). Besides simple line charts, different types of line charts can be used in various contexts for different analytical purposes including multiple line charts and compound line charts.[11]

*Multiple line chart*

Multiple line chart involves plotting several lines on the same chart, each representing different data series. For example, a line chart shows the number of emergency department visits at four hospitals during 2020–2024 (Figure 3(b)).

*Compound line chart*

A compound line chart or stacked line chart shows the cumulative effect of several data sets stacked on top of each other. For example, a line chart shows stacked numbers of emergency department visits at four hospitals during 2020–2024 (Figure 3(c)).




**(a) Simple line chart** **(b) Multiple line chart** **(c) Compound line chart**

**Figure 3. Different types of line charts**

Presenting data in graphic format can be misrepresented or misinterpreted when placed in the wrong style of data visualization.[1] Upon choosing the wrong chart type, we may end up not only failing to present our message clearly but also misleading our readers. So, which chart should we pick? There is no clear-cut answer as it depends on several factors including types of data, subject matter, desired format, intended message, intended audience, and personal preferences.[12] Here are some suggestions.[8] When we want to compare data among different categories, the bar chart is a better choice. A part-to-whole can be presented as a pie chart or a stacked bar chart. If we want to convey change over a period of time as a trend, the line chart is the choice.

## Chart Attributes

Unique graphical attributes should be applied to both quantitative and qualitative data in terms of shape, color, size, angle and position.[8] Good charts should have clear labels, legends, and annotations. Elements of a visualization can be modified to emphasize or diminish the impact of the data. Some recommendations are as follows.[1,8,10,13–16]

### Legends and Annotations

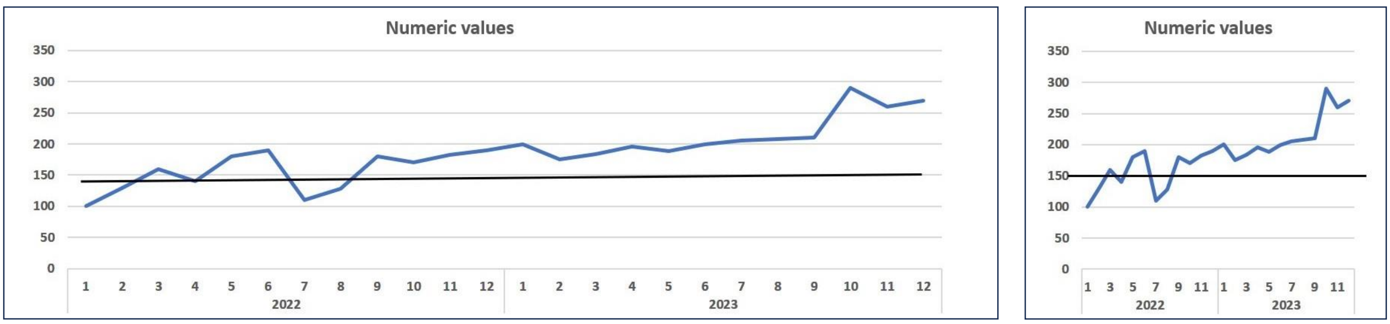
Legends and annotations describe a chart's information. Annotations should highlight data points, data outliers, and any noteworthy content. Text can be used to label different chart elements including chart titles, data labels, axis labels, and legends. Applying "bold text" on too many elements can make it harder to identify important elements. Unclear label wording can induce bias.

### Colors

Colors can stimulate subconscious emotional reactions. While colors are used to provide contrast and emphasis, too many colors in a single chart can hinder focus.

### Tick Mark Spacing

Tick mark spacing can emphasize granularity. The line can be styled in different ways, such as using colors, dashes or varied opacities. Be careful that increasing the length of the horizontal scale can flatten the perception of the rising line. In the opposite way, squeezing the axis can be misleading because it exaggerates change (Figure 4).

