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COVID-19 Case and Vaccination Rates, Thailand, 2021

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An abstract of
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Abstract

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By Charuttaporn Jitpeera

Coronavirus Disease 2019 (COVID-19) pandemic caused high morbidity and mortality worldwide. COVID-19 vaccination was expected to be a game-changer for the pandemic. Thailand was one country implementing COVID-19 vaccination. This study described the characteristics of COVID-19 cases and vaccination in Thailand during 2021. An association between vaccination and case rates was estimated with potential confounders, by ecologic level (i.e., color zone, curfew by provincial authorities, tourism, and migrant movement) and considering time at two, four, six, and eight weeks. We used the Spatial Panel Model for bivariate data to explore the relationship between case rates and each variable and included weekly variables in multivariate analyses. In 2021, Thailand had 1,965,023 cases and 45,788,315 first vaccination doses (63.6% of the Thai population). High case and vaccination rates were found among 31 – 45 year olds. Vaccination rates had a positive association with case rates due to the allocation of hot spot pandemic areas in the early period. The proportion of migrants and color zones had positive associations with case rates at the provincial level. The proportion of tourists had a negative association. Vaccination should be provided to migrants, and collaboration between tourism and public health should prepare for the new era of tourism.

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Chapter 1: Introduction

1.1 Introduction

Coronavirus disease 2019 (COVID-19) is a pandemic caused by the SARS-CoV-2 virus. The outbreak was first reported in China Dec 2019; then, the disease spread globally. The World Health Organization (WHO) first announced COVID-19 as a Public Health Emergency of International Concern (PHEIC) Feb 2020. (1) As of Jan 1, 2022 there had been 288 million global cases with 4.8 million deaths. (2) Pandemic public health measures (e.g., home quarantine, social distancing, travel restrictions, shutting down cities) affect mental health and economics. (3-6)

Currently, there is no specific treatment for COVID-19; numerous drugs are being developed. (7) COVID-19 vaccines were invented, approved, and implemented quickly to control the pandemic. (8, 9) Seven vaccines of three different types were approved for emergency use by WHO. (10, 11) Each country's policymakers decided to purchase and prioritize the target population to be vaccination. To estimate the efficacy of COVID-19 vaccines in the real world, the study should consider the country's location and population. (12)

1.2 Problem statement

Thailand was the first country to detect COVID-19 outside China. (13) The government implemented interventions to respond to the situation (e.g., city shutdown and nationwide curfews). (14) The government's public measures affected social sectors (e.g., job losses and suspension, income reduction). School closures impacted public health measures and increased learning losses and gaps in education. (15) Moreover,

COVID-19 affected mental health with reports of significant stress, anxiety, and depression. (16) By Dec 31, 2021, COVID-19 had caused > 2.2 million cases and 21,614 deaths in Thailand. (17)

Like others, Thailand has attempted to return to normal life and open for international tourism. COVID-19 vaccination was implemented among the Thai population beginning Feb 28, 2021; Sinovac and AstraZeneca were two primary vaccines. The first immunized were healthcare workers and people in epidemic areas and expanded to others. (18) In July, Thailand became the first country to mix Sinovac and AstraZeneca due to the surge of COVID-19 and the struggle with vaccine supply. (19) Pfizer and Sinopharm were later provided. (20) A booster dose was then delivered. (21)

1.3 Purpose statement

To date, vaccination is ongoing. This study will evaluate the pattern of vaccine distribution in Thailand and determine if there is an association with reduction in COVID-19 case rates.

1.4 Objectives

The aims of this study are to …

- describe the characteristics of COVID-19 vaccination people, Thailand, 2021.
- describe the characteristics of COVID-19 cases, Thailand, 2021.
- explore the association between COVID-19 vaccination and case rates in Thailand, 2021.

1.5 Significance

This study will show the pattern of COVID-19 cases and vaccination in Thailand, 2021. It will evaluate the association between the vaccination and cases.

1.6 Definition of terms

COVID-19 cases are individuals with laboratory positive results from Real-time Reverse Transcription–Polymerase Chain Reaction (rt-PCR) identified as SARS-CoV-2 and reported to the COVID-19 case database.

COVID-19 vaccination are individuals who received COVID-19 vaccine and reported to COVID-19 vaccination database.

The COVID-19 case database collects cases in Thailand under the authority of the COVID-19 Emergency Operation Center, Department of Disease Control (DDC), Ministry of Public Health (MoPH), Thailand.

The COVID-19 vaccination database collects data from the COVID-19 vaccination under the authority of the Immunization Center, Office of the Permanent Secretary, MoPH, Thailand.

Chapter 2: Literature Review

This literature review aimed to understand the COVID-19 situation in Thailand during 2021. It was divided into four main topics: COVID-19 in Thailand, 2021; COVID-19 vaccination in Thailand, 2021; public health and social measures; and related studies about the association between COVID-19 cases and vaccination.

Inclusion criteria

- Peer-reviewed articles related to COVID-19 in Thailand
- Reports, press releases, and other documents about COVID-19 in Thailand released by the World Health Organization, the Thai government, and the Thai Department of Disease Control
- Online news and texts published in English
- Full text available through the Emory Library or other systems

Exclusion criteria

- Incomplete texts or reports

Search Strategy

The four main topics were explored with accompanying scopes, definitions, and keywords listed below.

1. COVID-19 in Thailand, 2021

This topic included the COVID-19 situation in Thailand, 2020 and the COVID-19 situation in Thailand, 2021 and gave an overview of clusters throughout 2021.

Keywords, synonyms include COVID-19 AND (cases OR death OR rates OR incidence OR prevalence OR epidemiology OR mortality OR clusters) AND Thailand.

2. COVID-19 vaccination in Thailand, 2021

This topic included vaccine lists, regimens, and allocation in Thailand throughout 2021.

The keywords, synonyms were COVID-19 AND vaccine* AND Thailand.

3. Public health and social measures

Public health and social measures (PHSMs) by individuals, institutions, communities, local and national governments, and international bodies attempt to slow or stop the spread of infectious diseases, such as COVID-19. (22) PHSMs include personal protective measures (e.g., physical distance, avoiding crowded settings, hand hygiene, respiratory etiquette, mask-wearing); environmental measures (e.g., cleaning, disinfection, ventilation); surveillance and response measures (e.g., testing, genetic sequencing, contact tracing, isolation, and quarantine); and physical distancing measures (e.g., regulating the number and flow of people attending gatherings, maintaining distance in public or workplace). This did not include medical countermeasures (e.g., drug administration or vaccination) in this context. (23)

Keywords, synonyms include COVID-19 AND (public measures OR social measures OR regulations OR prevention OR mandates) AND Thailand.

4. Related studies about the association between COVID-19 cases and vaccination

Keywords, synonyms include COVID-19 AND vaccine* AND (cases OR incidence OR epidemiology) AND (association OR effect).

Citation library information

Citations were exported and recorded using Endnote™. Submission to IRB was not necessary because human subject research was not conducted.

2.1 COVID-19 in Thailand, 2021

The first confirmed COVID-19 case in Thailand was reported Jan 13, 2020; Thailand was the first country to detect COVID-19 outside China. (13) The majority of patients in Jan 2020 were identified among Chinese tourists. (24) Later, cases rapidly increased through clusters (i.e., boxing stadium clusters, pubs, bars, and night entertainment areas in Bangkok) from Mar to Jul 8, 2020. (25-27)

The wave from the first reported case until Jul 8, 2020 was called the first wave of COVID-19 in Thailand. (28) After that, there were 10 – 30 reports of new cases daily; these were mostly from designed quarantine hotels among travelers and Thai people who crossed over the Thai-Myanmar border illegally. (17, 29)

Beginning Dec 18, 2020 the Center for COVID-19 Situation Administration (CCSA) reported a 67-year-old Thai case who had a history related to the seafood market in Samut Sakhon. (30) She was the index case of the Samut Sakhon cluster and beginning of the second wave of COVID-19 in Thailand. Moreover, more than 45 reported cases were linked to the gambling den in Rayong Province. By the end of 2020, Thailand had reported 6,884 cumulative cases and 61 deaths. (31)

In 2021, most cases were linked to the Samut Sakhon cluster; this occurred in late Dec 2020. (32) Samut Sakhon is a province that depends on large numbers of migrant workers in industries and fishery. (33) Sellers from other provinces come to buy goods at the seafood market in Samut Sakhon. It became infected and spread COVID-19. Contact tracing and active case finding were conducted from the index case; 90% of

more than 500 cases were migrants. The Department of Medical Science confirmed the B.1.36.16 or Bangladesh/UK lineage, that spread in India and Myanmar and crossed the Thai-Myanmar border through undocumented migrant workers quickly spreading among migrant communities. (34) Worker living conditions are densely populated making social distancing or masking difficult. (35) This cluster spread to > 50 Thai provinces. (32) The daily number of cases surged and peaked at 930 reported cases Jan 31, 2021. (36)

The curve of cases in the second wave declined until Apr 1, 2021, when the daily number of reported cases was < 30. Thailand had 28,889 cumulative cases and 94 deaths at the end of this wave. (37)

The CCSA reported > 15 cases per day from the Bangkok Metropolitan Region beginning Apr 2, 2021; these were linked to a history of visiting entertainment venues, including pubs, bars, and karaoke. (38-41) Alpha (B.1.1.7 variant) first detected in the United Kingdom and was predominate (88.5% of sample sequenced by Jun 10, 2021) in this third wave and spread nationwide by people traveling from the capital to their hometowns. (42-44) The virus spread to various settings and caused many clusters (e.g., prisons, factories, hospitals). (43, 45-47) The daily number of cases in this third wave rocketed to > 2,000 cases per day and Thailand surpassed 100,000 cumulative cases by May 16, 2022. (48) As of Jul 5, 2022 Thailand had 289,233 cumulative cases and 2,276 deaths. (49)

Jul 6, 2021, Dr.Udom Kachintorn – advisor to the CSCA – announced that Thailand entered into the fourth wave due to the domination of Delta (B.1.617.2). (50) This variant was found among workers at a construction camp in the Laksi District, Bangkok.

And by May 24, 2022 was found in other ten provinces. (51) Delta (B.1.617.2) was found in most reported cases (63% by Jul 22, 2021). (52) It affected the COVID-19 incidence in Thailand, doubling the daily number of reported cases and reaching a peak of 22,782 reported cases by Aug 12, 2021. (53) After that, the daily incidence steadily dropped with an average daily reported cases of 2,500 per day. (54)

Dec 6, 2021, the CSCA announced the first Omicron variant case in Thailand; the patient had travelled from Spain. (55) After that, local transmission through the Kalasin Cluster spread to other provinces. (56) By Dec 31, 2021 the Department of Medical Sciences reported that Thailand had 934 Omicron cases, of which 38% were locally transmitted. (57) As of Jan 1, 2022, Thailand had reported 2,226,446 cumulative cases and 21,708 deaths. (58)

All COVID-19 cases were reported through the COVID-19 Situation Awareness Team of Department of Disease Control, Ministry of Public Health, Thailand. Positive cases from Antigen Test Kits were not included in this database.

