Mobile Applications Leveraged in the COVID-19 Pandemic in East and South-East Asia: Review and Content Analysis

Bohee Lee, Siti Aishah Ibrahim, Tiying Zhang

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Abstract

Background: The COVID-19 pandemic increased attention to digital tools to support governmental public health policies in East and South-East Asia. Mobile applications (apps) related to COVID-19 continue to emerge and evolve with a wide variety of characteristics and functions. However, there is a paucity of studies evaluating such apps in this region, with most of the available studies conducted in the early days of the pandemic.

Objective: This study aimed to examine free apps developed or supported by governments in the East and South-East Asian region and highlight their key characteristics and functions. We also sought to interpret how the release dates of these apps were related to the commencement dates of other COVID-19 public health policies.

Methods: We systematically searched for apps in Apple App Store and Google Play Store and analysed the contents of eligible apps. Mobile apps released or updated with COVID-19-related functions between 1 March 2020 and 7 May 2021 in Singapore, Taiwan, South Korea, China (mainland), Japan, Thailand, Hong Kong, Vietnam, Malaysia, Indonesia, and the Philippines were included. The CoronaNet Research Project database was also examined to determine the timeline of public health policy commencement dates in relation to the release dates of the included apps. We assessed each mobile app's official website, media reports, and literature using content analysis. Descriptive statistics were used to summarise relevant information gathered from the mobile apps using R studio.

Results: Of the 1,943 mobile apps initially identified, 46 were eligible, with almost 70% of the mobile apps being intended for the general public. Most apps were from Vietnam (n=9, 20%), followed by Malaysia, Singapore and Thailand (each n=6, 13%). Significantly, most apps for quarantine monitoring (n=6, 13%) were mandatory for the target users or a population subset. The most common function was health monitoring (n=32/46, 70%), followed by raising public health awareness (n=19/46, 41%) through education and information dissemination. Other functions included monitoring quarantine (n=12/46, 26%), providing health resources (n=12/46, 26%). COVID-19 vaccination management functions began to appear in parallel to vaccination rollout (n=7/46, 15%). Regarding the timing of introducing mobile solutions, the majority of mobile apps emerged close to the commencement dates of other public health policies in the early stages of the pandemic between March and April 2020.

Conclusions: In East and South-East Asia, most governments employed mobile health apps as adjuncts to public health measures for tracking COVID-19 cases and delivering credible information. In addition, these apps have evolved by expanding their functions for COVID-19 vaccination.

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ABSTRACT

Background: The COVID-19 pandemic increased attention to digital tools to support governmental public health policies in East and South-East Asia. Mobile applications (apps) related to COVID-19 continue to emerge and evolve with a wide variety of characteristics and functions. However, there is a paucity of studies evaluating such apps in this region, with most of the available studies conducted in the early days of the pandemic.

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resources (n=12/46, 26%). COVID-19 vaccination management functions began to appear in parallel to vaccination rollout (n=7/46, 15%). Regarding the timing of introducing mobile solutions, the majority of mobile apps emerged close to the commencement dates of other public health policies in the early stages of the pandemic between March and April 2020.

Conclusions: In East and South-East Asia, most governments employed mobile health apps as adjuncts to public health measures for tracking COVID-19 cases and delivering credible information. In addition, these apps have evolved by expanding their functions for COVID-19 vaccination.

Keywords: mobile applications; eHealth; mHealth; digital health; telemedicine; telehealth; COVID-19; coronavirus; pandemic

Introduction

The role of digital technology has reached new heights, with 93% of the world's population having access to mobile broadband networks in 2020 [1]. Today, with more than half of the world's population (approximately 3.8 billion) owning a smartphone, there is an enormous potential and still growing opportunity to cost-effectively incorporate mobile applications (apps) into pandemic control strategies [2]. Mobile technologies in public health, mHealth, allow individuals to connect to health services, including surveillance, remote monitoring, and health information [3].

mHealth intervention has been continuously evolving in various settings, including resource-limited settings with the surging penetration of smartphones and continuous advancement of relevant technological capabilities [4]. Evidence has shown that mHealth has been used to enable healthcare providers to reach out to vulnerable individuals, conduct surveillance and provide treatment, health-related education and counselling [4-7].

Capabilities of mHealth intervention have grown quickly during the COVID-19 pandemic, but its abundant potential has been constantly predicted by many researchers, even pre-pandemic [8]. For instance, a pilot study by Pai and colleagues observed that an unsupervised HIV self-testing strategy using an internet application with mobile phones lead to counselling and treatment in patients testing positive in South Africa [9]. A case study in Uganda also highlighted the feasibility of mHealth approaches to implement anti-malaria strategies in a developing country [10].

Since World Health Organization (WHO) declared a global pandemic due to the 2019 novel coronavirus disease (COVID-19) in March 2020, the demand for digital tools to reinforce public health measures has dramatically increased worldwide [11]. mHealth solutions have been used for early detection, fast screening, patient monitoring, information sharing, education, and treatment management in response to the COVID-19 outbreak [8]. The pandemic has witnessed a rapid proliferation in the application of digital technologies for public health, with many governments around the globe developing mobile apps to reduce transmission of SARS-CoV-2 [12, 13].