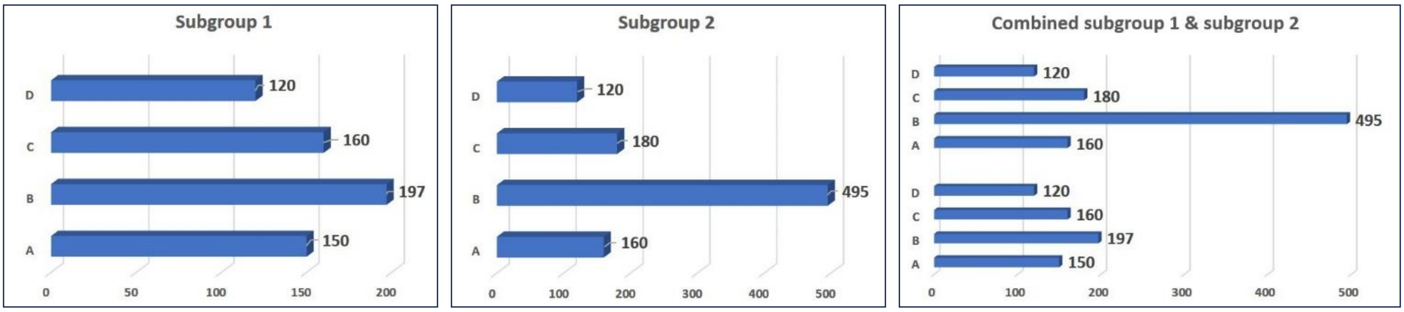



**Expand horizontal axis** **Compress horizontal axis**

**Figure 4. Comparison of trend graph in expand and compress horizontal axis format**

### Axis Scaling

Axis scaling can be a problem. Most software used to create charts often automatically scale to "best fit" the data values within the dataset. When comparing data values from different datasets in separate charts, be cautious to take notice of whether both datasets have the same scale or not. As shown in the example, different axis scaling could give a wrong impression about the length of bars in bar charts (Figure 5).

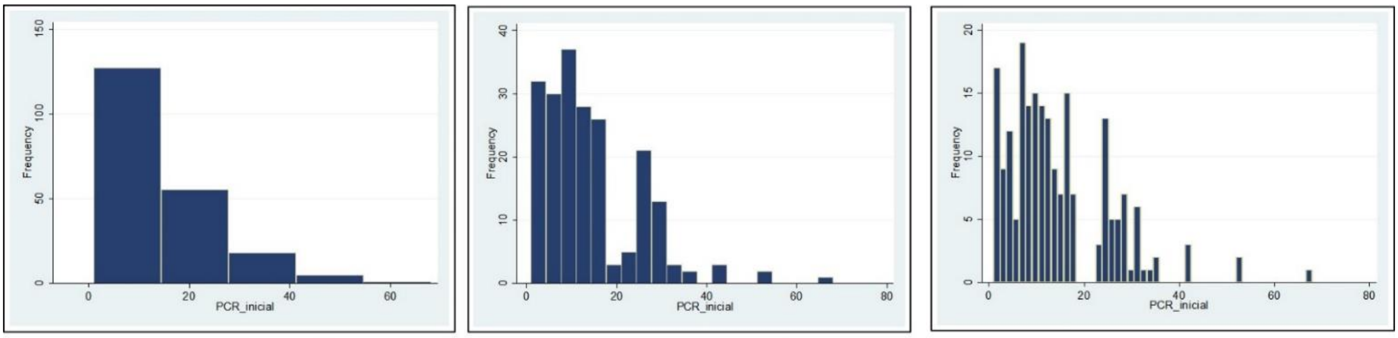



**Subgroup 1- data range: 0-200** **Subgroup 2- data range: 0-500** **Subgroup 1 & 2- data range: 0-500**

**Figure 5. Different axis scaling among subgroups**

### Blocking Size

The blocking size of a bar chart or histogram depends on the data intervals, so-called binning. Dissimilar bin values will give a different impression about data distribution. As shown in the example, distributions of PCR values of 200 patients look different in different bins (Figure 6).




