Research Article

COVID-19 proactive screening protocol during early outbreak using web-based application: Implementation in Thai Rural Area

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Abstract

Coronavirus disease 2019 (COVID-19) caused by an infection with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has been recognized as one of the biggest problems to human health worldwide. The potential strategy to control the spreading of the virus is awareness of infection status, especially among non-patient under investigation (non-PUI). Additionally, implementing gathering control and suspending “social distancing” are key to a decrease in the chance of infection. This study aimed to conduct and implement the pilot management system for COVID-19 testing and to perform proactive screening test among non-PUI people in Phayao Province, the rural area of Thailand. This was a cross-sectional study. People who could access websites- or mobile applications were eligible to be recruited into the study. An online questionnaire was developed to collect information on socio-demographics, medical conditions and symptoms related to COVID-19 from participants who were living in Phayao Province from July to August 2020. 200 participants performed self-evaluation but only 143 (71.5%) participants booked an appointment and visited the collecting site to get the test. There were 25 (9%) participants being at high risk of infection. The nasopharyngeal/throat swabs were collected and proceeded to determine a presence of SARS-CoV-2 using RT-PCR. Of all, none was found to be positive for SARS-CoV-2. In conclusion, this developed management system would be an important tool for managing laboratory testing during the COVID-19 outbreak by means of reducing the chance of infection in the epidemic situation. This proactive screening system can also be applied for other medical testing and services.

Keywords: COVID-19, Information system, Information technology, Testing management, Thailand

Introduction

The coronavirus disease 2019 (COVID-19) pandemic caused by the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) posed a new global challenge in 2020 [1]. Most nations, including Thailand, have made efforts to control the spread of the virus by reducing the chance of contacts between infected people and those who have not yet been exposed [2]. Identification of a new COVID-19 case is key to viral spread control. In Thailand, laboratory investigation was performed among all patients under investigation (PUIs) to confirm the diagnosis which could provide opportunities to detect confirmed cases and performed contact tracing [3, 4]. However, it appeared that most infected people experienced mild symptoms, and at least 30% were asymptomatic [5–7]. Many people infected with SARS-CoV-2 do not have symptoms but can spread the virus to others who may be susceptible to severe COVID-19 illness [8–10]. The proactive screening for an asymptomatic would be a powerful tool to help the government sectors to monitor and respond to the COVID-19 outbreak and contributes significantly to slowing the spread of COVID-19 in the community.

Simultaneously, technological, social, and medical approaches needed to be undertaken to flatten the curve of positive cases. One of the key success methods to achieve such reductions in contacts is referred to generically as "physical distancing" measures— also known as "social distancing" or "spatial distancing"[11–13]. There are also efforts for information technology (IT) development aimed to trace the travelling or to survey the health issues concerning COVID-19 [14, 15]. At this point, communication technology, as well as medical services management, has become a crucial tool to help to control the gathering of people and reduce the congestion of people in clinics or hospitals. Therefore, application technology is vital for managing and controlling the gathering of people needed to access COVID-19 testing as well as medical services. There were several mobile applications generated and used worldwide such as HealthLynked COVID-19 Tracker used in US. However, only one application "MorChana" was generated in Thailand since April 2020. It will track infection, probability and risk of COVID-19 and observe the outbreak situation from data provided by user [16]. Therefore, there was no linkage between probability and risk of COVID-19 and laboratory result that was notified to the user in this application.

Therefore, we conducted the research based on two objectives; 1) to develop and assess the feasibility of the usage of online application technology for the medical testing management system and 2) to assess the prevalence of SARS CoV-2 RNA positivity among non-PUI people in Phayao Province, a rural area of Thailand, through proactive COVID-19 testing approach.

Methods

Materials

All samples were collected in a sterile tube containing universal transport medium (UTM-RT transport medium, Copan Diagnostics, Murrieta, CA, USA) and were detected by real-time PCR (Da An Gene Co., Ltd. of Sun Yat-sen University, China).