2.2 COVID-19 vaccination in Thailand, 2021

The Ministry of Public Health aimed to provide COVID-19 vaccination in Thailand, including foreigners. However, there was a limit in the early phase. COVID-19 vaccine was allocated to high-risk groups as priorities; these were in five groups: healthcare workers in public and private sectors; people who had underlying diseases (i.e., chronic respiratory disease, cardiovascular disease, chronic kidney disease stage 5, cerebrovascular disease, diabetes mellitus, all types of cancer who were currently receiving chemotherapy or radiotherapy, those > 60 years old); COVID-19-related staff (i.e., village health volunteers, migrant health volunteers, soldiers, and polices who had

roles in screening people traveling from abroad or epidemic areas); and people in epidemic areas. (59)

In Feb 2021, COVID-19 vaccine was first distributed to 13 provinces. The first nine provinces are the highest-risk and strictly controlled zones (i.e., Samut Sakhon, Bangkok, Pathum Thani, Nonthaburi, Samut Prakan, Tak [Maesot], Nakornpathom, Samut Songkhram, and Ratchaburi). The rest are areas considered drivers of the economy and society; they are Chonburi, Phuket, Suratthani (Koh Samui), and Chiangmai. (60) On Feb 28, 2020 Thailand started the COVID-19 vaccination roll-out. Sinovac – an inactivated vaccine with an adjuvant in which two doses are required and injected 2-4 weeks apart – was provided early. (61) Later, the Ministry of Public Health expanded the COVID-19 vaccine coverage to target populations across all provinces from Apr 1, 2021. (37)

AstraZeneca – a viral vector vaccine in which two doses are required, injected 4-12 weeks apart – was the second vaccine implemented in Thailand beginning Mar 15, 2021. Prime Minister Prayuth Chan-o-cha was the first to received it. (62, 63) However, to vaccinate more faster, the Ministry of Public Health announced on May 24, 2021 that the interval between the first and second doses would be extended to 16 weeks. (64)

Sinovac and AstraZeneca were two primary vaccines that the Ministry of Public Health provided in Thailand without cost. Until Jun 25, 2020, Chulabhorn Royal Academy and some private hospitals imported Sinopharm, an inactivated vaccine with an adjuvant in which two doses are required and injected three weeks apart, to be an alternative to purchase. (65, 66) Due to the rapid increase in the proportion of Delta-variant cases in Thailand, the National Committee on Communicable Diseases changed the interval

between the first and the second dose on Jun 22, 2021. (67) Thailand implemented Mix-and-Match vaccines and a Booster Jul 12. (68) For Mix-and-Match or heterologous primary schedule, it defined the vaccine product used for the second dose differs from that used for the first dose. (69) Thailand used AstraZeneca as a second dose from those who received Sinovac as their first dose and as a third dose from those who completed two doses of Sinovac, which first priority was healthcare workers. (68)

In Aug 2021, the Department of Disease Control received 2.5 million doses of Pfizer, an mRNA vaccine in which two doses are required and injected three weeks apart, donated from the United States, and allocated to target groups in high-risk areas. (70, 71) After that, Pfizer was listed as a primary vaccine for people in Thailand provided without cost by the government.

Due to the increased number of cases among children, Pfizer was provided to children aged 12-18 in high-risk areas with an underlying disease as a priority on Aug 22, 2021, and expanded to other groups. (72) Additionally, Chulabhorn Royal Academy began administering doses of Sinopharm COVID-19 vaccine to children aged 10-18 years old, preparing for on-site school opening on Sep 20, 2021. (73)

Moderna, an mRNA vaccine in which two doses are required and injected four weeks apart, was the latest vaccine imported as an alternative vaccine, which people purchased in private hospitals. Some provincial authorities provided it for their residents without cost beginning Nov 2021. (74) According to the meeting of the Advisory Committee on Immunization Practice No.10/2564 Dec 9, 2021, the latest regimen of COVID-19 vaccines in Thailand were published. (Table 1)

Table 1. COVID-19 Vaccine Regimen, Thailand, 2021[a]

Doses 1 – 2	Dose 3	Interval Between Doses 2 and 3
Same Manufacture		
Sinovac-Sinovac or Sinopharm-Sinopharm	AstraZeneca/Pfizer/Moderna	At least four weeks apart from dose 2
AstraZeneca-AstraZeneca	Pfizer/Moderna	At least three months apart from dose 2
Pfizer-Pfizer or Moderna-Moderna	Pfizer/Moderna	At least six months apart from dose 2
Mix-and-Match		
Sinovac/Sinopharm-AstraZeneca	AstraZeneca/Pfizer/Moderna	At least three months apart from dose 2
Sinovac/Sinopharm-Pfizer	Pfizer/Moderna	At least three months apart from dose 2
AstraZeneca-Pfizer	Pfizer/Moderna	At least six months apart from dose 2

[a] Meeting of Advisory Committee on Immunization Practice No.10/2564, Dec 9, 2021

Jan 3, 2022, Thailand had administered > 100 million cumulative doses (51 million for the first dose, 46 million for the second dose, and 7 million for the third dose). (75) Fully vaccination individuals represented 69.8 per 100 population. (76)

All vaccination people from public and private sectors were reported to MoH Prom, the database under the TMoPH Immunization Center, Office of the Permanent Secretary.

2.3 Public health and social measures in Thailand, 2021

Four cities in Thailand were in the top 20 passenger destination cities from Wuhan, China in 2018; Bangkok was first. (77) After WHO notified all countries about the outbreak of unknown source pneumonia in Wuhan, Thailand began screening for symptoms of acute respiratory infection among direct flights from Wuhan beginning Jan 3, 2020. (78) The first case was reported in a Chinese tourist from Wuhan on Jan 13, 2020; Thailand was the first country with a confirmed case outside China. (28)

Thermal and respiratory infection symptom screening occurred for direct flights from Wuhan in the early phase; this expanded to cover all flights from China and other international flights. (79, 80) Because of the increase in cases in the first wave from boxing stadium clusters and night entertainment areas in Bangkok, the Centre for COVID-19 Situation Administration (CCSA) was established and chaired by Prime Minister Prayut Chan-o-cha Mar 12, 2020, to arrange the government's response with the Department of Disease Control and communicate to the public. (81)

Thailand declared a state of emergency for the COVID-19 situation Mar 26, 2020 and announced a nationwide curfew between 10 pm and 4 am, beginning Apr 3, 2020. (82) Wearing a mask when outside the home was requested. On the same date, the Civil Aviation Authority of Thailand (CAAT) announced a regulation prohibiting all commercial flights from entering Thailand until Apr 6, 2020. All returnees quarantined at designated hotels approved by the government for 14 days. (83) The government announced restrictions on avoiding movement between provinces, curfew between 10 pm to 4 am, delaying school openings, banning selling of alcohol, and mass gathering restrictions to stop the first wave. (84) After the decline, the restrictions were relaxed Jun 16, 2020.

(85) The remaining measures promoted hand hygiene, wearing masks, social distancing, and quarantine for people entering Thailand; these kept Thailand safe until the second wave in late Dec 2020.

Thailand faced three COVID-19 pandemic waves in 2021. The CSCA raised the level of restricted prevention measures implemented nationwide, and provincial authorities implemented measures to stop the virus in their provinces.

2.3.1 Color zones

CSCA implemented the first color zone measure Dec 24, 2020. Thailand was divided into four area zones: 1) maximum control or red zone (many infected cases in > one subarea); 2) control or orange zone (> 10 cases and tending upward); 3) high-level or yellow zone (< 10 cases and tending to control); and 4) surveillance or green zone (no cases). Mask wearing, hand hygiene, social distancing, and installing a tracking app were measures the CSCA strongly emphasized in all zones. However, each province considered and implemented other measures (i.e., closing places). (86, 87) Later, the CSCA announced a list of provinces in each color zone, effective from Jan 4 to Feb 1, 2021. Eight measures were used in the maximum control area: 1. prohibit utilization of educational buildings by providing online classes; 2. prohibit organization of many people gathering together; 3. authorize the closure of establishments and places at risk; 4. conditions for opening establishments in the maximum control areas varied; 5. closure of places or activities in responsible areas; 6. stopping travel across provinces and setting up checkpoints; 7. using work from home approaches; and 8. relaxing measures according to the situation. (88)

Feb 1, 2021 the CSCA added an additional zone. (89) The CSCA adjusted the list of provinces in each color zone based on the country's situation Feb 22, Jun 26, Jul 10, Jul 18, Aug 1, Oct 15, and Oct 30. (90-96) After Nov 1, 2021, the CSCA reopened the country and assigned one new zone for tourism. (97) After that, the CSCA relisted provinces based on the situation on Nov 13, Nov 30, and Dec 15. (98-100)

2.3.2 Curfew by provincial authorities

Once the CSCA allowed provincial authorities to deploy stricter restrictions than nationwide measures, the provincial authorities implemented curfews depending on the situation, with people refrained from going outside from 10.00 PM – 04.00 AM. They also asked for public cooperation to refrain from unnecessary travel. (101-108)

2.3.3 Migrant workers movement control in each province

Thailand had 2.9 million registered migrant workers in 2020, accounting for 6.67% of the workforce; this decreased from 2019 by 8.09% due to the pandemic. (109) Migrants contributed to Thailand's economy about 4.3 - 6.6% of Thailand's GDP in 2010. (110) Undocumented migrant workers were suspected to be the origin of the Samut Sakhon cluster. The cabinet announced migrant workers must register for work permits to curb COVID-19 spread. (111) Moreover, the CSCA directed all provinces in Thailand to monitor risks among traders, workers, and migrant workers when reopening, intensifying surveillance, and conducting proactive screening of migrant workers who entered illegally. (112, 113)

2.3.4 Tourism promotion and control in each province

Most clusters were involved people traveling around the country. Provincial authorities implemented measures to stop the virus from spreading depending on the color zones and their provincial situations (i.e., screening temperature at the entry of provinces, showing vaccination cards, showing test results, or shutdown down provinces). (114-116)

June 15, 2021, the National Communicable Disease Committee approved “Phuket Sandbox” to begin Jul 1, 2021. This project aimed to promote tourism of Thailand, which contributes the majority of Thailand’s GDP, by focusing on tourists from low-to-medium-risk countries who have confirmatory vaccination certificates and get tested after arrival date without quarantine. (117) Later, the CSCA changed the “Blue Zone Sandbox” project to open 17 pilot provinces for fully vaccination tourists from low-risk countries beginning Nov 1, 2021. (97, 118)

