



Misalignment between Influenza Vaccination Timing and Epidemic Dynamics in Thailand: A Policy Analysis, 2011–2025

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Abstract

Objectives: To assess the alignment between influenza vaccination timing and epidemic dynamics in Thailand and examine the implications of epidemiological variability, program design, and implementation processes for national influenza vaccination policy.

Methods: We conducted a mixed-methods policy analysis integrating a longitudinal analysis of national influenza surveillance data from 2011–2025, assessment of vaccination program performance, and a rapid systematic review of global evidence. Epidemic onset and seasonal patterns were characterized using weekly case data. Alignment between vaccination timing and epidemic onset was quantified using a lag-time metric, defined as the interval between vaccination initiation and epidemic onset.

Results: Influenza activity demonstrated increasing seasonal variability, transitioning from a single annual peak to more complex patterns with multiple waves and shifting epidemic onset. Across the 15-year study period, dual-wave or multi-wave patterns were identified in multiple years. The national vaccination program achieved consistently high delivery efficiency (>90% of allocated doses administered), although coverage remained uneven across population groups. Lag-time analysis showed substantial interannual variability, ranging from –11 to +15 weeks, with a median lag time of +11 weeks. In several years, including 2014, 2019, and 2025, vaccination was initiated after epidemic onset, indicating misalignment between vaccine delivery and transmission dynamics.

Public Health Recommendations: Fixed annual vaccination schedules may not provide optimal protection in settings with variable epidemic timing. Strengthening the integration of real-time surveillance data into vaccination planning is essential. Adaptive strategies, including flexible vaccination timing and region-specific approaches, should be considered to improve alignment with epidemic risk. Simple metrics such as lag-time can support routine monitoring and guide policy adjustment. These actions are critical to enhance the effectiveness of influenza control programs in Thailand and similar countries in tropical settings.

Keywords: influenza, vaccination timing, seasonality, surveillance, policy analysis



Introduction

Influenza remains a significant cause of morbidity and mortality worldwide. Vaccination is the primary preventive strategy, but its population-level effectiveness depends on both coverage and vaccination timing relative to epidemic activity. In temperate regions, influenza seasonality is relatively predictable, allowing vaccination campaigns to be scheduled ahead of a single annual peak. However, in tropical and subtropical regions, influenza transmission is more complex, often characterized by multiple peaks, year-round activity, and substantial interannual variability.^{1–8}

Thailand reflects this dynamic influenza epidemiology. National surveillance data indicate increasing variability in seasonal patterns, with shifts in epidemic onset and the emergence of multi-wave transmission in recent years.^{9,10} Such variability challenges the assumption that a fixed annual vaccination schedule can consistently provide optimal protection.

Thailand's publicly financed influenza vaccination program, introduced in 2004, has expanded substantially, with increasing vaccine allocation and consistently high delivery efficiency.^{11–14} However, the program continues to operate on a fixed May–August schedule, assuming a relatively stable epidemic pattern which may not adequately account for increasingly variable transmissions patterns.

Evidence from tropical and subtropical settings suggests that misalignment between vaccination timing and epidemic dynamics can reduce vaccination effectiveness, particularly when vaccination occurs after transmission onset.^{1,3–5,15,16} However, this relationship has largely been described qualitatively or through modeling approaches, and simple, reproducible metrics to quantify alignment between vaccination timing and epidemic onset at the population level remain lacking.

This study addresses this gap by analyzing national surveillance data from Thailand (2011–2025) and introducing a lag-time metric to quantify temporal alignment between vaccination initiation and epidemic onset. Using a policy analysis framework, we examine how epidemiological variability, program design, and implementation processes interact to influence the alignment between vaccination timing and epidemic dynamics and inform more adaptive, data-driven vaccination strategies in Thailand.

Methods

Study Design

We employed a mixed-methods policy analysis integrating: (1) longitudinal analysis of national

influenza surveillance data, (2) quantitative assessment of vaccination program performance, and (3) a rapid systematic review of global evidence on influenza seasonality and vaccination timing.

We examined temporal changes in influenza epidemiology, quantified alignment between epidemic dynamics and vaccination delivery, and contextualized national findings within evidence from tropical and subtropical settings. The study was conceptually informed by the Health Policy Triangle framework,¹⁷ examining interactions among epidemiological context, policy content (vaccination strategy), policy processes (procurement and delivery systems), and implementation factors.

Longitudinal Epidemiological Analysis

National influenza surveillance data from 2011 to 2025 were obtained from the Division of Epidemiology, Department of Disease Control (DDC), Thailand. The surveillance system integrates case-based, sentinel syndromic, event-based, and laboratory-confirmed surveillance through a nationwide network of public and private healthcare facilities, including tertiary, provincial, district hospitals, as well as selected sentinel outpatient and laboratory surveillance sites.