Before the advent of COVID-19 vaccines, many governments in East and South-East Asia have gained unprecedented attention for their effective COVID-19 containment and incredibly low death

tolls compared to countries in the West [14]. Governments in this region had experienced the consequences of outbreaks such as the severe acute respiratory syndrome (SARS) in 2003 and the Middle East respiratory syndrome (MERS). Therefore, they ensured that their public health systems were better prepared for similar outbreaks by establishing early warning systems and relevant policies [15-18]. Critical medical capacities were augmented while early warning systems and relevant policies were established long before COVID-19 was identified [16, 18]. In addition, they actively capitalised on technological solutions to contain the pandemic by leveraging existing regional digital infrastructure through the ASEAN Smart Cities Network (ASCN), a collaborative platform working towards a common goal of smart and sustainable urban development [12, 19, 20]. These experiences also created a culture of mask-wearing, solidarity, and collective responsibility in the general public [21].

Although a number of systematic reviews had looked at COVID-19 apps available on a global scale, there is a paucity of studies focusing on mobile apps in this region which share similar cultural characteristics [13, 22, 23]. Ming and colleagues found that most apps developed in the USA before May 2020 had tracing or mapping of COVID-19 cases and surveillance features but not educational contents [24]. A recent review by Alanzi examined the functionalities of mobile apps developed by governments in 6 countries such as Saudi Arabia, Italy, Singapore, the United Kingdom, the USA, and India as of August 2020 [13]. The author found that the most prevalent function was contract tracing, while very few apps had functions for raising public awareness and providing COVID-19 information [13]. Almalki and Giannicchi assessed mobile apps in a total of 51 countries as of September 2020. They demonstrated that the most common function was basic health information followed by contact tracing, self-assessment, live statistics and the latest news [25]. However, only five East and South-East Asian countries (Vietnam, Malaysia, Thailand, Singapore, and South Korea) were included in this assessment.

Given the diverse economic sizes and varying digital adaptation in East and South-East Asian region [26], it is crucial to know how these governments have developed readiness and abilities to deploy digital technologies integrated with public health measures [14]. In addition, in view of the evolving nature of the pandemic, there is a need to examine how COVID-19 mobile apps are employed in the public health context, particularly focusing on this region. Therefore, our review aimed to explore COVID-19 mobile apps which governments in East and South-East Asia have introduced.

Materials and methods

Search strategy

This study adopted a systematic search strategy using a modified version of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) guidelines to identify COVID-19 apps currently freely available in this region and their characteristics and functions [27]. Adjustments were needed because of the different search nature of mobile app stores.

We referred to Bloomberg's Covid Resilience Ranking evaluating the 53 largest economies on their success at containing the virus (March 2021) [28]. This ranking covers a wide range of COVID-19 status, from mortality rates and COVID-19 testing to vaccination and lockdown severity, and quality of life in the pandemic [28]. In this ranking, there were 11 governments in East and South-East Asia as of March 2021: Singapore, Taiwan, Hong Kong, South Korea, China (mainland), Japan, Thailand, Vietnam, Malaysia, Philippines and Indonesia. The summarised details of the scores of each selected government based on Bloomberg's Covid-19 Resilience Ranking in March 2021 are presented in Multimedia Appendix 1.

Two largest app stores worldwide, iOS-based Apple App Store and Android-based Google Play Store, were searched for potentially relevant mobile apps released or updated from 1 March 2020 to

7 May 2021. The following search terms were used: "COVID-19", "COVID", "coronavirus", "corona virus", "corona" and "SARS-CoV-2". In order to circumvent the regional restriction setting for searching apps, we utilised a website, fnd.ios, to look for apps on Apple App Store and changed the region settings in Google Play Store [29, 30]. News articles, media reports were also searched to find further eligible apps that may have been missed. For searching the literature, MEDLINE and Google Scholars were explored by combining two search strings, including terms related to mobile apps and COVID-19 such as ("digital health" OR "m-health" OR "mobile health" OR "e-health" OR "mobile apps") AND ("COVID-19" OR "coronavirus" OR "SARS-CoV-2"). Draft searches were piloted in each database and then finalised. Searches were conducted on 7 May 2021 by two reviewers (BL, TZ). To identify and examine the mobile app described in the native language (non-English) of the corresponding government, we searched the app's official website and news reports to see if there was any information provided in the English language. Google Translator was used if the information about the app was unavailable in either English or the four languages spoken by the three reviewers (Chinese, Korean, Malaysian, and Japanese).