2.4 Related studies between COVID-19 case and vaccination rates

Sinovac, AstraZeneca, Sinopharm, Pfizer, and Moderna were used. (119-123) After many countries implemented vaccination, studies about the effectiveness were published. A systematic review and network meta-analysis comparing the clinical efficacy of COVID-19 vaccines found that COVID-19 vaccines reduced cases and symptoms among those vaccination. (124) A cross-sectional study from Jan 18 to Mar 18, 2021, in Brazil, which implemented Sinovac and AstraZeneca, discovered that seven weeks after the vaccine roll-out, there was a 62% increase in vaccine roll-out new cases of COVID-19 among healthcare workers. (125)

Due to variants (i.e., Alpha, Delta, Omicron) many breakthrough infections were reported worldwide, and the efficacies were dropped. A six-month follow-up study in the United States found that vaccine effectiveness of people who vaccination fully with Pfizer against Delta was 75%. In comparison, overall vaccine effectiveness (VE) for other variants was 91%. (126) A study in Guangzhou, China, during the Delta period, found that among those fully vaccination Sinovac and Sinopharm, 59% were protected against the Delta variant infection; this was lower than the prior VE (~79.3%). (127)

However, asymptomatic and less severe cases occurred in vaccination people more than those unvaccination. In the United States, from Jul–Dec 2021 (the period of Delta variant predominance) those fully vaccination by Pfizer aged 12-18 years old had fewer incidences of Multisystem Inflammatory Syndrome in Children (MIC) (5%) than the unvaccination; none needed respiratory or cardiovascular life support during their hospitalization. (128)

Booster doses were implemented because of immunity warnings against variants. A cohort study with the Pfizer booster in Israel found asymptomatic and symptomatic incidence rates among those booster-immunized were less than booster-nonimmunized. (129) A third vaccine dose of mRNA vaccine was highly effective preventing hospitalization during Delta and Omicron periods. (128)

2.5 Methods

2.5.1 Study design and sample

Secondary data analyses were conducted using two databases: Thai COVID-19 cases reported in 2021 to the Department of Disease Control (DDC), Thailand Ministry of Public Health (TMoPH) and Thai COVID-19 vaccination people reported to the TMoPH Immunization Center, Office of the Permanent Secretary beginning Feb 28, 2021 through Dec 31, 2021.

2.5.2 Inclusion and exclusion criteria

All reports registered in the COVID-19 case database by the DDC, TMoPH from Jan 1, 2021 through Dec 31, 2021 were included. For COVID-19 vaccination analyses all reported from Feb 28, 2021 through Dec 31, 2021 were included.

COVID-19 cases reported to State Quarantines (SQs) or Alternative State Quarantines (ASQs) that were imported and detected were excluded. Incomplete records (variables missing) were also excluded.

2.5.3 Data collection

Data were collected in Excel™ from Jan 1, 2021 through Dec 31, 2021 for COVID-19 cases and from Feb 28, 2021 through Dec 31, 2021 for those COVID-19 vaccination. For COVID-19 cases, each record included gender, age, nationality, patient type, and province of treatment. For the COVID-19 vaccination people, each record included aggregated data for each date in terms of gender, age, type of vaccine group, vaccination province, and dose.

Potential confounders at the ecologic level (e.g., COVID-19 zoning areas, curfew measure in provinces, proportion of foreign workers each month, and proportion of tourists each month) were included. COVID-19 zoning areas were coded by color: dark red as maximum, strictly controlled areas; light red as maximum controlled areas; and orange as controlled areas. This information was available from the website for COVID-19 (www.moicovid.com). The proportion of foreign workers were extracted from the statistics of foreign workers available at https://www.doe.go.th/prd/alien/statistic/param/site/152/cat/82/sub/0/pull/category/view/list-label. The proportion of tourists was published at https://www.mots.go.th/more_news_new.php?cid=630.

2.5.4 Data analyses

Analyses were divided into two parts: the distribution of COVID-19 cases and vaccination in Thailand between Jan 1, 2021 through Dec 31, 2021, grouped by gender,

age, and province were calculated and presented as percentage, mean, and standard deviation or median and interquartile range, depending on data distribution and R studio™ was used; second, the association between COVID-19 case rates and vaccination rates in Thailand between Apr 1, 2021 through Dec 31, 2021 and poisson regression was used. Spatio-temporal analysis was used to find the association between the COVID-19 case rates and vaccination in each province considering the time lags at week two, week four, week six, and week eight after vaccination. R studio™ version 1.4.1106 with spml, spdep, lme4, lmerTest, and geepack packages was used to conduct these analyses.

2.5.5 Ethical considerations

The study was approved by the Ethical Committee of Department of Disease Control, Ministry of Public Health, Thailand.

Chapter 3: Manuscript

COVID-19 Case and Vaccination Rates, Thailand, 2021

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Contribution of Student:

Ms. Jitpeera was responsible for writing the proposal, obtaining approval, conducting data analysis, and leading authorship of the manuscript.

Abstract

Coronavirus Disease 2019 (COVID-19) pandemic caused high morbidity and mortality worldwide. COVID-19 vaccination was expected to be a game-changer for the pandemic. Thailand was one country implementing COVID-19 vaccination. This study described the characteristics of COVID-19 cases and vaccination in Thailand during 2021. An association between vaccination and case rates was estimated with potential confounders, by ecologic level (i.e., color zone, curfew by provincial authorities, tourism, and migrant movement) and considering time at two, four, six, and eight weeks. We used the Spatial Panel Model for bivariate data to explore the relationship between case rates and each variable and included weekly variables in multivariate analyses. In 2021, Thailand had 1,965,023 cases and 45,788,315 first vaccination doses (63.6% of the Thai population). High case and vaccination rates were found among 31 – 45 year olds. Vaccination rates had a positive association with case rates due to the allocation of hot spot pandemic areas in the early period. The proportion of migrants and color zones had positive associations with case rates at the provincial level. The proportion of tourists had a negative association. Vaccination should be provided to migrants, and collaboration between tourism and public health should prepare for the new era of tourism.

Introduction

The SARS-CoV-2 virus causes coronavirus Disease 2019 or COVID-19 pandemic; the first outbreak occurred in China in late December 2019 and then spread worldwide. (1) The pandemic is causing high cases and deaths. As of Jan 1, 2022, there have been 288 million cases with 4.8 million deaths globally. (2) Currently, there is no specific treatment for COVID-19. Thus, all countries had been trying to stop the pandemic spread using public health measures (e.g., home quarantine, keeping social distance, travel restrictions, shutting down cities). However, these measures also have negative externalities by affecting each country's mental health and economics. (3-7) COVID-19 vaccines were emergency invented, approved, and implemented to control the pandemic since Dec 2020 aimed to be a game-changer for the pandemic. (8, 9) Each country's policymakers decided to purchase and prioritize the target population to be vaccination.

Thailand was the first country to detect the first COVID-19 case outside China where most in early 2020 were imported and found local transmission. (13, 25) In 2021, Thailand confronted three waves of COVID-19, that were titled due to COVID-19 variants: Second Wave from B.1.36.16 or Bangladesh/UK lineage (Dec 18, 2020, to Apr 2021), Third Wave from Alpha or B.1.1.7 variant (Apr 2 to Jul 5, 2021), and Forth Wave from Delta or B.1.617.2 variant (Jul 6 to Dec 31, 2021). (31, 37, 42, 49, 50, 58, 75)

As of Jan 1, 2022, Thailand had reported 2,226,446 cumulative cases and 21,708 deaths. (58) COVID-19 vaccination became the main implementation in many countries. Thailand has implemented COVID-19 vaccination with two primary vaccines:

Sinovac and AstraZeneca, beginning Feb 28, 2021 (18). Later, other vaccines (Sinopharm, Pfizer, and Moderna) were imported in mid 2021. (20)

There was no descriptive study on the COVID-19 situation and vaccination in Thailand in 2021. Also, the association between the vaccination rates and case rates at the provincial level has not been investigated. Thus, this study aimed to describe the characteristics of COVID-19 cases and vaccination people, Thailand, 2021. It determined if there was an association at the provincial level with a reduction in COVID-19 case rates, by vaccination and related variables.

Methods

We conducted a secondary data analysis using two databases that reported during Jan – Dec 2021: Thai COVID-19 cases reported to the Department of Disease Control (DDC), Ministry of Public Health (MoPH); and Thai COVID-19 vaccination people reported to the MoPH Immunization Center, Office of the Permanent Secretary, MoPH.

Data collection

Data were collected in Excel™ and aggregated reports in the DDC database from Jan 1, 2021, to Dec 31, 2021 for COVID-19 cases which defined COVID-19 case as any person who tested positive for SARS-CoV-2 by Reverse Transcription Polymerase Chain Reaction (RT-PCR) test, and reported to the database. This database did not include cases detected by Antigen Test Kit. For vaccination reports, we included reports from the MoPH Immunization Center during Feb 28, 2021, to Dec 31, 2021, because the vaccination was started on Feb 28, 2021. We excluded imported COVID-19 patients reported from State Quarantine (SQ) or Alternative State Quarantine (ASQ). Incomplete records with missing variables were excluded. To estimate an association between case rates and vaccination rates, we analyses at the provincial level and selected data since Apr 1, 2021 into analyses, because vaccines were allocated to all provinces after that time.

For COVID-19 cases, the aggregated report included date, gender, age, patient type, and the province of treatment. For the aggregated report of COVID-19 vaccination people included vaccination date, gender, age, type of vaccine group, vaccination province, and dose.

Potential confounders at the ecologic level (e.g., COVID-19 zones, curfew measures by provincial authorities, the proportion of foreign workers, and the proportion of tourists) were included. COVID-19 zones were coded by color: dark red as maximum, strictly controlled areas; light red as maximum controlled areas; orange as controlled areas; yellow as high-level areas; green or surveillance areas; and blue or tourism areas. This information was available from the website for COVID-19 by the Ministry of Interior (www.moicovid.com). The proportion of foreign workers reporting each month was extracted from the statistics of foreign workers available at https://www.doe.go.th/. The proportion of tourists in each province reporting each month was published at https://www.mots.go.th/.

Data analyses

Analyses were divided into two parts: characteristics and distribution of COVID-19 cases and vaccination people in Thailand between Jan 1, 2021, through Dec 31, 2021, grouped by gender; and age calculated and presented by percentage, median, and interquartile range. New daily COVID-19 cases and cumulative vaccination rates were mapped by month; we selected the period after Apr 1, 2021 (week 14) for Spatial Panel Model analyses because all provinces in Thailand received vaccines after that time. Number of population in each province to calculate case rates per 100,000 for each province was extracted from the Bureau of Registration Administration, Department of Provincial Administration Registration, Ministry of Interior (March 2021),

Spatial Panel Model analysis was used to determine an association between the COVID-19 case rates per 100,000 populations and vaccination rates in each province, considering the time lags at two, four, six, and eight weeks after vaccination.