Influenza-like illness (ILI) was defined according to the national surveillance guidelines¹⁸ as fever of at least 38 °C with cough and/or sore throat in the absence of another known cause. Laboratory-confirmed influenza cases were identified primarily by reverse transcription polymerase chain reaction and, in some settings, rapid influenza diagnostic testing.

Epidemic onset and seasonal patterns were characterized using weekly aggregated syndromic and laboratory surveillance data. National surveillance definitions and reporting structures remained broadly consistent throughout the study period, although surveillance sensitivity and completeness likely improved with system expansion and increased testing capacity. Weekly case counts were used to characterize epidemic onset, peak timing, wave structure, and interannual variability.

Definition of epidemic onset and peak

Epidemic onset was defined using a relative threshold approach. Weekly influenza activity was considered epidemic when case counts exceeded the annual median plus 1.5 standard deviations for at least two consecutive weeks. The epidemic peak was defined as the week with the highest case count within each wave.

Characterization of seasonal patterns

Annual influenza activity was classified as single-wave, dual-wave, or multi-wave. Peak timing was categorized as early-season (February–March), mid-year (May–July), or late-season (August–October), based on clustering in national data and evidence from tropical and subtropical settings demonstrating multiple peaks and variable seasonal patterns.^{3,4,19–21} Temporal variation in epidemic onset, peak timing, and dominant waves was assessed across years.

Quantitative Assessment of Vaccination Program Performance and Implementation

Information on vaccination policy, target populations, vaccine allocation, coverage, and implementation was compiled from national vaccination program records and official documents, including guidelines, annual reports, and publicly accessible resources from the Ministry of Public Health (MOPH), DDC, and National Health Security Office (NHSO). During the study period, Thailand's publicly financed influenza vaccination program targeted high-risk groups, including older adults, individuals with chronic diseases, pregnant women, young children, persons with obesity or disabilities, and healthcare personnel. These sources were also used to contextualize vaccination timing, program responsiveness, and implementation processes.

Assessment of vaccination coverage and delivery

Program performance was assessed using administrative indicators, including delivery efficiency (the proportion of allocated doses administered) and coverage among eligible populations.

Assessment of alignment between vaccination timing and epidemic dynamics

To quantify alignment between vaccination timing and epidemic dynamics, a lag-time metric was defined as the interval between vaccination initiation and epidemic onset. Vaccination timing followed the national vaccination schedule (May–August), with initiation standardized to epidemiological week 18 (1 May) for analytical consistency.

Lag-time was calculated as the epidemic onset week minus the vaccination initiation week, with positive values indicating that vaccination preceded epidemic onset, whereas negative values indicating that vaccination began after transmission started. This continuous measure enabled comparison of temporal alignment across years. Alignment was categorized as well aligned (at least 4 weeks before epidemic onset),

partially aligned (0–3 weeks before onset), or misaligned (after epidemic onset) to aid interpretation of temporal relationships between vaccination timing and epidemic dynamics.

Rapid Systematic Review

To contextualize Thailand's finding within broader evidence from tropical and subtropical settings, a rapid systematic review was conducted to identify studies describing influenza seasonality, epidemic timing, and implications for vaccination timing. Literature searches were performed using PubMed and Scopus.^{22,23}

Studies published between January 2010 and December 2025 were searched using combinations of keywords and Medical Subject Headings (MeSH) terms related to influenza, seasonality, epidemic timing, vaccination timing, and tropical or subtropical settings.

Study selection

Studies were included if they reported influenza seasonal patterns and/or epidemic timing in tropical or subtropical settings. Both country-specific and multi-country studies were eligible. Studies were excluded if they were not published in English, lacked sufficient information on seasonality or epidemic timing, focused exclusively on virological or laboratory methods without epidemiological analysis, or if full texts were unavailable.

Data extraction and synthesis

Data were extracted on study setting, seasonal characteristics, epidemic timing, and vaccination implications. Findings were synthesized descriptively and compared with national observations from Thailand.