To evaluate when mobile apps were introduced in relation to other public health policies, we utilised the dataset of CoronaNet Research Project collating governmental public health policies worldwide in the context of COVID-19 [31]. This project comprises a dataset providing comprehensive government policies across 195 countries, apprehending 18 broad policy types, including timings of each policy. Any ambiguity was resolved by discussion with a reviewer in the CoronaNet Research Project (CC). We selected national-level policies of 11 governments and validated relevant policies by checking data sources. We narrowed 18 policy types to six, which were deemed to be associated with the functions of mobile apps such as public awareness measure, COVID-19 testing, quarantine monitoring, health monitoring, vaccination, and health resources [31].

Eligibility assessment and selection of apps

After initial deduplication, two authors (SAI, BL) with backgrounds in public health screened mobile apps based on the identified apps' titles, keywords, and descriptions. Irrelevant apps were excluded during the preliminary screening step. After screening, the two reviewers independently assessed the eligibility of mobile apps based on the eligibility criteria. We included apps if they were: (1) related to COVID-19; (2) available free of cost with no in-app purchase requirement; (3) released or updated with COVID-19 related functions during the research period; (4) still available to users on the specified search date; (5) developed or supported by governments or authorities; and (6) with full information regarding the app accessible. However, we excluded mobile apps developed by global organisations, non-governmental organisations or communities not representing a government or broader regions. Discrepancies were resolved through discussion between two reviewers or arbitration by a third reviewer to reach a consensus.

Data extraction and synthesis

We used a modified framework of prior studies and the CoronaNet Project database for data extraction [13, 31]. This framework covers key characteristics and functions of mobile apps in accordance with coding and policy definitions by the CoronaNet Research Project [31]. Key characteristics include the country of origin, platform availability (Apple App Store and Google Play Store), release date, developer, target users, uptake requirement, and required technology. Key functions were merged into six policy types. Definitions of key functions and lists of subordinate functions are described in Textbox 1.

Based on this framework, we developed a data extraction form, and two independent reviewers extracted the relevant data. Each mobile app's official website, relevant media reports and literature were assessed by content analysis technique [32]. Through this technique, we identified and quantified relevant keywords indicating key characteristics and functions [32]. At each step,

disagreements were resolved by consensus. In case of persistent disagreement, arbitration by the third reviewer settled the discrepancy. Descriptive statistics were used to summarise relevant information gathered from the mobile apps using R studio version1.3.1056.

Textbox 1. Definitions of key functions and list of subordinate functions of eligible mobile apps

Public Awareness Measures: Government efforts to disseminate or gather reliable information about COVID-19
- News or government measures
- Up-to-date statistics
- COVID-19 health information
- Health management guidelines
- COVID-19 related services information
- Hotspot/risk area identification

COVID-19 Testing: Government policies to detect COVID-19 cases
- Obtain COVID-19 test
- Report of test results

Quarantine Monitoring: Targets of the policy are obliged to isolate themselves for at least 14 days because there is reason to suspect a person is infected with COVID-19
- Regular health check
- Location tracking

Health Monitoring: Government policies to monitor the health of individuals to limit the spread of COVID-19
- Digital contact tracing
- Digital check-in
- Alert contacts of COVID-19 cases
- Report suspected cases/rule infringement
- Health code/status generator
- Health/travel declaration
- Self-symptom assessment

Vaccination: Government policy made with regards to either the research and development, regulation, production, purchase and/or distribution of a given COVID-19 vaccine
- Vaccination information
- Vaccination registration/appointment
- Vaccination certificate
- Reporting adverse reactions

Health Resources: Government policies that affect the material (e.g. medical equipment, number of hospitals for public health) or human (e.g. doctors, nurses) health resources of a country
- Virtual medical consultation
- Emergency helpline
- Accessing medical records
- Personal protective equipment (PPE) distribution

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Results

Selected apps

Figure 1. PRISMA flowchart of the search process

Figure 1 illustrates an overview of the process involved in selecting the apps for study synthesis. A total of 1,943 potential apps were obtained through systematic searches, of which 46 met our eligibility criteria. Although three of the apps, namely Alipay, WeChat and My Health Bank, have pre-existed before March 2020, we included them in the review as they have since been updated to include COVID-19-related services during the pandemic.

Characteristics of the included apps

All of the included apps were free for users to download and use without any in-app purchase requirements. Furthermore, they were official apps developed or supported by the government and maintained by the relevant authority for COVID-19-related service provision. Descriptive analytics related to the characteristics of the apps were summarised and presented in Table 1. Most of the apps (n=9, 20%) come from Vietnam, followed by Malaysia, Singapore, and Thailand, with six apps each. Almost 98% of the apps were available on both iOS and Android platforms through the Apple App Store and Google Play Store.

Twenty-four mobile apps (52%) were mandatory, with a mandate for target users to install them on their smartphones. Target users were mainly a subset of the population only, for example, people living in high-risk areas with tight pandemic restrictions and confirmed or suspected COVID-19 cases.