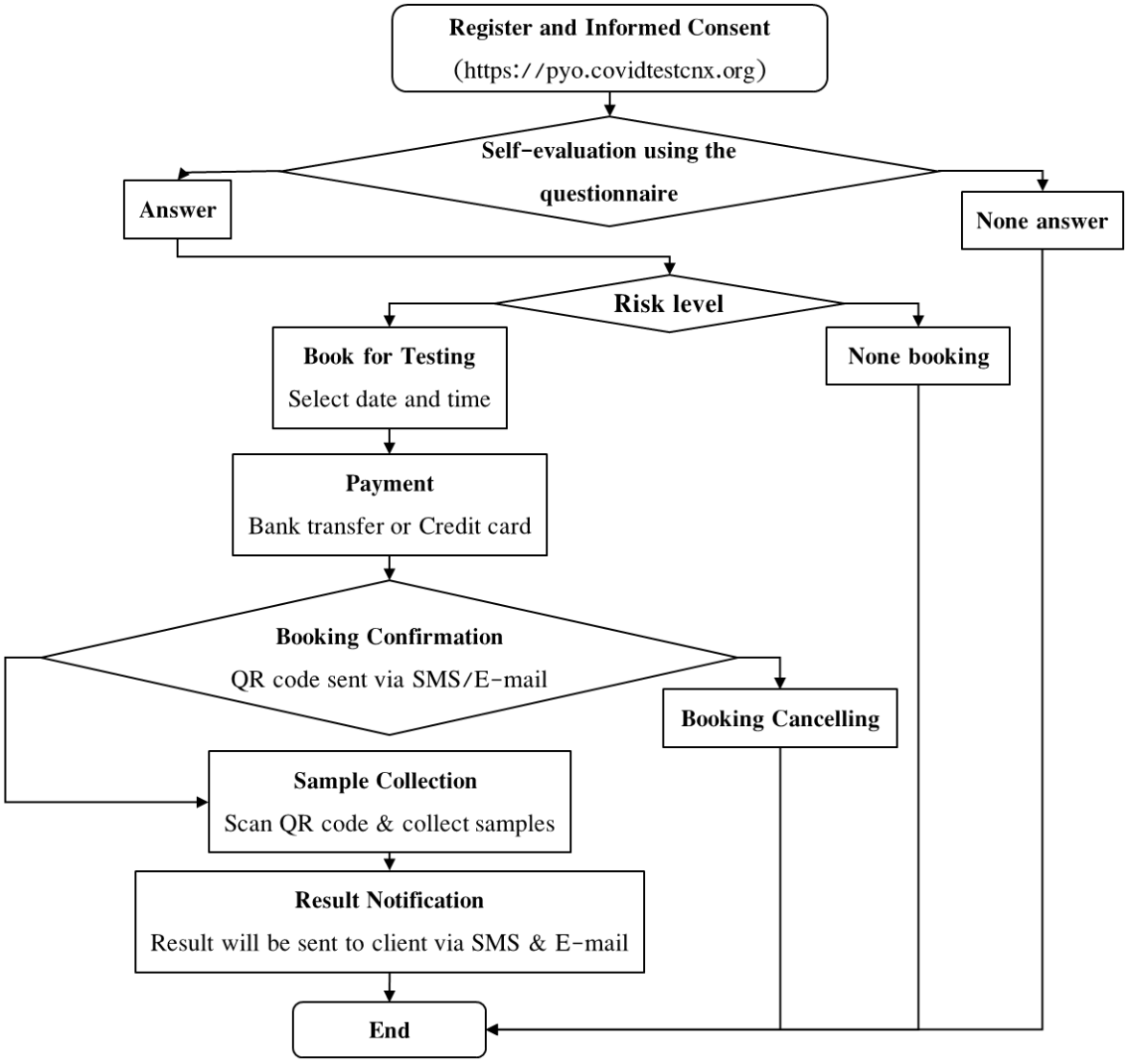
Development of a system for COVID-19 testing management

The web-based testing management system named "www.pyo.covidtestcnx.org" was developed to avoid gathering people in clinics or hospitals. The main features of this system included registration, informed consent, self-screening

questionnaires for COVID-19, appointment making, payment, specimen management and result notification and report. Participants could access to this system by scanning QR code on the project promotion (PR) board. Demographic data including sex, age, address, occupation, underlying diseases, and medical conditions and symptoms associated with possible COVID-19 infection were obtained by reviewing questionnaire in the developed system.