Results

Longitudinal Epidemiological Analysis

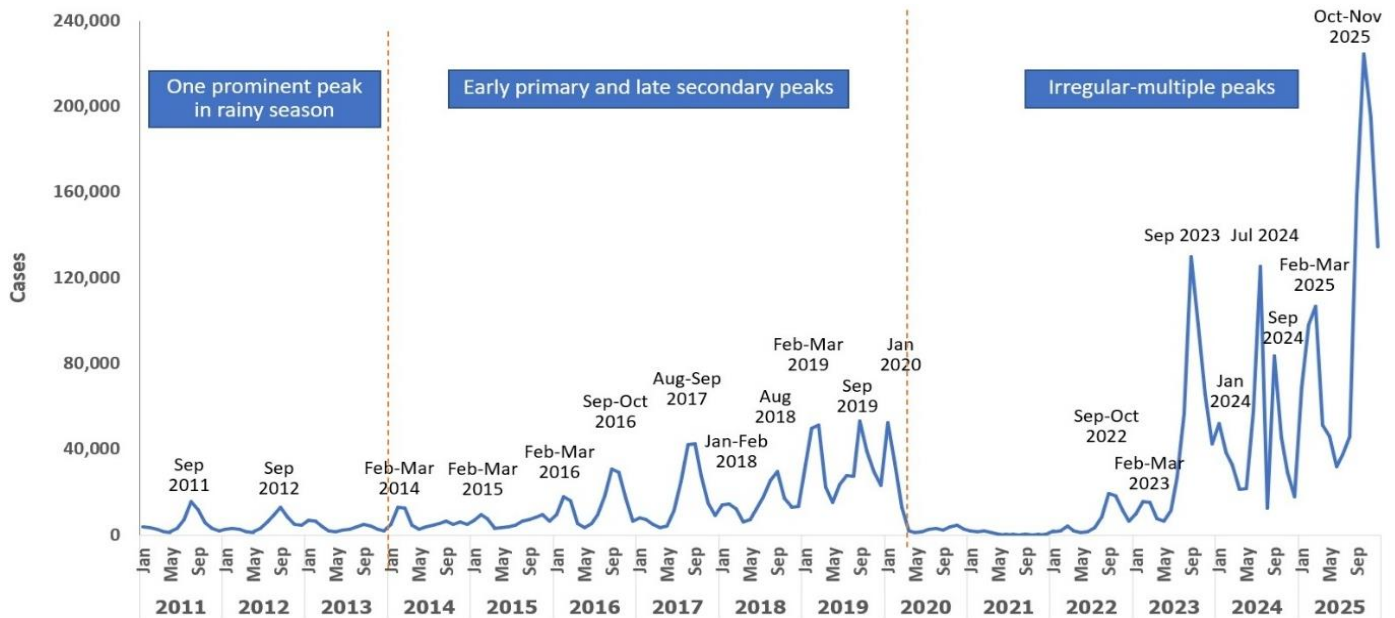
Evolving variability in influenza seasonality

Analysis of national surveillance data from 2011 to 2025 demonstrated increasing variability in influenza transmission patterns over time.

In 2011–2013, influenza activity showed a single, well-defined annual peak, typically during the late rainy season. From 2014 onwards, transmission patterns became more complex with dual-wave profiles, often comprising an early-season wave (February–March) followed by a larger late-season wave (August–October).