**Histogram @ Bin (5)** **Histogram @ Bin (20)** **Histogram @ Bin (50)**

**Figure 6. Different blocking size (binning)**

### Data Overload

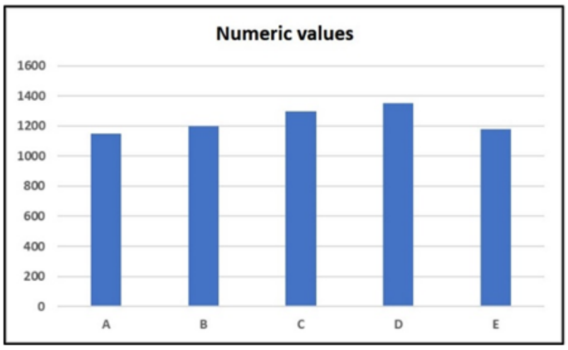
Data overload can occur when there is too much information in a chart because it will make the chart look unfocused, fuzzy and difficult to interpret. Crossing too many variables will make the chart difficult to understand, and the readers may make inaccurate assumptions due to bias and confusion. A good chart should actually say more with less. Removing unnecessary formatting and clutter can make the graphics more impactful and easier to interpret.

## Misleading and Lie

The main principle of data visualization is to present the information with respect to accuracy, clarity, and integrity in a way that doesn't distort it.[8] It is easy to lie with any kind of charts. Deceptive or misleading charts typically center on visual tricks.[8,10,14,16–18]

### Axis Cropping

Axis cropping may be done either on the X- or Y-axis (or both) to show a subset of the data. A truncated axis is a common violation of data visualization design. There must be a good reason to do the cropping. Manipulating the Y-axis by zooming in so that it doesn't start at zero (0) may be done when the baseline value is further away from the zero baseline; but zooming in too much can misrepresent the trend, or exaggerate small differences to appear larger in the reader's eye (Figure 7).



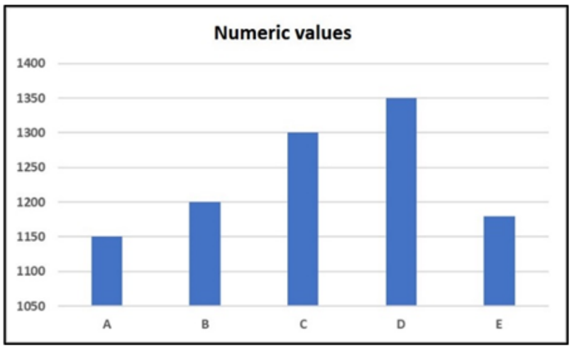




**Figure 7. Axis cropping (Truncated Y-axis) showing the differences among the 5 groups**

### Inverted Vertical Axis

Inverted vertical axis should be rarely used as it can easily introduce the incorrect conclusion. A classic example of a chart showing gun deaths in the inverted vertical axis misleads the readers to think that gun deaths have been declining (Figure 8).