Chi-Square Test with Poisson distribution were used to test spatial heterogeneity, and Global Moran's I with Poisson distribution was used to test spatial dependence with statistical significance cut-off level at p value of 0.05. We divided the estimation into three periods: overall (Week 14 – 52), ascending phase (Week 14 – 32), and descending phase (Week 34 – 52). The unit of analyses were provincial level. Bivariate analyses were conducted to explore an association between case rates and each variable. For multivariable analyses, we focused on the association of case rates and each variable at lagged two weeks in three periods. Statistical significance cutoff level at p value of 0.05 was applied. R studio™ version 1.4.1 with spml, spdep, lme4, and lmerTest packages were used to conduct these analyses.

Ethical considerations

The Ethical Committee approved the Department of Disease Control study, Ministry of Public Health, Thailand (Ref.No.64060).

Results

COVID-19 Cases and Case Rates, per 100,000 Population, Thailand, 2021

In 2021, there were 1,965,023 confirmed cases by RT-PCR; the highest daily cases were reported Aug 13, 2021 (21,770 cases). [Figure 1] The median of daily reported cases was 3,173.5 (IQR 8,606 – 759.8). Most (1,724,092; 87.74%) were in the Fourth Wave of Thailand (Jul 5 – Dec 31, 2021, or Week 28 – 53). Most were in age group 16 – 30 years (29.6%) and age group 31 – 45 years old (29.2%). Among these, 51.8% were female. [Table 2]

In early 2021, each province had < 101 cases per 100,000 population until Apr, when cases were clustered in the central part of Thailand, Bangkok, and metropolitan areas. After Apr 2021 cases were distributed from the central to surrounding areas and reached a peak in Aug. Then, case rates in most of Thailand were decreased, except the southern part that reported high case rates until Nov. [Figure 2] Of 77 provinces, Bangkok had the highest median new daily case rates per 100,000 population (772, IQR 95.75 – 1568.25). Meanwhile, Phrae had the lowest median new daily case rates (48; 2 – 12). Bangkok and 40% of provinces (2/5) in Metropolitan areas (Samut Sakhon and Samut Prakan) hit the top ten provinces and had high cumulative case rates in 2021 (5206,104, 11240.32, and 6919.2, respectively). Three Southern Border Provinces (Pattani, Narathiwat, and Yala) also hit the top ten (6393.88, 5154.74, and 5005.36, respectively). Other provinces that in the top ten provinces had high cumulative case rates were Chonburi, Samut Songkhram, Chachoengsao, and Rayong (5546.14, 5505.42, 4949.36, and 4812.86, respectively)

COVID-19 Vaccination Counts and Rates, Thailand, 2021

The first COVID-19 vaccine in Thailand was administered Feb 28, 2021. By the end of 2021, Thailand had 45,788,315 total cumulative first vaccination doses, accounting for 63.60%. 57.70% and 8.74% of people in Thailand received complete vaccination and booster doses, respectively. [Figure 1] At the peak of COVID-19 new daily cases (Aug 13, 2021), the coverage of first dose and second dose were 22.59% and 0.82%, respectively. In fact, 26.9% of people who received the first dose were 31 – 45 years old. Females (52.2%) received the first dose higher compared to males. [Table 2]

Vaccination people were localized in the central of Thailand by the end of Feb 2021. Vaccination was expanded to other regions, especially in Thailand's northern, eastern, western, and southern. [Figure 2] Of 77 provinces, Bangkok had the highest cumulative vaccine of one dose coverage rate (108.01), and Nong Bua Lam Phu had the lowest cumulative vaccine of one dose coverage rate (44.99). 28.57% (22/77) of all provinces had cumulative vaccine of one dose coverage rates less than 0.50. Bangkok also had the highest cumulative vaccine coverage rate (101.10) and Bueng Kan had the lowest cumulative vaccine coverage rate (36.3) for the second dose. 9.09% (7/77) of all provinces had cumulative vaccine of two doses coverage rates less than 40%: Bueng Kan (36.3), Nong Bua Lam Phu (36.36), Pattani (38.23), Narathiwat (38.56), Nakhon Phanom (38.6), Sakon Nakhon (39.34), and Mae Hong Son (39.83).

COVID-19 Case Rates and Vaccination Rates, Thailand, 2021

Spatial heterogeneity with Poisson distribution among COVID-19 cases (per 100,000 population) and vaccination rates was determined for 1,069,759 ($p<0.01$) and 39,273.54 ($p<0.01$), respectively. Global Moran's I with Poisson distribution were tested among

COVID-19 case rates per 100,000 population and vaccination rates were shown for spatial dependence as 0.33 ($p<0.01$) and 0.12 ($p=0.05$), respectively.

The results of bivariate analyses in the overall period found that vaccination rates (week 0, lagged 2 wks, lagged 4 wks), color zones (Yellow zone in lagged 4, 6, and 8 wks, orange zone in lagged 6 and 8 wks, light red zone in lagged 2, 4, 6 and 8 wks, and dark red zone in all times), curfew by provincial authority, and proportion of migrants had positive relationships with case rates ($p<0.05$). Meanwhile, a higher proportion of tourists had a negative relationship with case rates ($p<0.05$). Focusing on the ascending phase (Figure 1), we found that vaccination rates, color zones (Yellow zone in lagged 4 and 6 wks, orange zone in lagged 8 wks, light red zone in all times except week 0, and dark red zones in all times and light red zone in all times except week 0), curfew by provincial authorities, and proportion of migrants had a positive relationship with case rates ($p<0.01$). Meanwhile, proportion of tourists had a negative relationship with case rates ($p<0.01$). Conversely, the descending phase (Figure 1) found that vaccination rates, color zones (dark red zone in lagged 8 wks), curfew by provincial authorities (lagged 8 wks), and proportion of tourists had negative relationships to case rates ($p<0.05$). The color zone (dark red zone in all times except lagged 8 wks) and proportion of migrants had positive relationships with case rates ($p<0.01$). [Table 3]

We excluded curfew by provincial authorities in multivariate analyses because it was a part of color zones. Lagged two weeks of all variables were included. The overall period in the multivariate analysis found that dark red zone and proportion of migrants had positive relationships with case rates ($p<0.01$); meanwhile, the proportion of tourists had a negative relationship with case rates ($p<0.01$). For the ascending phase, vaccination

rate, dark red zone, and proportion of migrants had positive relationships with case rates ($p<0.01$). However, yellow zone and orange zone had negative relationships ($p<0.01$). For the descending phase, vaccination rate, and light red zone had negative relationships with case rates ($p<0.01$); however, proportion of migrants had a positive relationship of case rates ($p<0.01$).

Discussion

Since late 2019, the COVID-19 pandemic was emerged and is still ongoing. Because of mutation of the SARS-CoV-2 virus emerging variants contribute to the continuation of the pandemic, World Health Organization (WHO) announced and updated the list of Variants of Interest (VOIs) and Variants of Concern (VOCs) to monitor and assess the evolution of SARS-CoV-2. (130, 131) In 2021, COVID-19 cases in Thailand were affected by three variants of SARS-CoV-2: B.1.36.16 or Bangladesh/UK lineage, Alpha, and Delta variants, which caused 1,965,023 Most of the cases in 2021 (87.74%) were reported in Delta variant period which this variant is more transmissible than Alpha variant (40-60%) and almost twice as the original strain. (132) Thus, the number of cases in 2021 was much higher than in 2021 (6,884 cases) affected by the original Wuhan strain. (32) Monitoring COVID-19 variants are helpful to understand the infectivity of each variant and controlling outbreaks from the evidence. (133, 134) In Thailand, the Department of Medical Sciences, MoPH, and 15 Regional Medical Sciences center (RMSc) laboratories started SARS-CoV-2 Variants surveillance on Apr 1, 2021, which contributed to the understanding of the COVID-19 situation in Thailand and helped the MOPH to plan strategies to control the spread. (135) The genomic surveillance should be continued, comprehensive, and collaborative worldwide. (155)

Focusing on the provincial level, Bangkok and the Metropolitan areas (Samut Sakhon and Samut Prakan) had a high population density in terms of Thai and migrant workers. So, the virus can spread quickly through outbreaks that involve activities or places that many people attend (i.e., markets, prisons, hospitals, and factories). (43, 45-47) Otherwise, three southern border provinces (Pattani, Yala, and Narathiwat) had

crowded communities, religious activities, and illegal immigration issues contributing to infectious clusters. (136, 137)

By the end of 2021, 63.6% and 42.3% of people in Thailand received the first vaccination and complete vaccination, respectively. It achieved the goal of the WHO target aimed to reach 40% COVID-19 full vaccination population coverage target by the end of December 2021. (138) The peak of COVID-19 new daily cases was on Aug 13, 2021, during the Delta variant predominance, in which the coverage of first and second doses was 22.59% and 0.82%, respectively. Due to the small number of COVID-19 vaccines in the early period, the MoPH had to prioritize allocating vaccines to high-risk groups and in high spot areas. (59, 60) So, the vaccination rates in high cases were higher than in low cases in the early period. The strategic plan of MoPH has followed the WHO that prioritizes the old population. (139) In contrast, modeling studies in Japan and India recommended providing vaccination to a young population to control the infection. (140, 141) Most vaccination age groups were 31 — 45 years old (26.90%) and 16 – 30 (25.50%). However, it cannot explain the decline of new COVID-19 daily cases because they were the highest proportion in the age structure population (25 – 54 years old; 45.10%). (142) To understand the relationship between different age group vaccination and the dynamic of COVID-19 infection, it should be further explored. Focusing on the provincial level, provinces with a high population density (i.e., Bangkok, Chonburi, Samut Sakhon, Phuket, and Chiang Mai) had higher cumulative vaccination rates of one and two doses. As the WHO goal is to achieve 40% of two doses, we found that the overall country passed the goal. However, seven provinces did not accomplish this goal, and most of these provinces (71.43%, 5/7) had low density of population and

lower number of cases, Narathiwat and Pattani were two provinces that had high cumulative case rates but had low cumulative vaccination rates. Conflict in the Deep South leading mistrust in the government management and vaccine hesitancy contributed to low vaccination rates in these provinces. (143, 144) Religious leaders were vaccination to convince their fellows to follow. (145) These conflicts may need time and collaboration from all stakeholders in the areas (i.e., religious committee and public health). Vaccine hesitancy in these areas would be study further to understand the context and find the solution.

For the association between case rates and interested variables, we found that the vaccination rates in the ascending phase had a positive association. Conversely, there was a negative relationship in the descending phase. Thus, the overall period found that there was a slightly positive association. As discussed previously, vaccines were allocated to the hot spot areas in the early period, so it would not reflect the impact of vaccination. However, the effect of vaccination rates might not be fully explained in the descending phase. The decline of COVID-19 new daily cases may have occurred because of the dynamic of COVID-19 infection. New cases would be decreased after the peak incidence date due to herd immunity for the Alpha variant period. (146) Counterfactual scenarios should be studied further.