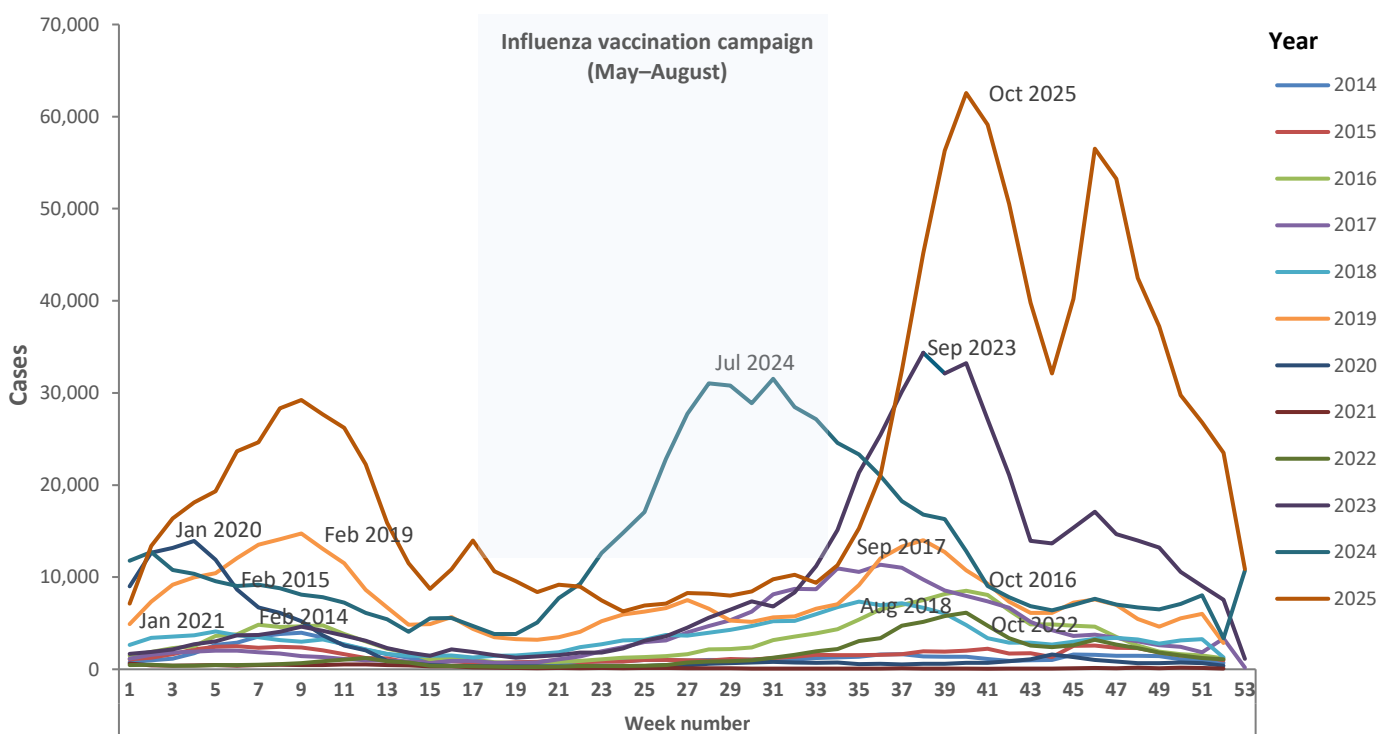
From 2020 onwards, seasonality became increasingly irregular, with multi-wave activity and marked interannual variation in both timing and magnitude of peaks. Epidemic onset also showed increasing variability across years, with earlier onset observed in several recent years.

Overall, influenza seasonality in Thailand shifted from a relatively stable annual pattern to more heterogeneous transmission dynamics, characterized by variable onset, multiple peaks, and inconsistent dominance of early versus late waves (Figures 1–2).



Source: Adapted from the national surveillance data, Division of Epidemiology, Department of Disease Control, Ministry of Public Health, Thailand.

Figure 1. Temporal changes and increasing variability in influenza seasonality in Thailand, 2011–2025.



Source: Adapted from the national surveillance data, Division of Epidemiology, Department of Disease Control, Ministry of Public Health, Thailand.

Figure 2. Seasonal patterns of influenza activity in relation to the annual vaccination period in Thailand, 2014–2025.

Quantitative Assessment of Vaccination Program Performance and Implementation

Evolution of policy and program expansion

Thailand's publicly financed influenza vaccination program evolved through distinct phases, with progressive expansion in target populations, financing mechanisms, and program scale. Before 2004, vaccination was mainly private sector-based, with minimal public provision (less than 20,000 doses annually). A publicly coordinated program began in 2004, initially targeting healthcare workers using donated vaccines.

Between 2005 and 2007, the program expanded to frontline health personnel and avian influenza response workers, with vaccine supply increasing to approximately 300,000–400,000 doses annually. From 2008 to 2011, integration into the Universal Health Coverage Scheme enabled expansion to high-risk groups, including older adults and individuals with chronic diseases.

From 2012 onwards, the program expanded further to include pregnant women, young children, and immunocompromised individuals, with annual vaccine allocation increasing to approximately 3–6 million doses. Since 2024, further expansion has been proposed and partially implemented, including broader risk groups and expanded pediatric eligibility.

Overall, vaccine provision increased from fewer than 20,000 doses annually before 2004 to several million doses in recent years, reflecting a transition from a limited occupational program to a large-scale publicly financed program. This expansion occurred within a rigid annual delivery framework, providing important context for interpreting alignment between vaccination timing and evolving epidemic dynamics.

Vaccination coverage, delivery performance, and equity

Despite substantial increases in vaccine allocation, uptake among high-risk groups remained limited.

Reported coverage reflects programmatic performance rather than population-based coverage, representing administered doses relative to allocated vaccines within the national benefit package rather than the total estimated high-risk population (approximately 12 million individuals).

According to the NHSO annual report 2025, 5.36 million of 5.64 million allocated doses were administered, corresponding to a delivery efficiency of 95.0%. This indicates strong implementation once vaccines are available but also highlights a supply–demand gap, with allocated doses covering less than half of the total high-risk population.

Uptake was uneven, with highest coverage among older adults and persistently low uptake among pregnant women and young children. Geographic disparities were evident, with provincial delivery ranging from 83% to 96% of allocated doses.