Study Design and data collection

A cross-sectional study was conducted in Phayao Province. The proactive screening procedure used in this study was tested within a pilot study between July- August 2020. The selection criteria of participants based on participants willing to be tested for COVID-19 and able to answer questionnaires in the self- risk screening by the dedicated application through www.pyo.covidtestcnx.org, which was available on either mobile devices or web-based system. The algorithm and flowchart of the system was shown in Figure 1. The socio-demographic characteristic, medical history and symptoms associated with COVID- 19 were presented as frequencies and proportions. Data collection and analysis were approved by the University of Phayao Ethics Committee (approval number 1.1/004/64).



The algorithm and flowchart of developed web-based management system.

Specimen Collection

Combined oropharyngeal and nasopharyngeal swab specimens in a single sterile tube containing UTM-RT transport medium were obtained under transmission-based precautions from all participants. All biological samples were sealed and transferred to the laboratory in strict accordance with the standard protocol.

RT-PCR for SARS-CoV-2 detection

RNA was extracted and purified from sample and subsequently detected by real-time PCR using commercial extraction kit (Da An Gene Co., Ltd. of Sun Yat-sen University, China) following the instruction [20]. Conditions for amplification were 50 °C for 15 min, 95 °C for 3 min, followed by 45 cycles of 95 °C for 15 s and 60 °C for 30 s. The concentration of 1,000 copies/μl of SARS-CoV-2 whole viral-genome RNA was the limit of detection of this assay. A sample with a cycle threshold value (Ct-value) less than 40 was defined as a "SARS-CoV-2 RNA detectable result", and a Ct-value of 40 or more was defined as a "SARS-CoV-2 RNA undetectable result". A doubtful sample, defined as a Ct-value of 36-40, required confirmation by retesting. SARS-CoV-2 RNA detectable result was determined by the presence of the two SARS-CoV-2 targets, nucleocapsid (N) and RNA-dependent RNA polymerase (RdRp genes), and the internal control target (human RNase P gene). Specimens were processed and results were reported within 6–8 hours. To ensure the integrity and verification of detection system, internal control was analyzed in parallel for each sample, as well as testing one replicate of the positive control and one replicate of the negative control in each batch. Acceptable control results for the SARS-CoV-2 and internal control were required for the run to be acceptable.

Statistical Analysis

Due to the fact that the participants in our study was not derived from random selection, all statistics are deemed to be descriptive, and the collected data was non-normal distribution, thus non-parametric statistical analysis was used. Continuous variable values were expressed as medians and interquartile ranges or simple ranges, as appropriate. Categorical variable values were summarized as counts and percentages. No imputation was made for missing data. All analyzes were performed using STATA version 16.0.

Results

COVID-19 test management system

The main purpose of this testing management system was to execute the social distancing in the COVID-19 pandemic in order to reduce the gathering of people in clinics or hospitals. The process of registration, informed consent, and self-screening evaluation was completed *via* application anonymously. In addition to reducing the number of people visiting public health service centers, which might lead to a wider spread of the virus, the application reduced the workload of medical personnel in answering questions. Self-screening was evaluated by using questionnaires depicting the signs and symptoms revealed the COVID-19 (e.g. fever, dry cough, tiredness, sore throat, difficulty breathing or shortness of breath) besides the risk exposures related to COVID-19 (e.g. visited countries in the last 14 days, the occupation, the chance of contact with infected people, travelled from the endemic area or foreigner visitors). Then the application automatically arranged the data resulting in an indication of their overall condition. The result from the questionnaire was presented as one of three risk levels of evaluation and advice: (i) Recommend

immediately contacting a physician (reported fever, unusual cough or unusual sneezing), (ii) Need a test as soon as possible (did not report fever, unusual cough or unusual sneezing but reported at least one of the following: runny nose, sore throat, out of breath, lack of smell or taste, or age >60 years) and (iii) Do not recommend immediate testing and re-evaluation of the situation every 24 hours (Did not report any of the COVID-19 related symptoms). The final decision for COVID-19 testing will be made by the participant independent of the risk evaluation. If the participant makes a booking, the date and time will be selected and booking confirmation will be sent to the participant *via* registered SMS and E-mail after the payment has been processed. The test result would be reported directly to the participant via SMS and E-mail within 24 hours after sample collection at the service site. However, in this study, the payment was omitted due to the objectives of the system prototype and proactive screening.