Most of these apps (n=32, 70%) were intended for the general public. Six apps (13%) were especially intended for quarantined people: four apps (9%) for quarantined residents and two apps (4%) for quarantined inbound travellers. Six apps (13%) targeted travellers: domestic and overseas travellers (n=2, 4%), overseas travellers including those who required quarantine (n=3, 7%), and outbound travellers (n=1, 2%). Overall, Global Positioning System (GPS) was the most required technology (n=28, 61%), followed by Bluetooth (n=16, 35%) and QR scanner (n=16, 35%). Artificial Intelligence (AI), Application Programming Interface (API) and facial-recognition technology were also utilised in three apps (n=3, 7%). Details of apps with associated characteristics currently available across 11 governments included in this review are described in Multimedia Appendix 2.

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Table 1. Overview of the included apps (N=46).

Origin, n(%)		
	China (mainland)	2 (4)
	Hong Kong	3 (7)
	Indonesia	3 (7)
	Japan	4 (9)
	Malaysia	6 (13)
	Philippines	1 (2.2)
	Singapore	6 (13)
	South Korea	3 (7)
	Taiwan	3 (7)
	Thailand	6 (13)
	Vietnam	9 (20)
Platform, n(%)		
	iOS (App Store)	45 (98)
	Android (Google Play Store)	46 (100)
Uptake requirement, n(%)		
	Mandatory	24 (52)
	Voluntary	22 (48)
Target users, n(%)		
	General public	32 (70)
	Travellers – domestic and overseas	2 (4)
	Travellers – overseas	1 (2)
	Travellers – quarantine	2 (4)
	Travellers – outbound	1 (2)
	Foreign workers	1 (2)
	Quarantined individuals	4 (9)
	Business owners	1 (2)
	Vaccinated individuals	2 (4)
Required technology, n(%)		
	Global Positioning System (GPS)	28 (61)
	Bluetooth	16 (35)
	QR scanner	16 (35)
	Others[a]	3 (7)

[a]Others: Artificial Intelligence (n=1), Application Programming Interface (API) (n=1), Facial recognition (n=1)

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Functions of included apps

Overall, 25 common functions were identified, and they were subsequently organised into six overarching domains that characterised the functions of these apps, as shown in Table 2. The functions supported by each app are detailed in Multimedia Appendix 3.

Table 2. Main functions and subordinate functions of the included apps (N=46).

Main functions and subordinate functions	N (%, %a)
Public awareness measures	19 of 46 (41)
News or government measures	12 (26, 7)
Up-to-date statistics	10 (22, 6)
COVID-19 health information	9 (20, 5)
Health management guidelines	9 (20, 5)
COVID-19 related services information	9 (20, 5)
Hotspot/risk area identification	5 (11, 3)
COVID-19 testing	9 of 46 (20)
Obtain COVID-19 test	4 (9, 2)
Report of test results	7 (15, 4)
Quarantine monitoring	12 of 46 (26)
Regular health check	5 (11, 3)
Location tracking	10 (22, 6)
Health monitoring	32 of 46 (70)
Digital contact tracing	11 (24, 7)
Digital check-in	11 (24, 7)
Alert contacts of COVID-19 cases	12 (26, 7)
Report suspected cases/rule infringement	5 (11, 3)
Health code/status generator	7 (15, 4)
Health/travel declaration	7 (15, 4)
Self-symptom assessment	8 (17, 5)
Vaccination	7 of 46 (15)
Vaccination information	4 (9, 2)
Vaccination registration/appointment	3 (7, 2)
Vaccination certificate	4 (9, 2)
Reporting adverse reactions	1 (2, 1)
Health resources	12 of 46 (26)
Virtual medical consultation	4 (9, 2)
Emergency helpline	7 (15, 4)
Accessing medical records	1 (2, 1)
Personal protective equipment (PPE) distribution	4 (9, 2)
Total functions	169

a%, Calculated from the total functions (n=169)

The most common function served by the apps was health monitoring (n=32, 70%). Eleven apps (24%) were used for digital contact tracing by tracking, documenting, and retaining mobile phone users' encounters with other devices using Bluetooth or

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GPS. Twelve apps (26%) had the function of alerting contacts of COVID-19 cases. If one of the app users contracted COVID-19, authorities with access to the data could request the infected user to upload the relevant anonymised data for analysis so that others with the same installed app who were in close contact may be alerted for further actions. Eleven apps (24%) served the digital check-in function with the same goal for contact tracing: keeping an efficient digital log of visitors so that officials could quickly reach out to those who might have been in close contact with a COVID-19 case present in the same events or premises.

The second most common function associated with the apps was public health awareness (n=19, 41%). More than half of these apps were developed to disseminate the latest news (n=12, 26%), up-to-date statistics (n=10, 22%). Also, this main function included subordinated functions such as providing health management guidelines (n=9, 20%) and health information and advice about COVID-19 (n=9, 20%) and sharing the location and helpline number of facilities offering services during this pandemic (n=9, 20%). In addition, some apps (n=5, 11%) provided maps of hot spots or high-risk areas with increased COVID-19 transmission to better inform the public of their travel plans.