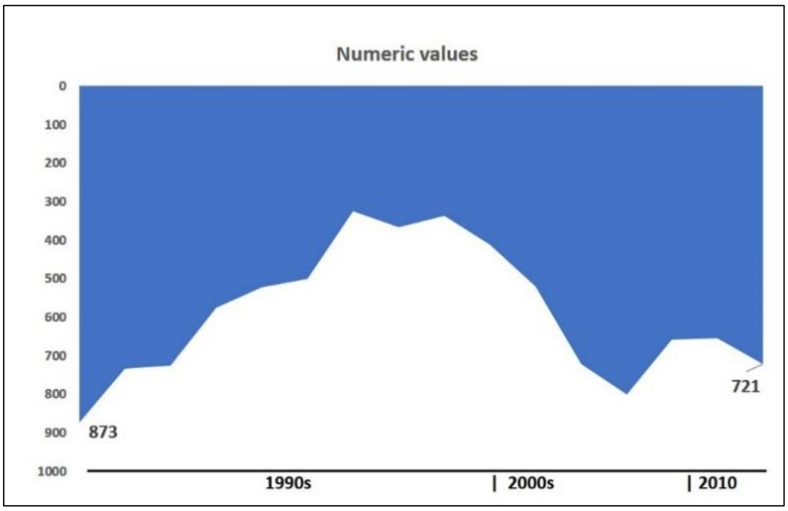
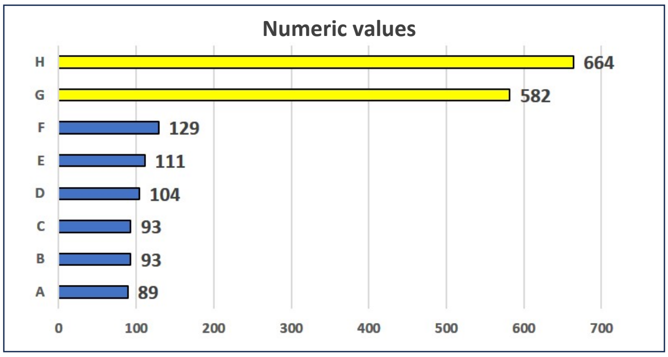



**Figure 8. Inverted vertical axis showing numbers of gun deaths over the years**

### Broken Bar Chart

A broken bar chart is often done by adding a symbol // to denote that the length of the bar is "broken" when it actually extends much longer. However, it is still misleading, so the readers should be informed to interpret the results with caution (Figure 9).



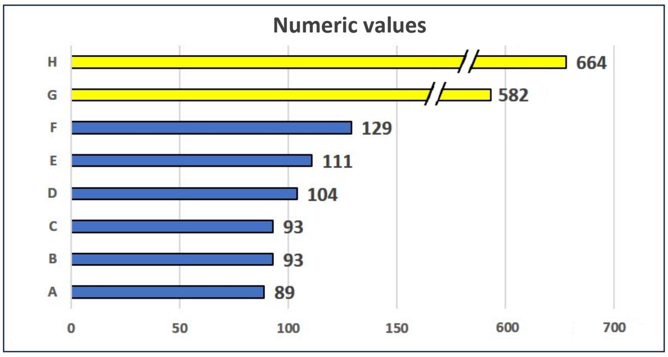




**Figure 9. A broken bar chart cutting the length of two long bars**

### Dual Axis Chart

A dual axis chart is sometimes used to present two data series in one chart. When a vertical axis shows the scale of the first data series on the left side and a second vertical axis on the right side of a chart, it may be confusing, difficult to interpret, and mislead the readers to conclude the trends of the two lines as the causal effect, rather than association (Figure 10).