Participant characteristics

There were 207 registered participants through the application pyo.covidtestcnx.org. The number of completed questionnaires was 200. The socio-demographic characteristics of the participants were shown in Table 2. Most of the participants were female (63%) with a median age of 22. Most of the participants had their education level above high school (74%).

Table 2 Socio-demographic characteristics of participants

Socio-demographic characteristics of online-registered participants	**N = 200** **n (%) or median (IQR)**
Sex	
Female	125 (63%)
Male	75 (37%)
Age (years)	22 (21 – 40)
Country of birth	
Thailand	198 (99%)
Laos	1 (<1%)
Cambodia	1 (<1%)
Height (cm)	163 (157 – 169)
Weight (kg)	59 (50 – 70)
Body Mass Index (kg/m^2)	22 (20 – 25)
Number of people living in the household	
1 (living alone)	34 (17%)
2	25 (13%)
3	41 (20%)
4	48 (24%)
5	26 (13%)
More than 5	26 (13%)

Socio-demographic characteristics of online-registered participants	N = 200 n (%) or median (IQR)
Educational Level	
Never attended school	4 (2%)
Primary school	7 (3%)
Secondary school	2 (1%)
High school	40 (20%)
Above high school	147 (74%)
Occupation	
Students	111 (55%)
Farmers	3 (2%)
Trading	6 (3%)
University Lecturer / Staff	44 (22%)
Civil servants	12 (6%)
Other	24 (12%)
Currently working	**91/200 (46%)**
In a place with other colleagues	85 (93%)
In the presence of customers	52 (57%)
Work remotely	10 (11%)
Work outdoors	18 (20%)
Self-employed	25 (28%)

Although, the highest number of participants is student (55%) and university staff (22%). However, the distribution of participants based on province showed that the major participants were the people from Phayao province (88%) as shown in Table 3. The other participants (less than 1%) were the people who travelled from somewhere such as Bangkok, Petchabun, Tak, Nan, Chiangmai, Chiangrai, Kamphaeng phet, Nakonnayok, Prajinburi, Pichit, Phitsanulok, Yasothon, Ratchaburi, Lampang, Lamphun, and Songkhla. This result indicated that the developed web-based system could be distributed and served as the service to the local people.

Table 3 Distribution of participants enrolled in the web-based application and made an appointment for sample collection for laboratory detection based on province

Residences of Participants (Province)	**Number of subject enrolled in the online system, N = 200, n(%)**	**Number of subject collected sample for SAR-Cov2 detection, N = 143, n(%)**
Phayao	175 (87.5%)	130 (90.9%)
Bangkok	7 (3.5%)	3 (2.0%)
Petchabun	2 (1.0%)	1 (0.7%)
Tak	2 (1.0%)	2 (1.3%)
Nan	2 (1.0%)	1 (0.7%)
Chiangmai	1 (0.5%)	0 (0.0%)
Chiangrai	1 (0.5%)	1 (0.7%)
Kamphaeng Phet	1 (0.5%)	0 (0.0%)
Nakonnanyok	1 (0.5%)	0 (0.0%)
Prajinburi	1 (0.5%)	0 (0.0%)
Pichit	1 (0.5%)	0 (0.0%)
Phitsanulok	1 (0.5%)	0 (0.0%)
Yasothon	1 (0.5%)	1 (0.7%)
Ratchaburi	1 (0.5%)	1 (0.7%)
Lampang	1 (0.5%)	1 (0.7%)
Lamphun	1 (0.5%)	1 (0.7%)
Songklha	1 (0.5%)	1 (0.7%)

Medical conditions and symptoms associated with possible COVID-19 infection

Most of the participants (88%) reported no history of severe medical conditions. High blood pressure or cardiovascular disease or treatment for the heart-related condition was the most reported illness history (5%) as shown in Table 4. The symptoms within the last few days before completing the self-assessment questionnaire that possibly related to signs of COVID-19 were reported such as unusually fatigue (17%), runny nose (15%), dried month (13%), sore throat (9%), unusual sneeze (8%) and diarrhoea (6%) (See Table 5).