Color zones, especially the high restriction or dark red zone, had a positive association with case rates in each province in the overall period of multivariable analyses, which included only lagged two weeks for interested variables. The restriction measure was implemented following high incidence to prevent the spread, so the effect may not reflect immediately. Long lagged time seemed to associate case rates in the bivariable

analyses negatively. However, it was longer than a study that found a strong relationship in social distancing policy resulting in decreasing mobility and associated with reducing COVID-19 case growth two or three weeks later. (147) The performance of color zones measures should be evaluated.

Another variable that had a positive association with case rates in each province was the proportion of migrant workers. The cause of the second wave in Thailand was the B.1.36.16 or Bangladesh/UK lineage, which undocumented migrant workers were suspected to be the origin of the Samut Sakhon cluster. (34) Undocumented migrant workers were allowed to register for a work permit during the pandemic. (111) However, some undocumented migrant workers might not be registered. Thus, the Center for COVID-19 Situation Administration (CCSA) directed all provinces in Thailand to conduct proactive screening of migrant workers who entered illegally. (112, 113) Migrants, regardless of work permit document status, should be received vaccination like other people in Thailand, which would produce the most effective outcome in terms of health and economy. (148) Also, active case finding among migrants would be combined to reduce COVID-19 morbidity and mortality. (149)

The proportion of tourists had a negative relationship with case rates because tourists may perceive the risk of getting an infection and not take it from traveling. (150) COVID-19 has impacted the tourism industry, especially in Thailand, with high proportions of income from this industry. Multidiscipline, such as tourism and public health, should be collaborated, prepared, and planned to recover in a new manner during or after the pandemic. (151)

This study had several limitations. First, we cannot explore the vaccination history among cases at an individual level because these two databases did not link, and this variable was not complete in the COVID-19 database. The ecological fallacy was also an issue for the interpretation of the results. Second, cases in this database were only from PCR confirmed tests and might be lower than the actual situation. However, this study still evident the situation of COVID-19 in Thailand. Third, ecological-level confounders like color zones measure, curfew at provincial level measure, migrants, and tourists, were concerned and put into analyses. However, there might be other ecological-level confounders that we cannot control in the analyses. Last, the reverse causality between COVID-19 vaccination rates and case rates was issued in this study. Otherwise, we tried to solve this issue by dividing the analyses' phases into ascending and descending phases.

Conclusion

In 2021, Thailand had 1,965,023 cumulative COVID-19 cases, of which most (87.7%) were reported in the Fourth Wave. Thailand has implemented COVID-19 vaccination since Feb 28, 2021. At the end of 2021, 63.6% (45,788,315) of the Thai population received one dose vaccination, and 57.7% were fully vaccination. Those 31 – 45 years old had a high proportion of cases and the highest vaccination (29.2% and 26.9%, respectively). Vaccination was distributed to hot spot pandemic areas early, concurring with high case rates. Overall, vaccination rates had a slightly positive association with case rates. Focusing on specific periods, vaccination rates had a positive association in the ascending phase and a negative association in the descending phase. The proportion of migrant workers and the color zones measured had positive associations with case rates. Meanwhile, the proportion of tourists had a negative association with case rates. It may because of risk perception to get an infection from traveling. Vaccination and active case finding should be targeted on migrants. Thus, the tourism industry and public health should collaborate, prepare, and plan for the future of the tourism industry.

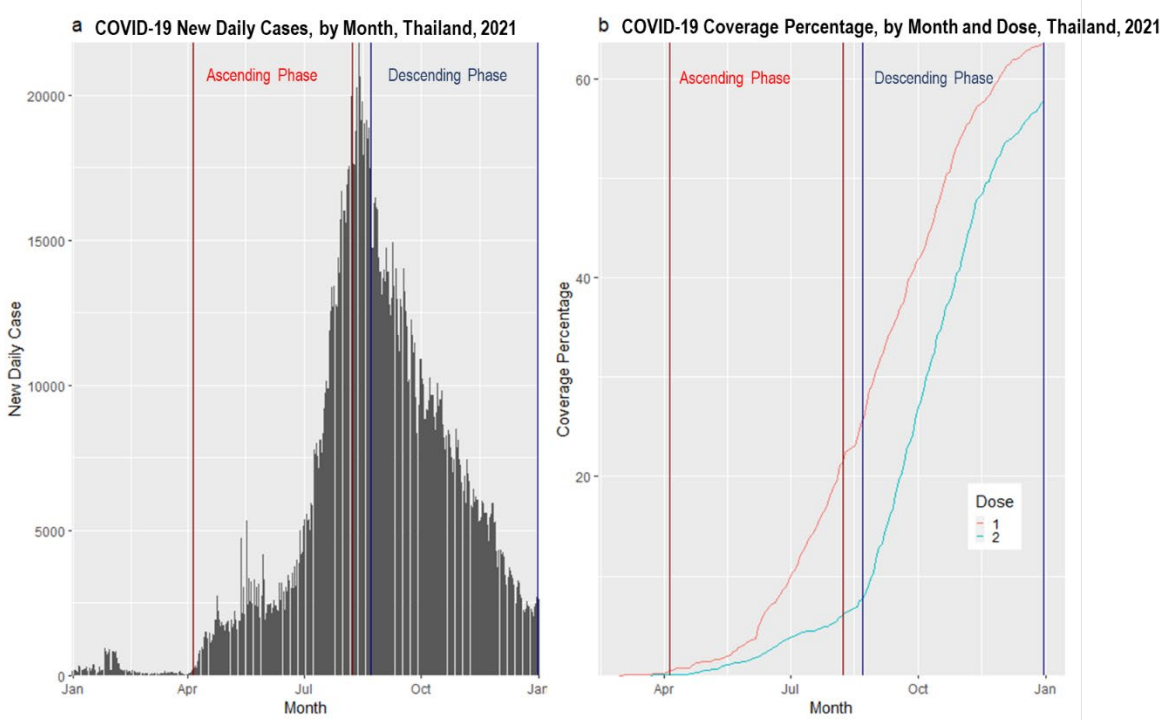

Fig 1. (a) COVID-19 New Daily Cases, by Month, Thailand, 2021; (b) COVID-19 Coverage Percentage, by Month and Dose Thailand, 2021

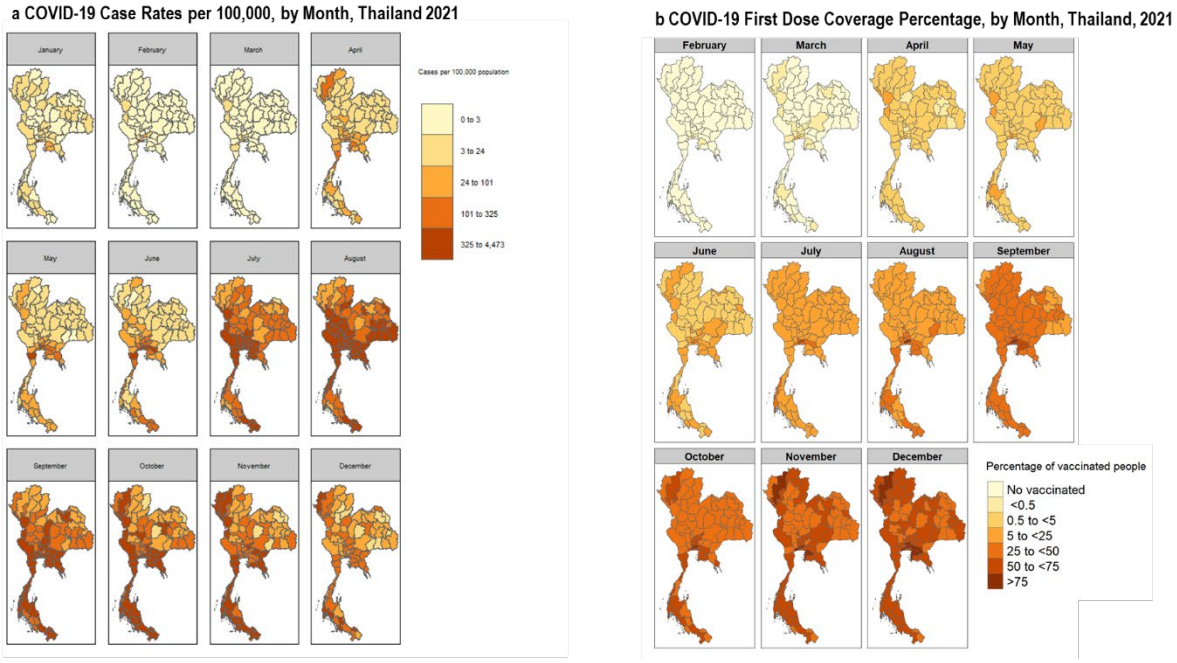

Fig 2. (a) COVID-19 Case Rates per 100,000, by Month, by Thailand, 2021; (b) COVID-19 First Dose Coverage Percentage, by Month, Thailand, 2021

Table 2. Characteristics of COVID-19 Cases and Those Vaccinated, Thailand, 2021

Characteristics	Cases (%)	Vaccinated (%)
Age; Median (IQR)	34 (47-23)	
- Less than 15	266,055 (13.5)	2,204,217 (4.8)
- 16 – 30	581,236 (29.6)	11,675,207 (25.5)
- 31 – 45	574,452 (29.2)	12,318,571 (26.9)
- 46 – 60	363,541 (18.5)	11,519,634 (15.2)
- 61 – 75	140,066 (7.1)	6,330,258 (13.8)
- 76 – 90	36,959 (1.9)	1,658,310 (3.6)
- More than 90	2,714 (0.1)	82,118 (0.2)
Gender		
- Male	946,355 (48.2)	21,888,301 (47.8)
- Female	1,018,668 (51.8)	23,900,014 (52.2)
Total	**1,965,023**	**45,788,315[a]**

[a]Vaccination at least one dose

Table 3. Bivariate Analyses of COVID-19 Case Rates and Related Variables, Thailand, 2021