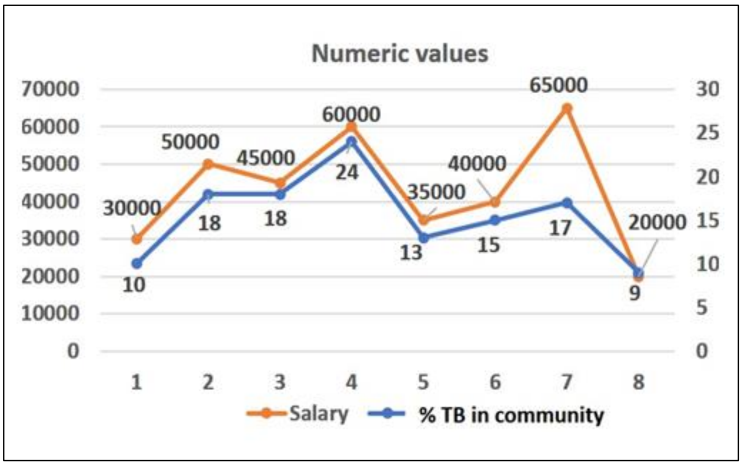



**Figure 10. Dual axis chart showing average salary and percentage of TB cases in eight communities**

## Incorrect Curve-fitting Chart

An incorrect curve-fitting chart can occur when attempting to show the correlation or relationship between two variables with a scatter plot together with its regression line. To correctly explain the trend of the data points, make sure that the data suggest a linear or non-linear trend, and perform the proper "curve-fitting" model accordingly. Do not simply draw an arbitrary line and claim that the data trend corresponds to the drawn line (Figure 11).

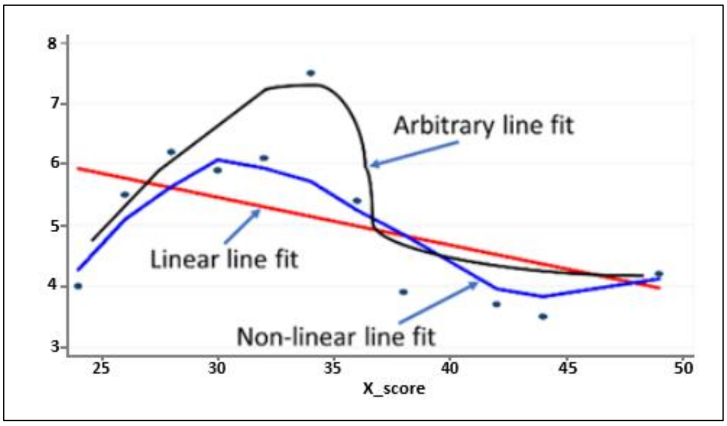
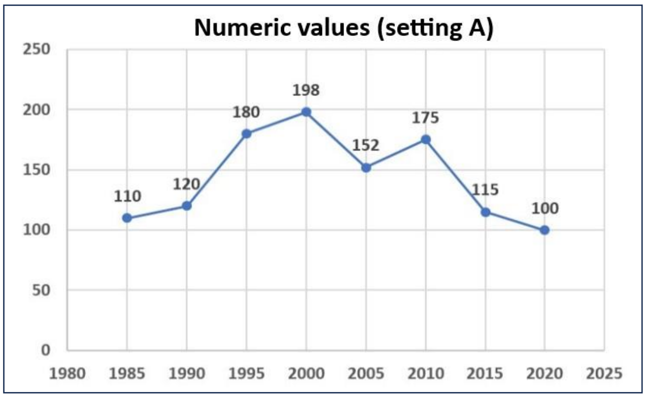



**Figure 11. Curve fitting line chart with correct non-linear trend (not the incorrect linear or arbitrary line fit)**

## Unequal Time Spacing Charts

Unequal time spacing charts are not comparable. When comparing trends over time, take notice that the charts are not based on different time frame or have unequal time intervals (i.e., month over month, quarter over quarter, year over year, etc.). It is not a good idea to collate two charts that are based on unequal time spacing because it can make the readers perceive a false impression about the data trends (Figure 12).