Table 4 History of medical conditions of participants

History of medical conditions	N = 200, n (%)
No history of the medical condition	176 (88%)
High blood pressure or cardiovascular disease or treatment for a heart-related condition	10 (5%)
On immunosuppressive therapy (e.g. corticosteroids, methotrexate, ciclosporin, tacrolimus, azathioprine, or cyclophosphamide)	6 (3%)
Have a respiratory disease (e.g. tuberculosis) or followed by a lung specialist	3 (2%)
Diabetes	2 (1%)
Have a chronic liver disease (e.g. viral hepatitis B or C)	2 (1%)
Ever had cancer	1 (<1%)
Have chronic kidney disease or dialysis	0 (0%)
Have an infection known to weaken the immune system (e.g. HIV)	0 (0%)

Table 5 Symptoms associated with possible COVID-19 infection within the last few days before completing the self-assessment questionnaire

Symptoms within the last few days	N = 200, n (%)
Experienced unusually fatigue	33 (17%)
- Forced to rest for more than half of the day	11/33 (33%)
The mouth is currently dry	26 (13%)
Had a sore throat	17 (9%)
Sneezed more than usual	16 (8%)
Had diarrhoea at least 3 times within the last 24 hours	11 (6%)
Coughed more than usual	10 (5%)
Felt unusually confused	10 (5%)
Out of breath when talking or having a light physical activity	9 (5%)
Had fever	8 (4%)
Experienced a loss of taste or smell (anosmia)	6 (3%)
Had important difficulties to eat or drink during a period of more than 24 hours	3 (2%)

COVID-19 risk evaluation and laboratory confirmation

A risk level of 200 participants who self-evaluated using a questionnaire was analyzed based on the clinical sign following the criteria of the Department of Diseases Control showed in Table 6. Regarding to the patient under investigation (PUI) criteria from Department of Diseases Control on 23 June 2020 (https://ddc.moph.go.th/viralpneumonia/file/g_srrt/g_srrt_230663.pdf), PUI include travelers from endemic countries/areas, suspected case/patients for covid-19 infection, healthcare providers, individuals involved with Covid-19 cluster. These PUI can be tested for SAR-CoV-2 with free-of-charge.[17-18]

The number of participants at the risk level 1 and level 2 was 25 (12.5%), equally. Additionally,

the number of risk level 3 were 150 (75%) which was a majority of the participants. The total appointments were made by 159 (79.5%) participants; however, 16 participants cancelled the appointments. Finally, 143 samples were collected for SAR-CoV-2 detection and result of all samples were "SAR-CoV-2 undetectable". This result reflected a prevalence of COVID-19 was very low in non-PUI population. Therefore, this may be limited by the number of participants in this study. However, the prevalence may be evaluated and confirmed using the large scale of participant.

Table 6 COVID-19 risk evaluation

COVID-19 risk level	**Booked an appointment**	**Did not book an appointment**	**Total**
1. Recommend immediately contacting a physician *(reported fever, unusual cough or unusual sneezing)*	18 (9%)	7 (3.5%)	25 (12.5%)
2. Need a test as soon as possible *(did not report fever, unusual cough or unusual sneezing but reported at least one of the following: runny nose, sore throat, out of breath, lack of smell or taste, or age >60 years)*	18 (9%)	7 (3.5%)	25 (12.5%)
3. Do not recommend immediate testing and re-evaluate the situation every 24 hours *(Did not report any of the above symptoms)*	123 (61.5%)	27 (13.5%)	150 (75%)
Total	159 (79.5%)	41 (20.5%)	200 (100%)