Variables	Time	Overall		Ascending Phase (wk 14 – 32)		Descending Phase (wk 34 – 52)	
		Estimate [95%CI]	P-value	Estimate [95%CI]	P-value	Estimate [95%CI]	P-value
Vaccination Rates	Week 0	0.14 [0.07, 0.20]	<0.01	2.15 [1.89, 2.42]	<0.01	-0.52 [-0.67, -0.36]	<0.01
	Lagged 2 wks	0.11 [0.04, 0.17]	<0.01	2.42 [2.11, 2.74]	<0.01	-0.59 [-0.73, -0.45]	<0.01
	Lagged 4 wks	0.08 [0.01, 0.15]	0.02	2.68 [2.30, 3.06]	<0.01	-0.65 [-0.79, -0.51]	<0.01
	Lagged 6 wks	0.06 [-0.02, 0.13]	0.14	3.14 [2.64, 3.64]	<0.01	-0.73 [-0.88, -0.59]	<0.01
	Lagged 8 wks	0.03 [-0.05, 0.10]	0.50	3.96 [3.28, 4.63]	<0.01	-0.83 [-0.97, -0.68]	<0.01
COVID-19 zones	Week 0						
	- Green zone	-	-	-	-	-	-
	- Yellow zone	-0.63 [-13.42, 12.16]	0.92	-2.47 [-12.99, 8.06]	0.65	-	-
	- Orange zone	-2.37 [-14.40, 9.66]	0.70	-4.79 [-14.39, 4.81]	0.33	-7.35 [-17.28, 2.58]	0.25
	- Light red zone	10.51 [-1.46, 22.48]	0.09	10.01 [0.17, 19.83]	0.05	2.74 [-6.41, 11.89]	0.56
	- Dark red zone	71.74 [59.03, 84.45]	<0.01	93.16 [81.19, 105.12]	<0.01	49.95 [39.15, 60.74]	<0.01
	- Blue zone	24.92 [5.56, 44.29]	0.01	-	-	-6.54 [-25.75, 12.66]	0.50
	Lagged 2 wks						
	- Green zone	-	-	-	-	-	-
	- Yellow zone	0.90 [-7.44, 9.23]	0.83	-0.14 [-6.79, 6.51]	0.97	-	-
	- Orange zone	-2.68 [-9.75, 4.39]	0.46	-5.13 [-10.67, 0.40]	0.07	-3.60 [-15.82, 8.62]	0.56
	- Light red zone	7.20 [0.28, 14.11]	0.04	9.12 [2.98, 15.25]	<0.01	-2.74 [-14.13, 8.66]	0.64
	- Dark red zone	48.08 [40.08, 56.07]	<0.01	83.82 [72.70, 94.95]	<0.01	34.12 [21.34, 46.89]	<0.01
	- Blue zone	14.24 [-4.43, 32.92]	0.13	-	-	-8.12 [-29.84, 13.61]	0.46
	Lagged 4 wks						
	- Green zone	2.84 [-5.54, 11.22]	0.51	1.67 [-4.61, 7.95]	0.60	-	-
	- Yellow zone	8.50 [0.75, 16.25]	0.03	6.18 [0.27, 12.08]	0.04	-	-
	- Orange zone	2.79 [-3.75, 9.32]	0.40	-1.11 [-6.22, 4.01]	0.67	-11.46 [-33.27, 10.36]	0.30
	- Light red zone	8.82 [2.46, 15.18]	0.01	10.25 [3.98, 16.52]	<0.01	-12.82 [-24.57, 8.93]	0.25
	- Dark red zone	34.03 [26.88, 41.18]	<0.01	74.40 [62.41, 86.51]	<0.01	9.73 [-12.69, 32.15]	0.40
	- Blue zone	11.30 [-11.16, 33.75]	0.32	-	-	-23.34 [-54.22, 7.55]	0.14
	Lagged 6 wks						
	- Green zone	2.04 [-5.18, 9.27]	0.58	0.87 [-4.68, 6.41]	0.76	-	-
	- Yellow zone	10.52 [3.96, 17.09]	0.01	8.28 [2.43, 14.14]	<0.01	-	-
	- Orange zone	5.80 [0.72, 10.89]	0.03	1.39 [-2.81, 5.59]	0.52	-1.42 [-1.88, 15.15]	0.87
	- Light red zone	10.08 [5.20, 14.96]	<0.01	10.87 [5.09,16.64]	<0.01	-0.60 [-16.74, 15.54]	0.94
	- Dark red zone	22.66 [16.84, 28.49]	<0.01	65.53 [51.48, 79.58]	<0.01	3.12 [-14.34, 20.59]	0.73
	- Blue zone	3.42 [-26.36, 33.21]	0.82	-	-	-26.60 [-59.25, 6.05]	0.11
	Lagged 8 wks						
	- Green zone	2.39 [-4.52, 9.30]	0.50	1.43 [-4.23, 7.08]	0.62	-	-
	- Yellow zone	9.92 [3.66, 16.19]	0.01	1.63 [-11.02, 14.27]	0.80	-	-
	- Orange zone	10.30 [5.68, 14.93]	<0.01	4.21 [0.22, 8.20]	0.04	9.91 [-0.15, 19.97]	0.05
	- Light red zone	13.76 [9.34, 18.18]	<0.01	16.17 [10.35, 22.00]	<0.01	1.44 [-6.11, 9.01]	0.71
	- Dark red zone	12.54 [7.11, 17.98]	<0.01	58.22 [41.46, 74.97]	<0.01	-19.02 [-29.16, -8.88]	<0.01
	- Blue zone	-4.02 [-54.23, 46.19]	0.88	-	-	-31.66 [-79.55, 16.24]	0.20
Curfew	Week 0	56.43 [51.36, 61.49]	<0.01	66.48 [59.04, 73.92]	<0.01	49.43 [42.65, 56.22]	<0.01
	Lagged 2 wks	40.97 [36.04, 45.91]	<0.01	61.11 [51.73, 70.49]	<0.01	37.21 [30.25, 44.16]	<0.01
	Lagged 4 wks	27.63 [22.80, 32.47]	<0.01	56.44 [46.00, 66.89]	<0.01	22.48 [14.99, 29.97]	<0.01
	Lagged 6 wks	15.96 [11.20, 20.72]	<0.01	39.45 [27.64, 51.26]	<0.01	4.98 [-2.92, 12.89]	0.21
	Lagged 8 wks	5.57 [0.80, 10.34]	0.02	30.59 [17.6, 43.53]	<0.01	-20.68 [-29.27, -12.09]	<0.01
Migrants	Week 0	7.46 [5.74, 9.17]	<0.01	8.26 [6.40, 10.13]	<0.01	7.17 [4.93, 9.40]	<0.01
	Lagged 2 wks	7.80 [6.07, 9.53]	<0.01	8.46 [6.59, 10.33]	<0.01	7.09 [4.86, 9.32]	<0.01
	Lagged 4 wks	8.17 [6.43, 9.91]	<0.01	8.55 [6.67, 10.43]	<0.01	7.15 [4.92, 9.37]	<0.01
	Lagged 6 wks	8.38 [6.63, 10.13]	<0.01	8.63 [6.74, 10.51]	<0.01	7.03 [4.81, 9.25]	<0.01
	Lagged 8 wks	8.33 [6.60, 10.07]	<0.01	8.65 [6.76, 10.55]	<0.01	6.79 [4.58, 9.00]	<0.01
Tourists	Week 0	-0.10 [-0.20, -0.01]	0.03	-0.39 [-0.66, -0.13]	<0.01	-0.43 [-0.56, -0.29]	<0.01
	Lagged 2 wks	-0.23 [-0.34, -0.13]	<0.01	-0.30 [-0.49, -0.12]	<0.01	-0.49 [-0.63, -0.35]	<0.01
	Lagged 4 wks	-0.39 [-0.51, -0.27]	<0.01	-0.24 [-0.38, -0.09]	<0.01	-0.60 [-0.77, -0.43]	<0.01
	Lagged 6 wks	-0.54 [-0.67, -0.42]	<0.01	-0.26 [-0.39, -0.13]	<0.01	-0.79 [-1.00, -0.57]	<0.01
	Lagged 8 wks	-0.60 [-0.72, -0.47]	<0.01	-0.32 [-0.46, -0.19]	<0.01	-0.93 [-1.20, -0.65]	<0.01

Table 4. Multivariable Analyses of COVID-19 Case Rates and Related Variables with Lagged Two Weeks, Thailand, 2021

Variables	Overall		Ascending Phase (wk 14 – 32)		Descending Phase (wk 34 – 52)	
	Estimate [95%CI]	P-value	Estimate [95%CI]	P-value	Estimate [95%CI]	P-value
Vaccination Rates [Lagged 2 wks]	0.05 [-0.07, 0.17]	0.40	1.94 [1.54, 2.34]	<0.01	-0.80 [-1.09, -0.52]	<0.01
COVID-19 zones [Lagged 2 wks]						
- Green zone	-	-	-	-	-	-
- Yellow zone	-1.69 [-10.63, 7.24]	0.71	-10.71 [-18.55, -2.88]	<0.01	-	-
- Orange zone	-5.92 [-13.67, 1.84]	0.13	-9.74 [-16.27, -3.21]	<0.01	-11.32 [-25.37, 2.74]	0.11
- Light red zone	3.33 [-5.09, 11.76]	0.44	1.41 [-6.31, 9.13]	0.72	-18.62 [-33.41, -3.82]	0.01
- Dark red zone	42.63 [32.12, 53.15]	<0.01	64.18 [50.70, 77.66]	<0.01	17.56 [-0.56, 35.68]	0.06
- Blue zone	12.57 [-7.82, 32.97]	0.23	-	-	-10.70 [-34.08, 12.67]	0.37
Migrants [Lagged 2 wks]	6.44 [4.90, 7.99]	<0.01	3.12 [1.49, 4.76]	<0.01	8.38 [6.03, 10.72]	<0.01
Tourists [Lagged 2 wks]	-0.28 [-0.45, -0.10]	<0.01	0.06 [-0.19, 0.32]	0.62	0.14 [-0.18, 0.47]	0.39

*Curfew was not included because it was part of COVID-19 zones

Chapter 4: Conclusion and Recommendations

In 2021, COVID-19 cases in Thailand were affect by three variants of SARS-CoV-2: B.1.36.16 or Bangladesh/UK lineage, Alpha, and Delta variants, which caused 1,965,023 Most cases in 2021 (87.7%) were reported in Delta variant period which this variant is more transmissible than Alpha variant (40 – 60%) and almost twice as the original strain. (132) Thus, the number of cases in 2021 was much higher than in 2021 (6,884 cases) affected by the original Wuhan strain. (32) Monitoring COVID-19 variants is helpful to understand characteristics of each variant and control outbreaks from the evidence. (133, 134) Many countries are conducting genomic surveillance of SARS-CoV-2. (153-155) In Thailand, Department of Medical Sciences, MoPH, and 15 Regional Medical Sciences center (RMSc) laboratories started SARS-CoV-2 Variants surveillance in Thailand since Apr 1, 2021, which contributed the understanding of COVID-19 situation in Thailand and helped the MOPH to plan strategies to control the spread. (135) The genomic surveillance should be continued, comprehensive, and collaborative worldwide. (155)

Focusing on the provincial level, Bangkok and the Metropolitan areas (Samut Sakhon and Samut Prakan) had a high population density in terms of Thai and migrant workers. So, the virus can spread quickly through outbreaks that involve activities or places that many people attend (i.e., markets, prisons, hospitals, and factories). (43, 45-47) Otherwise, three southern border provinces (Pattani, Yala, and Narathiwat) had crowded communities, religious activities, and illegal immigration issues contributing to infectious clusters. (136, 137)

This study reported that Thailand started COVID-19 vaccination in Feb 28, 2021, which was behind United Kingdom the first country in the world and Singapore the first country in South East Asia around two months (Dec 8 and Dec 31, 2020, respectively). (156, 157) By the end of 2021, 63.6% and 42.3% of people in Thailand received first vaccination and complete vaccination, respectively. This achieved the goal the WHO target aimed to reach 40% COVID-19 full vaccination population coverage target by end Dec 2021. (138)