Seven (15%) apps supported the function for COVID-19 vaccination. Most of these apps provided information on COVID-19 vaccines (n=4, 9%) or issued digital proof-of-vaccination (n=4, 9%) to app users who have completed their vaccine doses. Users could also register and make appointments for COVID-19 vaccination (n=3, 7%) via the app. However, only one of the apps (2%), Taiwan V-watch, allowed users to report vaccination-related adverse reactions.

Figure 2 illustrates the total number of functions served by mobile apps in each government by adding up the number of functions of each app per government. For example, if a government introduced multiple mobile apps having the same functions, the total number of functions will be the sum of each function. Mobile apps in Taiwan and Malaysia had all main functions related to six different policy types, and those in Singapore and Japan covered most of the functions except for vaccination. Mobile apps in Thailand, Vietnam and Malaysia focused on functions for public awareness measures and health monitoring. Amongst these apps, "MySejahtera" app from Malaysia was the most comprehensive app, incorporating public awareness measures, quarantine monitoring, health monitoring, vaccination, and health resources. However, the types of functions served by mobile apps were relatively limited in the Philippines and Indonesia in comparison with other nine economies in Bloomberg's COVID Resilience Ranking.

Figure 2. Overview of the key functions of included apps by governments.

Relations between government measures and availability of mobile apps

Figure 3 shows the timeline of public health policies commencement dates and release dates of mobile apps. Each policy type consists of subtypes, and each point indicates the timepoints of when the policies were started. We did not examine the details of each policy.

All governments introduced mobile apps to support COVID-19 mitigation policies. There were no noticeable differences amongst the included governments with respect to the time of introduction of mobile apps. Also, there was no consistency in the introduction of mobile apps and the initiation of certain types of policies across the

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governments. Eight governments, namely Singapore, South Korea, China (mainland), Thailand, Hong Kong, Vietnam, Malaysia, and Indonesia, launched their first apps between March and April 2020. (Figure 3).

In 2021, Hong Kong, Taiwan and South Korea released apps to help track COVID-19 vaccinations, registrations, and side effects. Some apps such as WeChat (China (mainland)), "MySejahtera" (Malaysia), "Selangkah" (Malaysia) and "Bluezone" (Vietnam) were updated to include vaccination-related functions.

Figure 3. Governments COVID-19 policy commencement dates and release dates of the included apps

Discussion

Main findings

This study identified 46 mobile apps developed or supported by 11 governments in East and South-East Asia using a systematic search method. The most common function was health monitoring. Within the health monitoring function, the most popular function was alerting positive cases, followed by contact tracing and digital check-in. The second most common function was public awareness measures such as disseminating news or government measures.

Evidence showed that most apps initially focused on disseminating information or monitoring high-risk areas and later started having functions for contact tracing [25, 33]. As we searched mobile apps cross-sectionally, we did not examine changes in the functions over time. However most apps in our review had additional functions such as digital check-in, self-assessment of symptoms, virtual medical consultation, COVID-19 testing management, and vaccination-related processes. We noticed that the functions of COVID-19 apps were expanded to cover vaccination-related purposes too. Provision of information and issuance of vaccination certificates were the most frequent functions, followed by vaccination registration or appointment. In other governments, apps not having such functions at the time of our search in May 2021 subsequently integrated the functions in parallel with their nationwide administration of COVID-19 vaccines. In Singapore, test results and vaccination records were added to the pre-existing health information app "HealthHub SG" in February 2021 [34]. In Japan, the COVID-19 vaccination certificate will be available via a QR code using a smartphone in December 2021 [35]. Thus, mobile apps can play an important role in promoting the COVID-19 vaccination programs and increasing their coverage [36].

Since Alanzi reviewed 12 mobile apps in August 2020, we noticed that many mobile apps integrating various functions have emerged [13]. This change might be due to governments' efforts to address users' evolving needs and increase data management efficiency by health authorities [37, 38]. Furthermore, some governments such as Japan, Malaysia, and Vietnam have developed city-level or state-level apps that provided area-specific information, which supported the local health systems. Given the necessity of crisis management at subnational levels, app-based measures can be promising by promoting regional coordination [39].

Most governments in our review required travellers from overseas to use their apps for health declaration and monitoring. Notably, most quarantine monitoring apps were mandatory for people who required quarantine, mainly overseas travellers. Compulsory implementation of these apps to other settings or populations would not be simple considering national or regional policies regarding data protection and privacy [40]. Indeed, data security and sharing of data with third parties have been the main reason behind the reluctance to share information in mobile apps [41, 42]. Lack of public trust towards authorities is also a significant reason to refuse privacy trade-

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off [43, 44]. Hence, to maximise the effectiveness of the apps, there must be coordinated legal and ethical governance in place to confer protection against invasion of users' privacy [45].

We examined the timing of the rollout of COVID-19 mobile apps to see its relation to the introduction of other public health measures. All governments included in our review employed mobile apps to support the COVID-19 mitigation policies. We found that mobile apps from more successful economies such as Singapore and Malaysia tended to have diverse functions covering various measures. Most apps also first emerged close to the commencement dates of relevant public health policies between March and April 2020. Governments that showed successful performance tended to introduce COVID-19 apps in the early stages of the pandemic. We did not analyse statistically to see associations between the timing of introducing apps and epidemiological data. Therefore a further analysis is required.