These findings indicate that high delivery efficiency may mask limited population-level protection, particularly when vaccine supply is constrained and not optimally aligned with epidemic timing.

Alignment between vaccination timing and epidemic dynamics

Lag-time analysis for 2011–2025 demonstrated substantial interannual variability, ranging from –11 weeks (2014) to +15 weeks (2021), with a median lag time of +11 weeks. In most years, vaccination preceded epidemic onset. However, in several years with early transmission, including 2014, 2019, and 2025, vaccination began after transmission had started.

A transitional pattern was observed in 2024, with a small positive lag (+2 weeks), indicating partial alignment (Table 1; Figure 3).

Overall, alignment between vaccination timing and epidemic onset varied considerably across years, with misalignment occurring predominantly in years with early epidemic onset.

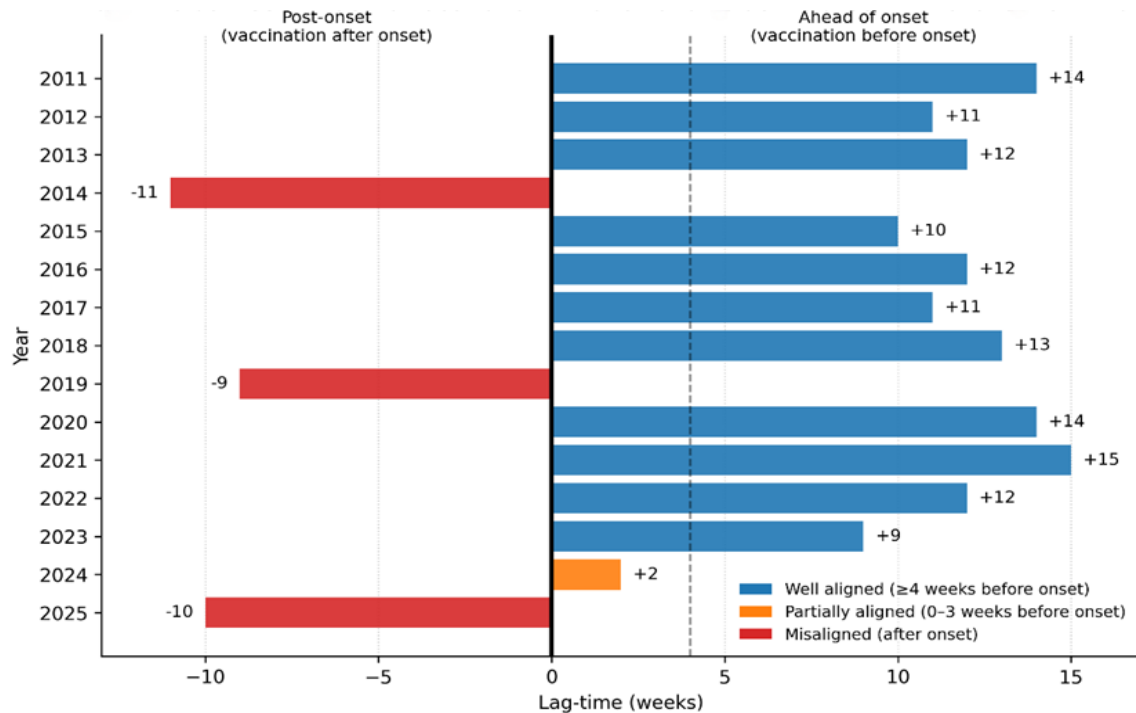
Table 1. Alignment between influenza epidemic onset and vaccination timing in Thailand, 2011–2025.

Year	Epidemic onset (week)	Lag-time (weeks)	Alignment	Predominant circulating strain*
2011	32	+14	Well aligned	A(H1N1)pdm09
2012	29	+11	Well aligned	A(H3N2)
2013	30	+12	Well aligned	Influenza B / A(H3N2)
2014	7	–11	Misaligned	A(H1N1)pdm09
2015	28	+10	Well aligned	A(H3N2)
2016	30	+12	Well aligned	Influenza B
2017	29	+11	Well aligned	A(H3N2)
2018	31	+13	Well aligned	Influenza B
2019	9	–9	Misaligned	A(H1N1)pdm09

Table 1. Alignment between influenza epidemic onset and vaccination timing in Thailand, 2011–2025 (cont.).