The peak of COVID-19 new daily cases was on Aug 13, 2021 during the Delta variant predominance, which the coverage of first dose and second dose were 22.6% and 0.8%, respectively. There were three main vaccines (Sinovac and AstraZeneca for public access, and Sinopharm for purchasing option) before Aug. (66) During Feb to Mar 2021, Thailand received small number of COVID-19 vaccines. The MoPH had to prioritize to allocate vaccines to five high-risk groups as priorities; healthcare workers, people who had underlying diseases, those > 60 years old, COVID-19-related staff, and people in pandemic hot spot areas. (59) Vaccines were distributed to hot spot areas (i.e., Samut Sakhon, Bangkok, Pathum Thani, Nonthaburi, Samut Prakan, Tak [Maesot], Nakornpathom, Samut Songkhram, and Ratchaburi) and tourism areas (i.e., Chonburi, Phuket, Suratthani (Koh Samui), and Chiangmai). (60) So, the vaccination rates in high case rates were higher than low case rates in the early period. Pfizer vaccines were donated by the United States in Aug 2021, which the MoPH allocated to target groups in high-risk areas and booster doses for health care works. (70) The strategy plan of MoPH was followed the WHO that prioritize old population. (139) In contrast, modelling studies in Japan and India recommended to provide vaccination in young population to

control the infection. (140, 141) Most vaccination age group were 31 – 45 years old (26.90%) and 16 – 30 (25.5%). However, it cannot explain the declining of new COVID-19 daily cases because these age group were the highest proportion in age structure population (25 – 54 years old; 45.1%). (142) To more understanding about the relationship between different age group vaccination and the dynamic of COVID-19 infection should be further explored.

Focusing on the provincial level, provinces with a high population density (i.e., Bangkok, Chonburi, Samut Sakhon, Phuket, and Chiang Mai) had higher cumulative vaccination rates of one and two doses. As the WHO goal is to achieve 40% of two doses, we found that the overall country passed the goal. However, seven provinces did not accomplish this goal, and most of these provinces (71.43%, 5/7) had low density of population and lower number of cases, Narathiwat and Pattani were two provinces that had high cumulative case rates but had low cumulative vaccination rates. Conflict in the Deep South leading mistrust in the government management and vaccine hesitancy contributed to low vaccination rates in these provinces. (143, 144) Religious leaders were vaccination to convince their fellows to follow. (145) These conflicts may need time and collaboration from all stakeholders in the areas (i.e., religious committee and public health). Vaccine hesitancy in these areas would be study further to understand the context and find the solution.

For the association between case rates and interested variables, we found that the vaccination rates in the ascending wave had a positive association. Conversely, there was a negative relationship in the descending wave. Thus, the overall period found that there was a slightly positive association. As discussed previously that vaccines were

allocated to the hot spot areas in early period, so it would not reflect the impact of vaccination. However, the impact of vaccination rates might not be fully explained in the descending period. The declining of COVID-19 new daily cases may be occurred because the dynamic of COVID-19 infection that new cases would be decreased after the peak of incidence date due to herd immunity for the Alpha variant period. (146) Counterfactual scenarios should be study further.

Color zones especially the high restriction or dark red zone had a positive association with case rates in each province in the overall period of multivariable analyses which included only lagged two weeks for interested variables. It because the restriction measure was implemented following high incidence to prevent the spread, so the effect may not reflect immediately. Long lagged time seemed to have a negative association with case rates as seen as in the bivariable analyses. However, it was longer than a study which found a strong relationship in social distancing policy resulting decreasing mobility and associated with decreasing COVID-19 case growth two or three weeks later. (147) The performance of color zones measure should be evaluated.

Another variable that had a positive association with case rates in each province was the proportion of migrant workers. The cause of the second wave in Thailand was the B.1.36.16 or Bangladesh/UK lineage which undocumented migrant workers were suspected to be the origin of the Samut Sakhon cluster. (34) Undocumented migrant workers were allowed to register for work permit during the pandemic. (111) However, some undocumented migrant workers might not be registered. Thus, the Center for COVID-19 Situation Administration (CCSA) directed all provinces in Thailand conducting proactive screening of migrant workers who entered illegally. (112, 113)

Migrants regardless document status should be received vaccination like other people in Thailand, which would produce the most effective outcome in terms of health and economy. (148) Also, active case finding among migrants would be combined together to reduce the COVID-19 morbidity and mortality. (149)

The proportion of tourists had a negative relationship with case rates, because tourists may perceive the risk to get infection and did not take it from travelling. (150) COVID-19 has impacted on the tourism industry, especially Thailand has high proportions of income from this industry. Multidiscipline, such as tourisms and public health, should be collaborated, prepared and planned for the recovery of new manner during or after the pandemic. (151)

This study had several limitations. First, we cannot explore the vaccination history among cases at an individual level because these two databases did not link, and this variable was not complete in the COVID-19 database. The ecological fallacy was also an issue for the interpretation of the results. Second, cases in this database were only from PCR confirmed tests and might be lower than the actual situation. However, this study still evident the situation of COVID-19 in Thailand. Third, ecological-level confounders like color zones measure, curfew at provincial level measure, migrants, and tourists, were concerned and put into analyses. However, there might be other ecological-level confounders that we cannot control in the analyses. Last, the reverse causality between COVID-19 vaccination rates and case rates was issued in this study. Otherwise, we tried to solve this issue by dividing the analyses' phases into ascending and descending phases.

Appendices

Table 5. Summary of New Daily COVID-19 Cases, by Province, Thailand, 2021

Province	Region	Bangkok and Metropolitan areas	Min	1st Quarter	Median	Mean	3rd Quarter	Max
Bangkok	Central	Yes	1	95.75	772	1107.26	1568.25	5124
Samut Prakan	Central	Yes	1	94.25	223	420.31	658	2228
Nonthaburi	Central	Yes	1	43	112	190.6	274	977
Pathum Thani	Central	Yes	1	26	62	125	159	1100
Phra Nakhon Si Ayutthaya	Central	No	1	27	55	111.9	126	585
Ang Thong	Central	No	1	5	15	44.97	53.5	361
Lop Buri	Central	No	1	9	47.5	71.47	105.75	450
Sing Buri	Central	No	1	3	10	14.71	20	96
Chai Nat	Central	No	1	3	8	13.22	19	75
Saraburi	Central	No	1	20	75	123.5	182	676
Chon Buri	East	No	1	89	202	379.8	631.5	1739
Rayong	East	No	1	16	71.5	157.2	289	701
Chanthaburi	East	No	1	10.75	36	79.07	127.5	449
Trat	East	No	1	8	25	37.53	59	170
Chachoengsao	East	No	1	35	82	135.6	178.8	626
Prachin Buri	East	No	1	13	75	98.57	148.75	399
Nakhon Nayok	Central	No	1	7	18	43.96	53.75	324
Sa kaeo	East	No	1	12	48	70.27	101	495
Nakhon Ratchasima	NorthEast	No	1	12	33	66.45	78	675
Buri Ram	NorthEast	No	1	4	10	41.04	25.5	431
Surin	NorthEast	No	1	5	26	60.09	77	356
Si Sa Ket	NorthEast	No	1	11.75	31	68.63	78.25	606
Ubon Ratchathani	NorthEast	No	1	9	62.5	88.36	112.5	614
Yasothon	NorthEast	No	1	3	8	25.72	29	315
Chaiyaphum	NorthEast	No	1	2	8	18.14	18	579
Amnat Charoen	NorthEast	No	1	2	5	11.51	13	84
Bueng Kan	NorthEast	No	1	2	4	8.034	11	95
Nong Bua Lam Phu	NorthEast	No	1	3	9	20.15	24	139
Khon Kaen	NorthEast	No	1	13	94	99.74	155.25	444
Udon Thani	NorthEast	No	1	6	20	45.32	46.5	536
Loei	NorthEast	No	1	5	13	19.43	26	138
Nong Khai	NorthEast	No	1	4	11.5	19.42	27.75	249
Maha Sarakham	NorthEast	No	1	5	18	43.66	46.75	361
Roi Et	NorthEast	No	1	7	19	56.11	51.5	478
Kalasin	NorthEast	No	1	6	22	34.13	46.5	214
Sakon Nakhon	NorthEast	No	1	4	9	26.19	28	244
Nakhon Phanom	NorthEast	No	1	3	6	20.56	20.25	150
Mukdahan	NorthEast	No	1	2	7	12.76	16	94

Province	Region	Bangkok and Metropolitan areas	Min	1st Quarter	Median	Mean	3rd Quarter	Max
Chiang Mai	North	No	1	19.5	58.5	103.6	133.5	508
Lamphun	North	No	1	7	15	20.44	27.5	100
Lampang	North	No	1	5	10	15.08	22	71
Uttaradit	North	No	1	4	11	20.54	29	110
Phrae	North	No	1	2	5.5	9.213	12	48
Nan	North	No	1	2	7	13.88	17	92
Phayao	North	No	1	3	8	13.26	18	79
Chiang Rai	North	No	1	11.5	20	21.34	29	71
Mae Hong Son	North	No	1	4	11	17.07	26	101
Nakhon Sawan	Central	No	1	13	56	61.29	95	287
Uthai Thani	Central	No	1	3	8	16.77	22	96
Kamphaeng Phet	Central	No	1	5	16.5	32.31	36	213
Tak	West	No	1	5	52.5	82.35	144	317
Sukhothai	Central	No	1	3	14	20.84	27	130
Phitsanulok	Central	No	1	11	32	33.34	47.75	161
Phichit	Central	No	1	5	15	23.65	30	218
Phetchabun	Central	No	1	5.5	25	42.68	54.5	640
Ratchaburi	West	No	1	15	80	138.1	225.2	729
Kanchanaburi	West	No	1	10.25	52	87.68	140.75	577
Suphan Buri	Central	No	1	8.25	31	55.43	74.75	373
Nakhon Pathom	Central	Yes	1	18	47	114.6	149	977
Samut Sakhon	Central	Yes	4	39	77	296	338.8	1861
Samut Songkhram	Central	No	1	5	15.5	32.97	48	364
Phetchaburi	West	No	1	21.75	66.5	76.58	108	962
Prachuap Khiri Khan	West	No	1	33	60	73.74	94.75	444
Nakhon Si Thammarat	South	No	1	14	47	94.82	146	524
Krabi	South	No	1	5	20	39.98	76	190
Phangnga	South	No	1	5	27	33.7	58.5	98
Phuket	South	No	1	9	48	65.92	105	257
Surat Thani	South	No	1	26	72	103.5	178	290
Ranong	South	No	1	8	19	38.73	54.4	304
Chumphon	South	No	1	6	60	67.23	111	224
Songkhla	South	No	1	52	216	240	390	691
Satun	South	No	1	13	29	41.66	70	138
Trang	South	No	1	13.25	47.5	66.3	87.75	410
Phatthalung	South	No	1	13	43	54.8	80	248
Pattani	South	No	1	35	169	184.9	269	655
Yala	South	No	1	23.25	69	106.31	143.75	574
Narathiwat	South	No	1	20	90	153.2	260	615