Discussion

The increasing number of COVID-19 patients and suspected cases spreading through many provinces in Thailand had caused a lot of panic and concern among the people. The local public health organizations encouraged people to stay at home and avoid social gathering; however, the need for testing access was increasing. Additionally, there were the period without any known local transmission of COVID-19 during July-August 2020 especially in rural area of Thailand where the feasibility of the SAR-CoV-2 testing were limited. These circumstances prompted the Department of Medical Technology, the University of Phayao in cooperation with Chiang Mai University to develop a medical testing management system using a web management system provided in two languages: Thai and English. The designed system containing a self-screening questionnaire served as a preliminary screening tool for the public who might feel nervous or suspect they had contacted the coronavirus as well as for those who wanted to know their infection status. This medical services management system, in particular COVID-19 testing as a model, would be helpful in developing countries where the number of medical staff is limited, and patients are normally overcrowded in clinics or hospitals. The reason is that this model is able to arrange the appointment for specimen collection, result reporting, as well as for the other operative practices. By this approach, participants or patients can make a self-screening and self-assessment to get the laboratory testing online which could reduce

the exposure of people in the community during the pandemic. The implement of testing management by mean of social distancing also saves medical resources, such as masks, hand sanitizers, alcohol-based disinfectant. This gives the healthcare professionals, and hospitals more valuable time to prepare, and help people with COVID-19. The aim of this web system is not only for self-screening but also for the laboratory management which is different from the other currently used application in Thailand. For example, Application MorChana is a tool that can help medical professionals, government agencies, business owners, and people to secure themselves from the spread of COVID-19 in Thailand [16]. The application will track COVID-19 infection, probability, and risk, as well as monitor the outbreak scenario. Additionally, Morprom, an application includes a number of features, such as the ability to display the most recent COVID-19 test results, book a vaccine, schedule a vaccination, see vaccination history, and view vaccination certificate.

However, the usage of mobile phones- or web-based testing management system has some limitations. In our study, some of the participants were not able to register or answer the questionnaire due to the abovementioned reasons. In the trial of the management system, most of the participants who completed registration have the education level at above high school. This issue may occur due to several reasons such as the limitation of device to access the system, the opportunity to get an announcement by social platform, the ability to use the online application, etc. Additionally, in rural area, there is no internet access or devices sufficiently available in every household. The level of IT literacy is also necessary for successfully implementing such a system.

The proactive screening procedure conducted between July-August 2020, involved public relations by social media for nasopharyngeal swabbing for SARS-CoV-2 PCR. Participants who are interested in taking the test will register and make an appointment in the developed testing management system. This approach allowed for early identification of asymptomatic and mildly symptomatic people, who probably otherwise would not have known of their infection status. This screening approach enabled us to establish a safer environment by lowering cross-transmission between community, thus ensuring optimal prevention during the crisis. We hypothesized that it might be an asymptomatic infection which could spread the virus to others who may be susceptible to severe COVID-19 complaint. Most participants are students in the University with the age of about 22-year-old, which are probably asymptomatic. Interestingly, all our participants have results of SAR-CoV-2 undetectable. This shows the success of pandemic control in Thailand at that time[19]. However, there were some participants who denied reserving the schedule for testing. The information from the individual interview reflected that the participant was curious about the effect on their occupation regarding COVID-19 status such as insecurity of daily income when self-quarantine required. In case of non-PUI people with no symptoms but positive for SARS-CoV2 RNA testing, they will be notified by the application and this case will be reported to local provincial public health office and then the case will be managed following the standard protocol for disease control.

The study was limited, however, to a small number of participants. A more extensive study on these cases needs to be conducted to evaluate the infection status among non-PUI and find independent risk factors for viral infection. To make

this effective, we suggest that public health measures should be implemented with the full engagement of all members of society, including communities and professional groups. All measures should be executed with clearer, more accessible, and more regular risk communication to explain the response strategy and enable people to be well-informed about their decisions to protect themselves and help achieve the public health goal of ending the outbreak.