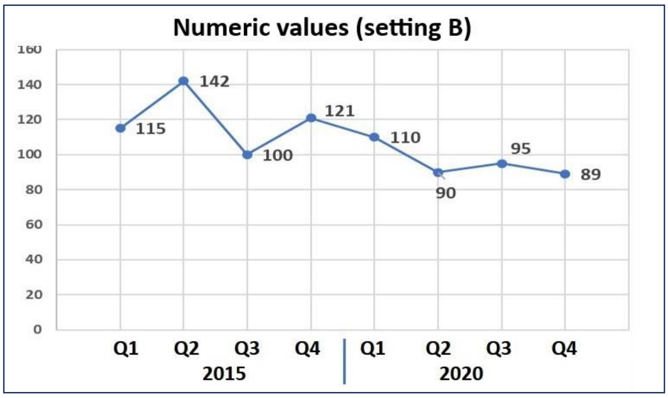
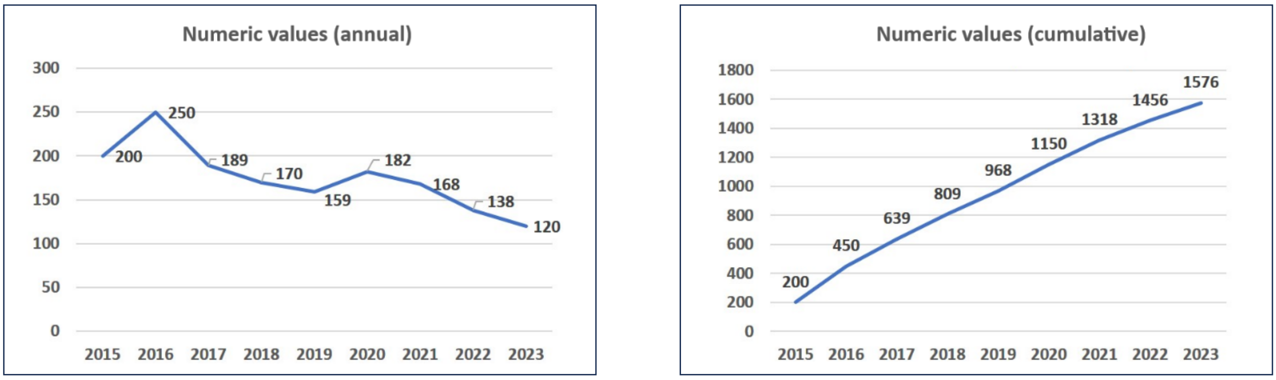



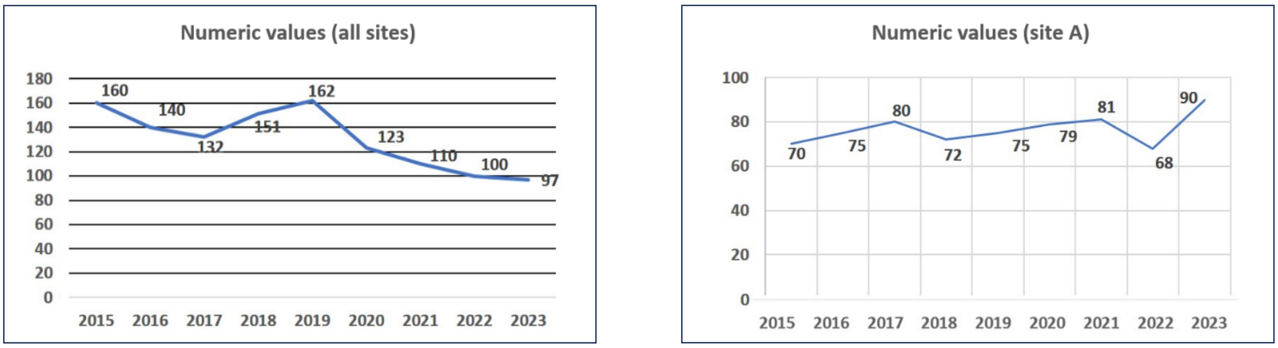

**Figure 12. Incomparable charts due to different time-spacing**

## Reasoning Errors

Reasoning errors can occur when comparing charts with unsupported assertions or logical fallacies. As shown in Figure 13(a), a confusing and incorrect conclusion may occur when comparing two charts showing the opposite direction, the trend of cumulative income (aggregated data) over the years vs. the trend of annual income over the years. The cumulative graph usually makes things seem a lot more positive than they actually are. On the other hand, "cherry-picking" occurs when presenting a chart with incomplete evidence which, in fact, could not be generalizable with more representative evidence. As shown in Figure 13(b), a chart presents an outcome of a subset group but falsely claims it as if it represents the whole group.