Year	Epidemic onset (week)	Lag-time (weeks)	Alignment	Predominant circulating strain*
2020	32	+14	Well aligned	Mixed circulation [†]
2021	33	+15	Well aligned	Low circulation / mixed
2022	30	+12	Well aligned	A(H3N2)
2023	27	+9	Well aligned	A(H3N2)
2024	20	+2	Partially aligned	A(H3N2)
2025	8	-10	Misaligned	A(H1N1)pdm09, A(H3N2)

*Predominant circulating strains were summarized from national influenza surveillance reports, Department of Disease Control, Thailand, Department of Medical Sciences surveillance updates, and published influenza surveillance studies. [†]Mixed circulation indicates co-circulation without a clearly dominant subtype.



Lag-time: epidemic onset week–vaccination initiation week (week 18; 1 May). Positive values indicate vaccination preceding epidemic onset; negative values indicate vaccination initiated after onset. Dashed line at +4 weeks indicates threshold for well aligned.

Figure 3. Lag-time between influenza vaccination initiation and epidemic onset in Thailand, 2011–2025.

Surveillance capacity and timing of program response

Thailand maintains a comprehensive influenza surveillance system integrating case-based, syndromic, event-based, and laboratory surveillance. However, vaccination timing has remained rigid, with vaccines typically available from April and administered between May and August. Consequently, variations in epidemic onset are not reflected in program timing, and in early transmission years, vaccination began close to or after epidemic onset, as indicated by minimal or negative lag times.

Program implementation involves multiple stakeholders, including the MOPH, the NHSO, and other bodies responsible for procurement, financing, and service delivery. Coordination within this multi-actor system is primarily structured around annual

planning and budget cycles, which may constrain timely adjustments to vaccination schedules in response to changing epidemiological patterns.

Together, these findings highlight a temporal gap between surveillance-detected changes in transmission and vaccination delivery, reflecting a structural disconnect between surveillance capacity and program implementation.

Rapid Systematic Review

Consistency with global evidence on shifting seasonality

The rapid systematic review identified 142 records, of which 18 studies met the inclusion criteria following screening and full-text assessment. These included both country-specific and multi-country analyses of

influenza seasonality in tropical and subtropical settings. Across the studies, influenza activity showed substantial temporal variability, with multiple annual peaks, year-round or near year-round transmission in equatorial regions, and marked interannual variation in epidemic timing.

Several studies also highlighted significant regional heterogeneity and limited predictability of epidemic timing, with some regions demonstrating biannual or irregular patterns. Epidemic timing in tropical

countries was often out of phase with standard hemispheric vaccination schedules, and optimal vaccination timing varied by region and year. In areas with early or irregular onset, fixed annual schedules frequently resulted in vaccination occurring after transmission had begun.

These findings are consistent with Thailand, which demonstrated variable epidemic timing and inconsistent alignment between vaccination delivery and transmission dynamics (Table 2).

Table 2. Studies included in the rapid systematic review on influenza seasonality and vaccination timing in tropical/subtropical settings

No.	Study	Setting/country	Main relevance/key finding
1	Baumgartner et al., 2012 ²⁴	Global (85 countries)	Demonstrated that multiple epidemic periods per year are more common in tropical countries, with less clearly defined seasonality than in temperate settings.
2	Kosasih et al., 2013 ¹⁹	Indonesia	Reported year-round circulation with a rainy-season peak, suggesting timing of prevention and control efforts around seasonal rainfall patterns.
3	Saha et al., 2014 ⁴	South and Southeast Asia (multi-country)	Identified peak activity typically between June and October, with occasional secondary peaks; recommended vaccination during April–June.
4	Koul et al., 2014 ²⁵	India (Srinagar, New Delhi)	Demonstrated substantial regional variation, with winter peaks in northern regions and monsoon peaks in central areas, indicating region-specific vaccination timing.
5	Chadha et al., 2015 ²⁶	India	Reported marked sub-national variation in epidemic timing, with direct implications for localized vaccination strategies.
6	Alonso et al., 2015 ²	Global (125 countries)	Showed that influenza peak timing in many tropical countries is out of phase with standard hemispheric vaccine recommendations.
7	Hirve et al., 2016 ³	Tropical and subtropical regions (multi-country)	Demonstrated less distinct seasonality, with multiple peaks and year-round transmission; proposed vaccination timing zones based on regional patterns.
8	Caini et al., 2016 ¹	Global (tropical and temperate)	Reported less defined seasonality in tropical regions, with implications for vaccine timing and formulation.
9	Lucero et al., 2016 ²⁷	Philippines	Reported peak activity between June and November, suggesting April–May as an optimal vaccination period.
10	Durand et al., 2016 ⁵	American tropics (16 countries)	Found epidemic onset typically around May, supporting vaccination in April using Southern Hemisphere formulations.
11	Althouse et al., 2018 ²⁸	Vietnam	Described seasonal patterns of respiratory virus hospitalizations, informing timing of influenza vaccination.
12	El Guerche-Séblain et al., 2019 ²⁹	Asia-Pacific region	Demonstrated substantial variation in epidemic timing and magnitude across countries, with inconsistent suitability of standard vaccination timing.
13	Horwood et al., 2019 ³⁰	Cambodia	Confirmed year-round circulation with a rainy-season peak, consistent with regional tropical patterns.
14	Suntronwong et al., 2020 ²⁰	Thailand	Demonstrated that influenza activity varies with climate factors, supporting variable and context-specific seasonal timing.
15	Servadio et al., 2023 ³¹	Vietnam	Reported limited repeatability of epidemic timing, indicating low predictability in tropical settings.
16	Yang et al., 2023 ²¹	Vietnam (Ho Chi Minh City)	Demonstrated that both annual and non-annual forces influence influenza dynamics, limiting predictability of epidemic timing.
17	Wan Puteh et al., 2024 ³²	Malaysia	Reported year-round transmission with irregular seasonal peaks, challenging fixed seasonal assumptions.
18	Sharma et al., 2025 ³³	North India	Identified biannual peaks (monsoon and winter), supporting region-specific vaccination timing strategies.