Conclusion

To conclude, we demonstrated the potential system for COVID-19 testing management and the proactive screening of the non-PUIs population during the COVID-19 pandemic. These strategies would be helpful to control the spread of the virus by means of the reduction of people gathering. Additionally, this model would be able to apply to other medical services also to other pandemic in the future.

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References

[1] Mahase E. Covid-19: WHO declares pandemic because of “alarming levels” of spread, severity, and inaction. BMJ. 2020;368:m1036.

[2] Dechsupa S, Assawakosri S, Phakham S, Honsawek S. Positive impact of lockdown on COVID-19 outbreak in Thailand [Internet]. Vol. 36, Travel Medicine and Infectious Disease. 2020.

[3] Department of Disease Control MoPH, Thailand. Case definition for patients under investigation (PUIs) with COVID-19 (edited on March 2, 2020). Thail Minist Publich Heal. 2020;21(1):1–9.

[4] Department of Disease Control MoPH, Thailand. Guidelines for Clinical practice, diagnosis, treatment and prevention of healthcare-associated infection in response to patients with COVID-19 infection. Thail Minist Publich Heal. 2020;4(8):1–2.

[5] Syangtan G, Bista S, Dawadi P, Rayamajhee B, Shrestha LB, Tuladhar R et al. Asymptomatic SARS-CoV-2 Carriers: A Systematic Review and Meta-Analysis. Front Public Heal. 2021;8:587374.

[6] Oran DP, Topol EJ. Prevalence of Asymptomatic SARS-CoV-2 Infection: A Narrative Review. Ann Intern Med. 2020;173(5):362–7.

[7] Johansson MA, Quandelacy TM, Kada S, Prasad PV, Steele M, Brooks JT et al. SARS-CoV-2 Transmission From People Without COVID-19 Symptoms. JAMA Net open. 2021;4(1):e2035057.

[8] Bai Y, Yao L, Wei T, Tian F, Jin DY, Chen L et al. Presumed Asymptomatic Carrier Transmission of COVID-19 [Internet]. JAMA - Journal of the American Medical Association. American Medical Association; 2020;323:1406–7.

[9] Yu X, Yang R. COVID-19 transmission through asymptomatic carriers is a challenge to containment [Internet]. Influenza and other Respiratory Viruses. Blackwell Publishing Ltd; 2020;14:474–5.

[10] Yu C, Zhou M, Liu Y, Guo T, Ou C, Yang L et al. Characteristics of asymptomatic COVID-19 infection and progression: A multicenter, retrospective study. Virulence. 2020;11(1):1006–14.

[11] Qian M, Jiang J. COVID-19 and social distancing [Internet]. Journal of Public Health. Springer; 2020; 1.

[12] Matrajt L, Leung T. Effectiveness of Social Distancing for COVID-19. CDC. 2020;26(8).

[13] Moosa IA. The effectiveness of social distancing in containing Covid-19. Appl Econ. 2020;52(58):6292–305.

[14] Intawong K, Olson D, Chariyalertsak S. Application technology to fight the COVID-19 pandemic: Lessons learned in Thailand. Biochem Biophys Res Commun. 2021;534:830–6.

[15] Whitelaw S, Mamas MA, Topol E, Van Spall HGC. Applications of digital technology in COVID-19 pandemic planning and response. The Lancet Digital Health. Elsevier Ltd; 2020;2:e435–40.

[16] Almalki M, Giannicchi A. Health Apps for Combating COVID-19: Descriptive Review and Taxonomy. JMIR mHealth uHealth. 2021;9(3).

[17] Department of disease control, Ministry of public health. Criteria for Coronavirus 2019 investigation of patients under investigation: PUIs) and Disease investigation for PUIs [Internet]. 2020.

[18] Department of disease control, Ministry of public health. Guidelines for surveillance and investigation of Coronavirus Disease 2019 (COVID-19) [Internet]. 2020.

[19] WHO. How a Strong Health System Fights a Pandemic. 2020;(September).

[20] Da An Gene. Instructions for use for Detection Kit for 2019 Novel Coronavirus (2019-nCoV) RNA (PCR-Fluorescence Probing). Sun Yat-sen University. 2019;4(1):75–84.