Although our findings focused on mobile apps, there are various other forms of digital solutions to fight COVID-19. For example, Taiwan did not have a particular mobile app for monitoring quarantine using GPS; however, it initiated the "Entry Quarantine System". This system was achieved by scanning the QR code directly or clicking on its website. Travellers were required to make an online health declaration within two days before arriving in Taiwan and complete 14-day quarantine at a government facility, a designated hotel or home. Then the "Electronic Fence system" tracks locations of individuals during their quarantine period using mobile location data to ensure that travellers do not leave their quarantine location [46]. In China (mainland), artificial intelligence solutions have been used in lung CT scans, minimising time and allowing for early diagnosis of COVID-19 cases [47]. Multifaceted digital approaches were utilised, and although they were not substitutes for traditional healthcare, their integration complemented and enhanced a functioning health system.

It is difficult to determine which mobile app was the most effective in curtailing COVID-19. As of 24 March 2021, Taiwan and Vietnam recorded 0 deaths per 1 million, 1 in Thailand, 5 in Singapore, 27 in Hong Kong, 3 in China (mainland), 33 in South Korea, 38 in Malaysia, 70 in Japan, 119 in the Philippines, and 146 in Indonesia [28]. Overall, governments introducing mobile apps covering various forms of public health measures showed lower death per million population. However, other factors such as the health system capacity and resources should be considered. For instance, although Malaysia had the most comprehensive COVID-19 apps in our review, Singapore was the top-performing government with the highest COVID-19 resilience in the Asia Pacific region, having the fastest inoculation programme and the lowest positive test rate (Multimedia Appendix 1). Future research could therefore consider other domains of public health to assess the performance of COVID-19 mobile apps.

Our included apps were purposefully selected from governments, which displayed the most cohesive responses to the pandemic as of March 2021. However, the unprecedented infiltration of the highly transmissible delta variant has wrecked the model of COVID-19 containment success exercised in East and South-East Asia. South-East Asia has emerged as the new virus epicentre; the bottom five in the latest Bloomberg's Covid-19 Resilience Ranking (August 2021) were all South-East Asian economies [48]. Although these economies showed effective resilience by adapting mobile apps in their public health policies, there are still barriers or blind spots that the current mhealth should overcome.

Practical implications

This review has several implications for the governments as well as for public health researchers. Our findings showed that governments in East and South-East Asia

initiated mobile solutions in the early days of the pandemic, and their COVID-19 mobile apps were used for various purposes.

Successful performance of mobile apps in both resource-rich and resource-limited settings in this region demonstrated the wide range of applications of these apps and their cost-effectiveness (Multimedia Appendix 3). Although we only compared the timing of mobile apps introduction in relation to the commencement dates of other public health policies (Figure 3), we observed how mobile apps are intertwined in the context of public health policies. Governments should consider these mobile solutions in East and South-East Asia to strengthen the current public health system and prepare for next outbreaks.

For public health researchers, there is an enormous potential for such apps, especially in epidemiological research, disease surveillance and allocation of health resources. Mobile apps can be designed to collect and generate research data to improve our understanding and response to this pandemic.

Limitations and recommendations for future studies

This study has limitations that are important to acknowledge. It is plausible that some apps may have been missed due to the restrictive setting of several regional app stores. To overcome this issue, we have scoured other sources of information such as current news articles, media reports and literature to find additional relevant apps. However, it is still likely that some relevant apps were missed as our search terms may not cover all the available apps, especially those named in the local languages.

Moreover, we did not collect data on the consumer ratings or user feedback of each app. We also neither examined the popularity nor considered the number of app downloads. Although some evidence suggests that contact-tracing apps should be adopted by at least 60-70% of the population to impact on the outbreak transmission rate, much lower app penetration could still be substantial in breaking transmission chains and preventing infection [49-51]. Nevertheless, given that the number of users determines the utility of mobile apps, our findings may not be generalisable to other countries or populations.

We also did not examine the mobile uptake proportion by people from different socioeconomic backgrounds. There is a need to assess how well these mobile apps were accessible by the most deprived, including the elderly, the homeless, immigrants, and rural residents [52-54].

Conclusions

In conclusion, our findings added knowledge on the COVID-19-related apps used in 11 governments in East and South-East Asia. The most common function was to monitor public health, followed by disseminating information and health education. Most apps deployed GPS, followed by Bluetooth and QR scanner technologies. Most countries in this region adopted mobile apps to support COVID-19 mitigation efforts and introduced them close to the relevant policy commencement dates in the early stages of the pandemic. In addition, some governments, which are relatively successful in suppressing COVID-19, tended to have all-in-one mobile apps or other complementary mobile apps. These apps could play pivotal roles in supporting governments' measures for tracking COVID-19 cases and delivering credible information. Mobile apps catering to the middle-ground strategy of widespread vaccination and reopening of economies can be adopted by the governments to reframe the way of life as we move towards the endemic phase of COVID-19.