Discussion

This study identifies a central policy challenge in Thailand's influenza control, a mismatch between increasingly variable epidemic dynamics and a rigid annual vaccination schedule. Over the study period, influenza transmission shifted from a relatively predictable annual pattern to heterogeneous dynamics, characterized by multiple waves and variable epidemic onset. This growing variability reduces the predictability of influenza activity and complicates the optimal timing of preventive interventions.¹⁻³ The observed transition suggests evolving influenza transmission dynamics in Thailand and contrasts with earlier analyses describing more stable rainy-season-dominated seasonal patterns.³⁴

Although reported influenza cases increased over time, this trend should be interpreted cautiously, as it may partly reflect improvements in surveillance sensitivity, reporting completeness, testing capacity, and system expansion rather than a true increase in transmission. Nevertheless, the increasing heterogeneity in seasonal patterns and epidemic timing observed across years remains the principal finding.

Thailand's influenza vaccination program has expanded substantially in scale and scope, achieving high delivery efficiency (more than 90% of allocated doses administered annually). However, vaccine uptake remained uneven across population groups and regions, indicating persistent gaps in population-level protection. These findings suggest that while the implementation is efficient once vaccines are available, vaccination timing is not consistently aligned with epidemic risk.

A major contribution of this study is quantifying temporal misalignment using a lag-time metric, demonstrating substantial interannual variation between vaccination initiation and epidemic onset, including both positive and negative lag times. In several years, vaccination started after epidemic onset, reducing time for immunity development before peak transmission and limiting the population-level vaccine impact.

Using the Health Policy Triangle framework, this misalignment reflects interactions across multiple policy domains. Changes in epidemiological context, particularly increasing variability in influenza seasonality, are not fully reflected in policy content, including fixed vaccination schedules. Policy processes, such as procurement timelines, annual budgeting cycles, and vaccine delivery mechanisms,

constrain timely adaptation, while coordination among multiple stakeholders shapes implementation in practice.^{4,6,17} These findings reveal a structural limitation; although surveillance systems can detect changing transmission patterns, this information is not fully translated into adaptive vaccination timing.

These challenges are not unique to Thailand. Studies from tropical and subtropical settings consistently demonstrate influenza activity with multiple peaks, irregular or year-round transmission, and substantial interannual variability.^{3,4,24,29} Epidemic timing is often heterogeneous, partially predictable, and frequently out of phase with standard hemispheric vaccination schedules, limiting the effectiveness of fixed annual vaccination strategies. Thailand's patterns are consistent with this global evidence, suggesting that timing misalignment represents a systemic challenge in similar epidemiological contexts.

From a policy perspective, these findings support a shift towards more adaptive and data-informed influenza control. Integrating syndromic surveillance indicators such as ILI with laboratory-confirmed surveillance may improve early detection and short-term forecasting of epidemic onset, supporting earlier and more responsive vaccination deployment, particularly in years with early transmission.

In parallel, strengthening domestic and regional influenza vaccine development and production should be considered a strategic priority. In settings with variable and sometimes early epidemic onset, reliance on fixed global production timelines may limit responsiveness. Expanding local manufacturing and procurement flexibility could improve vaccine availability and better align vaccination timing with epidemic dynamics.