(a) Annual data vs. cumulative data




(b) All sites data vs. specific site data

**Figure 13. Incomparable charts due to logical fallacy or cherry-picking**

## Misleading Comparisons

Misleading comparisons can occur when comparing data values across charts, but the data values are based on different attributes or units. It is also important to understand the numerator and denominator of the calculated statistics. As an example, percentage changes over time among different groups can be calculated in different ways. The percentage changes over time can be calculated from the baseline denominator of each group, or from different denominators (number of subjects) at each time point. With different calculations, the interpretation of the charts will be distinctively different (Figure 14).

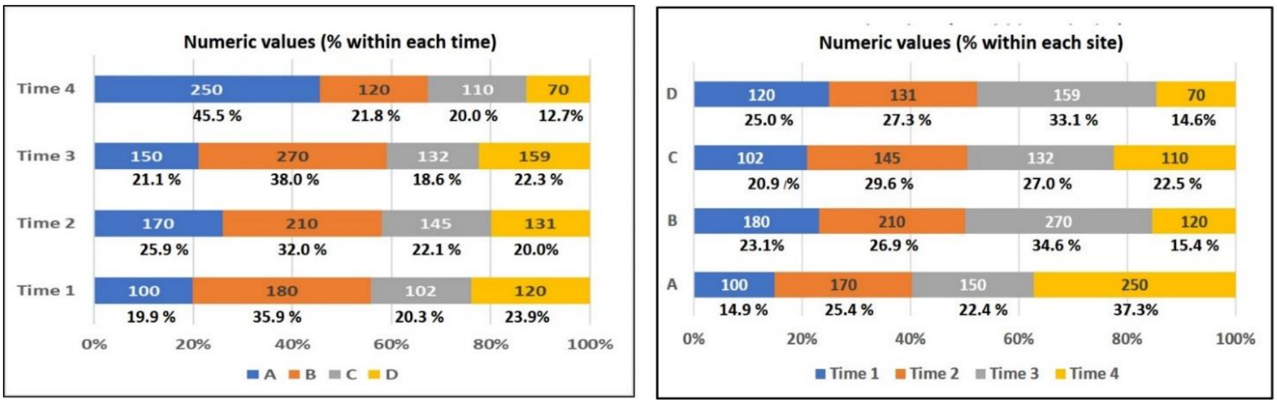



**Figure 14. Different conclusions from different percentage calculations**

**Incomplete Presentation**

Incomplete presentation occurs when there are missing categories, unintentionally or intentionally, in a chart. This will make the readers misinterpret the chart. A frequent mistaking is seen in a pie chart that the overall percentage does not add up to 100% due to missing certain categories or rounding up the numbers.

## Final Thoughts

Bar, pie and line can lie. In designing a chart, we should take into consideration both scientific and ethical viewpoints. A chart must *tell the truth* and be presented without biases and deception. Presenters, should avoid creating misleading data visualizations, and think carefully about choosing the right kind of chart to communicate the data in a truthful way. Readers, should appraise the data visualization carefully before interpreting and drawing any conclusion.