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Acknowledgements

Conflicts of Interest

Multimedia Appendix 1: Bloomberg's COVID-19 Resilience Ranking (March 2021)
Multimedia Appendix 2: List of included mobile apps and their associated characteristics
Multimedia Appendix 3: List of included mobile apps with their associated functions

References

1. International Telecommunication Union. Measuring digital development: Facts and figures   2020.
https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2020.pdf
[accessed Jun 06, 2021].

2. Ssali J. Infographic: Half the global population are now using the mobile internet. GSMA Intelligence. https://data.gsmaintelligence.com/research/research/research-2020/infographic-half-the-global-population-are-now-using-the-mobile-internet [accessed Jun 06, 2021].

3. World Health Organisation, mHealth: New horizons for health through mobile technologies. Global observatory for eHealth series. 2011. https://www.who.int/goe/publications/goe_mhealth_web.pdf [accessed Sep 05, 2021].

4. Wood CS, Thomas MR, Budd J, Mashamba-Thompson TP, Herbst K, Pillay D, Peeling RW, Johnson AM, McKendry RA, Stevens MM. Taking connected mobile-health diagnostics of infectious diseases to the field. Nature. 2019;566(7745):467-474. PMID: 30814711.

5. Mackillop L, Loerup L, Bartlett K, Farmer A, Gibson OJ, Hirst JE, Kenworthy Y, Kevat DA, Levy JC, Tarassenko L. Development of a real-time smartphone solution for the management of women with or at high risk of gestational diabetes. Journal of Diabetes Science and Technology. 2014; 8(6):1105-1114. doi:10.1177/1932296814542271.

6. Estcourt CS, Gibbs J, Sutcliffe LJ, Gkatzidou V, Tickle L, Hone K, Aicken C, Lowndes CM, Harding-Esch EM, Eaton S, Oakeshott P, Szczepura A, Ashcroft RE, Copas A, Nettleship A, Sadiq ST, Sonnenberg P.The eSexual health clinic system for management, prevention, and control of sexually transmitted infections: exploratory studies in people testing for Chlamydia trachomatis. Lancet Public Health. 2017;2(4):e182-e190. doi: 10.1016/s2468-2667(17)30034-8.

7. Hochstatter KR, Gustafson DH, Landucci G, Pe-Romashko K, Cody O, Maus A, Shah DV, Westergaard RP. Effect of an mHealth intervention on Hepatitis C testing uptake among people with opioid use disorder: Randomized Controlled Trial. JMIR

15

mHealth and uHealth. 2021;9(2):e23080-e23080. doi: 10.2196/23080.

8. Asadzadeh A and Kalankesh LR. A scope of mobile health solutions in COVID-19 pandemics. Informatics in Medicine Unlocked. 2021;23:100558. doi:10.1016/j.imu.2021.100558.

9. Pant PN, Behlim T, Abrahams L, Vadnais C, Shivkumar S, Pillay S, Binder A, Deli-Houssein R, Engel N, Joseph L, Dheda K. Will an unsupervised self-testing strategy for HIV work in health care workers of South Africa? A cross sectional pilot feasibility study. PLoS One. 2013;8(11):e79772. doi: 10.1371/journal.pone.0079772.

10. Larocca A, Moro VR, Marconi M. Malaria diagnosis and mapping with m-Health and geographic information systems (GIS): evidence from Uganda. Malaria Journal. 2016;15(1): 520. doi: 10.1186/s12936-016-1546-5.

11. World Health Organization. Rolling updates on coronavirus disease (COVID-19). 2020. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/events-as-they-happen. [accessed 5 June, 2021].

12. Clavier F, Ghesquiere F. Leveraging digital solutions to fight COVID-19 : Lessons from ASEAN Countries. Research and Policy Brief. World Bank Group. https://openknowledge.worldbank.org/handle/10986/35126 [accessed Jun 21, 2021].

13. Alanzi T. A review of mobile applications available in the App and Google play stores used during the COVID-19 outbreak. J Multidiscip Healthc 2021;14:45-57. PMID: 33469298.

14. Chorzempa M, Huang T. Lessons from East Asia and Pacific on taming the pandemic. Peterson institute for international economics. https://www.piie.com/blogs/realtime-economic-issues-watch/lessons-east-asia-and-pacific-taming-pandemic [accessed Jul 09, 2021].

15. Lim PL. Middle East respiratory syndrome (MERS) in Asia: Lessons gleaned from the South Korean outbreak. Trans R Soc Trop Med Hyg. 2015 Sep;109(9):541-2. PMID: 26286944.

16. Chua AQ, Al Knawy B, Grant B, et al. How the lessons of previous epidemics helped successful countries fight covid-19. BMJ. 2021;372:n486. PMID: 33707174.

17. Liu Q, Xu K, Wang X, Wang W. From SARS to COVID-19: What lessons have we learned? Journal of Infection and Public Health. 2020;13(11):1611-1618. PMID: 32888871.