Table 6. Cumulative Case Rates Per 100,000 Populations, by Province, Thailand, 2021

Province	Region	Bangkok and Metropolitan areas	Rate
Samut Sakhon	Central	Yes	11240.3
Samut Prakan	Central	Yes	6919.2
Pattani	South	No	6393.9
Chon Buri	East	No	5546.1
Samut Songkhram	Central	No	5505.4
Bangkok	Central	Yes	5206.1
Narathiwat	South	No	5154.7
Yala	South	No	5005.4
Chachoengsao	East	No	4949.4
Rayong	East	No	4812.9
Saraburi	Central	No	4683.6
Prachin Buri	East	No	4557.6
Phetchaburi	West	No	4386.2
Songkhla	South	No	4373.1
Ratchaburi	West	No	4330.6
Ranong	South	No	4321.5
Nakhon Nayok	Central	No	4303.4
Tak	West	No	4104.3
Ang Thong	Central	No	3986.5
Nonthaburi	Central	Yes	3778.2
Chanthaburi	East	No	3768.9
Phra Nakhon Si Ayutthaya	Central	No	3658.1
Trat	East	No	3625.9
Prachuap Khiri Khan	West	No	3494.9
Phuket	South	No	3165.9
Nakhon Pathom	Central	Yes	3156.9
Sa kaeo	East	No	3068.3
Chumphon	South	No	2980.1
Kanchanaburi	West	No	2748.8
Pathum Thani	Central	Yes	2745.8
Trang	South	No	2673.6
Phangnga	South	No	2671.3
Satun	South	No	2642.5
Phatthalung	South	No	2572.9
Lop Buri	Central	No	2500.1
Surat Thani	South	No	2470.4
Krabi	South	No	2003.8
Suphan Buri	Central	No	1759.1
Sing Buri	Central	No	1651.9
Chiang Mai	North	No	1617.4
Nakhon Si Thammarat	South	No	1595.2
Nakhon Sawan	Central	No	1532.6

Province	Region	Bangkok and Metropolitan areas	Rate
Khon Kaen	NorthEast	No	1455.1
Mae Hong Son	North	No	1313.1
Ubon Ratchathani	NorthEast	No	1231.1
Si Sa Ket	NorthEast	No	1222.1
Maha Sarakham	NorthEast	No	1176.6
Kamphaeng Phet	Central	No	1139.6
Yasothon	NorthEast	No	1109.4
Roi Et	NorthEast	No	1090.2
Lamphun	North	No	1053.1
Uthai Thani	Central	No	1048.6
Surin	NorthEast	No	1039.9
Phetchabun	Central	No	1027.5
Phichit	Central	No	1005.9
Uttaradit	North	No	956.4
Chai Nat	Central	No	867.9
Nong Bua Lam Phu	NorthEast	No	846.1
Nong Khai	NorthEast	No	830.6
Kalasin	NorthEast	No	819.9
Phitsanulok	Central	No	768.4
Sukhothai	Central	No	761.3
Mukdahan	NorthEast	No	730.2
Loei	NorthEast	No	707.1
Udon Thani	NorthEast	No	657.1
Nakhon Ratchasima	NorthEast	No	644.1
Nakhon Phanom	NorthEast	No	612.7
Buri Ram	NorthEast	No	589.5
Phayao	North	No	585.9
Nan	North	No	548.9
Amnat Charoen	NorthEast	No	542.1
Sakon Nakhon	NorthEast	No	525.7
Chiang Rai	North	No	471.4
Lampang	North	No	455.5
Phrae	North	No	421.7
Bueng Kan	NorthEast	No	336.1
Chaiyaphum	NorthEast	No	297.3

Table 7. Cumulative of One Dose Vaccine Coverage Rate, by Province, Thailand, 2021

Province	Region	Bangkok and Metropolitan areas	Cumulative Coverage Rate
Bangkok	Central	Yes	108.1
Samut Sakhon	Central	Yes	84.9
Chon Buri	East	No	83.0
Chiang Mai	North	No	80.9
Phuket	South	No	80.7
Chachoengsao	East	No	76.4
Pathum Thani	Central	Yes	75.1
Samut Prakan	Central	Yes	74.1
Ranong	South	No	73.8
Rayong	East	No	69.1
Songkhla	South	No	68.2
Surat Thani	South	No	67.1
Lamphun	North	No	66.7
Phangnga	South	No	66.7
Chiang Rai	North	No	65.6
Krabi	South	No	65.4
Chanthaburi	East	No	64.2
Prachuap Khiri Khan	West	No	63.7
Phetchaburi	West	No	63.2
Tak	West	No	62.3
Nonthaburi	Central	Yes	61.7
Trang	South	No	60.7
Phra Nakhon Si Ayutthaya	Central	No	60.5
Trat	East	No	60.1
Chumphon	South	No	60.0
Nakhon Si Thammarat	South	No	58.6
Saraburi	Central	No	58.5
Phayao	North	No	58.3
Prachin Buri	East	No	57.2
Nakhon Ratchasima	NorthEast	No	57.0
Uttaradit	North	No	56.8
Mae Hong Son	North	No	56.4
Lampang	North	No	56.2
Yala	South	No	55.7
Khon Kaen	NorthEast	No	55.6
Nan	North	No	55.5
Loei	NorthEast	No	55.4
Mukdahan	NorthEast	No	54.9
Buri Ram	NorthEast	No	54.2
Udon Thani	NorthEast	No	53.2
Ubon Ratchathani	NorthEast	No	53

Province	Region	Bangkok and Metropolitan areas	Cumulative Coverage Rate
Phrae	North	No	53
Kanchanaburi	West	No	52.9
Sing Buri	Central	No	52.7
Satun	South	No	52.6
Amnat Charoen	NorthEast	No	52.2
Phatthalung	South	No	52.1
Nakhon Sawan	Central	No	52.1
Phetchabun	Central	No	51.6
Chai Nat	Central	No	51.6
Nong Khai	NorthEast	No	50.9
Ratchaburi	West	No	50.5
Nakhon Pathom	Central	Yes	50.4
Nakhon Nayok	Central	No	50.2
Yasothon	NorthEast	No	50.1
Suphan Buri	Central	No	49.8
Sukhothai	Central	No	49.8
Samut Songkhram	Central	No	49.6
Chaiyaphum	NorthEast	No	49.5
Maha Sarakham	NorthEast	No	49.5
Uthai Thani	Central	No	49.2
Sa kaeo	East	No	49.1
Kamphaeng Phet	Central	No	49.1
Phichit	Central	No	48.5
Si Sa Ket	NorthEast	No	48.4
Nakhon Phanom	NorthEast	No	48.2
Lop Buri	Central	No	48.2
Narathiwat	South	No	48.1
Sakon Nakhon	NorthEast	No	48
Kalasin	NorthEast	No	47.6
Ang Thong	Central	No	47.6
Roi Et	NorthEast	No	47.4
Phitsanulok	Central	No	47.1
Bueng Kan	NorthEast	No	47.1
Pattani	South	No	46.5
Surin	NorthEast	No	46.1
Nong Bua Lam Phu	NorthEast	No	45

Table 8. Cumulative of Two Doses Vaccine Coverage Rate, by Province, Thailand, 2021

Province	Region	Bangkok and Metropolitan areas	Cumulative Coverage Rate
Bangkok	Central	Yes	101.1
Chon Buri	East	No	80.1
Samut Sakhon	Central	Yes	77.2
Phuket	South	No	76.4
Chiang Mai	North	No	73.7
Pathum Thani	Central	Yes	71.7
Ranong	South	No	70.8
Chachoengsao	East	No	65.9
Rayong	East	No	65.2
Phangnga	South	No	63.3
Songkhla	South	No	62.3
Samut Prakan	Central	Yes	62.3
Surat Thani	South	No	59.9
Nonthaburi	Central	Yes	59.8
Trang	South	No	58.9
Prachuap Khiri Khan	West	No	58.7
Phra Nakhon Si Ayutthaya	Central	No	58.4
Chanthaburi	East	No	58.2
Lamphun	North	No	58.1
Krabi	South	No	57.9
Phetchaburi	West	No	56.6
Saraburi	Central	No	56.2
Trat	East	No	55.4
Chiang Rai	North	No	54.1
Phayao	North	No	54
Nakhon Ratchasima	NorthEast	No	52.9
Prachin Buri	East	No	52.3
Chumphon	South	No	52.2
Lampang	North	No	51.8
Nan	North	No	51.3
Kanchanaburi	West	No	50.4
Nakhon Pathom	Central	Yes	50.3
Uttaradit	North	No	50.1
Buri Ram	NorthEast	No	49.3
Sing Buri	Central	No	49.2
Ratchaburi	West	No	49.2
Nakhon Sawan	Central	No	49.1
Phatthalung	South	No	49.1
Tak	West	No	48.8
Udon Thani	NorthEast	No	48.4

Province	Region	Bangkok and Metropolitan areas	Cumulative Coverage Rate
Satun	South	No	48.2
Nakhon Si Thammarat	South	No	48.2
Khon Kaen	NorthEast	No	47.9
Loei	NorthEast	No	47.8
Yala	South	No	47.6
Chai Nat	Central	No	47.5
Amnat Charoen	NorthEast	No	47.1
Suphan Buri	Central	No	47.1
Ang Thong	Central	No	47.1
Phrae	North	No	47.0
Uthai Thani	Central	No	46.9
Mukdahan	NorthEast	No	46.9
Phichit	Central	No	46.5
Nakhon Nayok	Central	No	46.1
Kamphaeng Phet	Central	No	45.9
Sukhothai	Central	No	45.3
Phetchabun	Central	No	45.3
Lop Buri	Central	No	45.1
Ubon Ratchathani	NorthEast	No	45.0
Nong Khai	NorthEast	No	44.5
Phitsanulok	Central	No	43.7
Samut Songkhram	Central	No	43.2
Yasothon	NorthEast	No	42.9
Roi Et	NorthEast	No	42.6
Maha Sarakham	NorthEast	No	42.3
Sa kaeo	East	No	42.1
Chaiyaphum	NorthEast	No	42.1
Surin	NorthEast	No	41.1
Si Sa Ket	NorthEast	No	41.0
Kalasin	NorthEast	No	40.0
Mae Hong Son	North	No	39.8
Sakon Nakhon	NorthEast	No	39.3
Nakhon Phanom	NorthEast	No	38.6
Narathiwat	South	No	38.6
Pattani	South	No	38.2
Nong Bua Lam Phu	NorthEast	No	36.4
Bueng Kan	NorthEast	No	36.3

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