## Suggested Citation

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## References

1. Tableau. What is data visualization? definition, examples, and learning resources [Internet]. San Francisco (CA): Salesforce, Inc; [cited 2024 Oct 20]. <https://www.tableau.com/learn/articles/data-visualization>
2. University Libraries. Data visualization: charts and graphs [Internet]. Las Vegas: University of Nevada Las Vegas: [cited 2024 Nov 10]. <https://guides.library.unlv.edu/c.php?g=991477&p=9562156#:~:text=Charts%20are%20the%20best%20option,with%20details%20allowing%20faster%20understanding>
3. Sheeba M. Graphs vs charts [Internet]. Mumbai: WallStreetMojo Team; [cited 2024 Nov 10]. <https://www.wallstreetmojo.com/graphs-vs-charts/>
4. Yi M. A complete guide to bar charts [Internet]. Sydney: Atlassian; [cited 2024 Oct 20]. <https://www.atlassian.com/data/charts/bar-chart-complete-guide>
5. Yi M. How to choose between a bar chart and pie chart [Internet]. Sydney: Atlassian; [cited 2024 Oct 20]. <https://www.atlassian.com/data/charts/how-to-choose-pie-chart-vs-bar-chart>
6. Carbon Design System. Data visualization, Simple charts [Internet]. New York: IBM; [cited 2024 Oct 20]. <https://carbondesignsystem.com/data-visualization/simple-charts/>
7. Pupkin J. Histogram [Internet]. [place unknown]: Wall Street Oasis; [updated 2023 Nov 24; cited 2024 Nov 10]. <https://www.wallstreetoasis.com/resources/excel/study/histogram>
8. Material Design. Data visualization [Internet]. Mountain View (CA): Google; [cited 2024 Oct 20]. <https://m2.material.io/design/communication/data-visualization.html>
9. Moore DS, McCabe GP, Craig BA. Introduction to the Practice of Statistics. 10th ed. New York: W. H. Freeman; 2021.
10. Fortney K. 5 ways data visualizations can lie [Internet]. San Francisco: Towards Data Science; 2017 May 27 [cited 2024 Oct 20]. <https://towardsdatascience.com/5-ways-data-visualizations-can-lie-46e54f41de37>
11. Thompson C. Line chart: definition, types, examples. New York: Investopedia; [updated 2024 Aug 16; cited 2024 Oct 20]. <https://www.investopedia.com/terms/l/linechart.asp>
12. Math Worksheets Center. Bar graphs, pie charts, and line graphs: how are they similar and how are they different? [Internet]. [place unknown]: Math Worksheets Center; [cited 2024 Oct 20]. <https://www.mathworksheetscenter.com/mathtips/barlinepiegraph.html#google_vignette>
13. Tracy S. How to lie with charts [Internet]. San Francisco: Medium; 2016 Sep 1 [cited 2024 Oct 20]. <https://stephen-tracy.medium.com/how-to-lie-with-charts-97396e4642>
14. PolicyViz. 10 ways to mislead with data visualization. [place unknown]: PolicyViz; 2023 Feb 7 [cited 2024 Oct 20]. <https://policyviz.com/2023/02/07/10-ways-to-mislead-with-data-visualization/>
15. Pop R. Lies, damned lies, and visualizations [Internet]. Bergen: Everviz; 2021 Nov 8 [cited 2024 Oct 20]. <https://www.everviz.com/blog/lies-damned-lies-and-visualizations/>
16. Dougherty J, Ilyankou I. Hands-on data visualization: interactive storytelling from spreadsheets to code [Internet]. [place unknown]: Jack Dougherty and Ilya Ilyankou; 2021.

Chapter 14.1, How to lie with charts; [cited 2024 Oct 20]; [about 12 p.]. <https://handsondataviz.org/how-to-lie-with-charts.html>

17. Parikh R. How to lie with data visualization [Internet]. San Francisco: Heap by Contentsquare; 2014 Apr 14 [cited 2024 Oct 20]. <https://www.heap.io/blog/how-to-lie-with-data-visualization>

18. Lisnic M, Polychronis C, Lex A, Kogan M. Misleading beyond visual tricks: how people actually lie with charts. Proceedings of the CHI'23: CHI Conference on Human Factors in Computing Systems; 2023 April 23–28; Hamburg, Germany. New York: Association for Computing Machinery; 2023. 21 p. doi:10.1145/3544548.3580910.

*"The cover reflects a world rapidly urbanizing
amid growing environmental crises.
It also symbolizes the One Health concept—
reminding us that outbreaks can emerge
in both urban areas and natural environments."*

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