Further research is needed to identify optimal vaccination timing in tropical settings. Predictive models integrating surveillance indicators, climate factors, and ILI trends could help define context-specific vaccination windows. Subnational analyses may also be important, given geographic variation in epidemic timing. Such evidence would support more precise and locally tailored vaccination strategies.

Finally, this study contributes methodologically by operationalizing alignment between vaccination timing and epidemic onset using a lag-time metric. Although previous studies have emphasized the importance of vaccination timing, it has often been described qualitatively or examined primarily through modeling approaches.^{3,4,15,16} The lag-time metric

provides a simple, reproducible, and policy-relevant approach for quantifying temporal alignment using routine surveillance data. It enables consistent year-to-year comparison and may support monitoring and evaluating vaccination timing in settings with variable influenza seasonality.

Limitations

This study has several limitations. First, the analysis was descriptive and did not include formal statistical or mechanistic transmission modeling. Second, vaccination coverage and program performance were based on administrative data, which may be subject to reporting variation and may not fully reflect population-level uptake or timeliness. Third, alignment classification depends on epidemic threshold definitions and may be sensitive to the criteria used to define onset. Fourth, the rapid review was limited to two databases and English-language publications, potentially introducing selection bias. Fifth, vaccine effectiveness or clinical outcomes were not assessed, limiting quantifying the impact of timing misalignment on disease burden.

In addition, vaccination initiation was standardized to epidemiological week 18 (1 May), while in actual practice vaccination occurs over an extended period (May–August) with variable uptake. As a result, the lag-time metric may not fully capture establishment of population-level immunity and may misclassify alignment, particularly when epidemic onset occurs near the start of the vaccination.

Public Health Recommendations

These findings have important implications for influenza control in Thailand and similar tropical settings. Increasing variability in epidemic timing and recurrent misalignment between vaccination delivery and epidemic onset suggest that fixed annual vaccination schedules may not consistently provide optimal population-level protection.

Strengthening integration of surveillance data into vaccination planning is essential. Real-time signals could enable earlier and more responsive vaccine deployment, particularly in early transmission years. Flexible approaches, including adaptive vaccination windows and region-specific strategies, should be considered to better reflect heterogeneous transmission patterns.

Improved coordination among the MOPH, the NHSO, and service delivery networks is needed for timely

procurement and delivery. Efforts to improve equitable vaccine uptake should be sustained, as gaps across population groups and regions persist.

Finally, lag-time metric may support routine monitoring and policy evaluation by assessing alignment and guiding program adjustment. Together, these actions support a more adaptive, data-informed vaccination strategy aligned with dynamic influenza transmission.

Conclusion

Influenza epidemiology in Thailand has become increasingly variable, while the annual vaccination schedule remains rigid, resulting in recurrent misalignment between vaccine delivery and epidemic onset. This misalignment occurred in multiple years and possibly limit the population-level vaccine impact. The findings highlight a critical gap between surveillance capacity and adaptive program implementation. Moving towards more flexible, data-informed vaccination strategies are needed to better align with evolving epidemic dynamics and strengthen influenza control in Thailand and similar settings.

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Author Contributions

Wichan Bhunyakitkorn: Conceptualization, methodology, supervision, writing—original draft writing—review & editing. **Pawinee Doung-ngern:** Conceptualization, formal analysis, investigation. **Oiythip Yasopa:** Data curation, validation. **Piyada Angsuwatcharakon:** Investigation, resources, writing—review & editing. **Nichakul Pisitpayat:** Validation, writing—review & editing. **Darin Areechokchai:** Supervision, writing—review & editing.

Ethical Approval

This study was based on secondary analysis of aggregated, non-identifiable data derived from national influenza surveillance systems and vaccination program records. No individual-level or personally identifiable information was accessed. The analysis was conducted in accordance with national data governance and public health surveillance practices.

This surveillance evaluation formed part of routine operational activities of the Division of Epidemiology and the Division of Communicable Disease, DDC, MOPH, Thailand. As the study used routinely collected, anonymized data for public health purposes, formal ethical approval and informed consent were not required. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Informed Consent

Informed consent was not required, as this study involved secondary analysis of aggregated, anonymized data.

Data Availability

The data supporting this study are available from the corresponding author upon reasonable request. Aggregated surveillance data are publicly accessible through the Digital Disease Surveillance (DDS) Portal at <https://ddsdoe.ddc.moph.go.th>.

Conflicts of Interest

The authors declare no conflicts of interest.

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

During the preparation of this manuscript, the authors used generative AI tools (including ChatGPT and Google Gemini) to improve language clarity and correct grammatical errors. The final manuscript was reviewed and edited by the authors, who take full responsibility for the content of the final manuscript.

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