18. An BY, Tang S-Y. Lessons from COVID-19 responses in East Asia: Institutional infrastructure and enduring policy instruments. The American Review of Public Administration. 2020;50(6-7):790-800. doi:10.1177/0275074020943707.

19. Huang Y, Sun M, Sui Y. How digital contact tracing slowed Covid-19 in East Asia. Harvard Business Review. https://hbr.org/2020/04/how-digital-contact-tracing-slowed-covid-19-in-east-asia [accessed Jul 05, 2021].

20. Tan SY, Taeihagh A, Sha K. How transboundary learning occurs: case study of the ASEAN Smart Cities Network (ASCN). Sustainability. 2021;13(11). doi: 10.3390/su13116502.

21. Navarro V. Why asian countries are controlling the pandemic better than the United States and Western Europe. International Journal of Health Services. 2021;51(2):261-264. doi: 10.1177/0020731421999930.

16

22. Davalbhakta S, Advani S, Kumar S, Agarwal V, Bhoyar S, Fedirko E, Misra DP, Goel A, Gupta L, Agarwal V. A systematic review of smartphone applications available for corona virus disease 2019 (COVID19) and the assessment of their quality using the Mobile Application Rating Scale (MARS). Journal of Medical Systems. 2020;44(9):164. doi: 10.1007/s10916-020-01633-3.

23. Zhang MWB, Chow A, Ho RCM, Smith HE. An overview of commercially available apps in the initial months of the COVID-19 pandemic. Frontiers in Psychiatry. 2021;12(424). doi: 10.3389/fpsyt.2021.557299.

24. Ming LC, Untong N, Aliudin NA, Osili N, Kifli N, Tan CS, Goh KW, Ng PW, Al-Worafi YM, Lee KS, Goh HP.Mobile health apps on COVID-19 launched in the early days of the pandemic: content analysis and review. JMIR Mhealth Uhealth. 2020;8(9):e19796. doi: 10.2196/19796.

25. Almalki M and Giannicchi A. Health apps for combating COVID-19: descriptive review and taxonomy. JMIR Mhealth Uhealth. 2021; 9(3):e24322. doi: 10.2196/24322.

26. World Bank. Digital Adoption Index. World Bank Group. https://www.worldbank.org/en/publication/wdr2016/Digital-Adoption-Index [accessed Jun 30, 2021].

27. Tricco AC, Lillie E, Zarin W, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Annals of Internal Medicine. 2018;169(7):467-473. PMID: 30178033.

28. Hong J, Chang R, Verley K. The best and worst places to be as variants outrace vaccinations. https://www.bloomberg.com/graphics/covid-resilience-ranking/ [accessed Apr 10, 2021].

29. Google Play Store. https://play.google.com/store [accessed May 07, 2021].

30. fnd: Experience the App Store and iTunes Anywhere. https://fnd.io/#/ [accessed May 07, 2021].

31. Cheng C, Barceló J, Hartnett AS, Kubinec R, Messerschmidt L. COVID-19 government response event dataset (CoronaNet v.1.0). Nature Human Behaviour. 2020;4(7):756-768. PMID: 32576982.

32. Hsieh HF and Shannon SE. Three approaches to qualitative content analysis. Qualitative Health Research. 2005;15(9):1277-1288. doi: 10.1177/1049732305276687.

33. Collado-Borrell R. Escudero-Vilaplana V, Villanueva-Bueno C, Herranz-Alonso A, Sanjurjo-Saez M. Features and functionalities of smartphone apps related to COVID-19: systematic search in app stores and content analysis. Journal of medical Internet research. 2020;22(8): e20334-e20334. doi: 10.2196/20334.

34. Ministry of Health Singapore. Health Hub. 2021. https://www.healthhub.sg/ [accessed Sep 05, 2021].

35. Mistry of Health, Labour and Welfare Japan. About the new corona vaccination certificate for overseas travel. 2021. https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/vaccine_certificate.html [accessed Sep 05, 2021].

36. Simeoni R, Maccioni G, Giansanti D. The vaccination process against the COVID-19: Opportunities, Problems and mHealth Support. Healthcare. 2021; 9(9).

17

doi: 10.3390/healthcare9091165.

37. Steinberg M. LINE as Super App: Platformization in East Asia. Social Media + Society. 2020;6(2):2056305120933285. doi:10.1177/2056305120933285.

38. Oxford Business Group. How South-east Asia's super apps are adapting to Covid-19. https://oxfordbusinessgroup.com/news/how-covid-19-changing-south-east-asia-super-apps [accessed Jun 21, 2021].

39. Organisation for Economic Co-operation and Development. OECD policy responses to Coronavirus (COVID-19): The territorial impact of COVID-19: Managing the crisis across levels of government. https://www.oecd.org/coronavirus/policy-responses/the-territorial-impact-of-covid-19-managing-the-crisis-across-levels-of-government-d3e314e1/ [accessed Jun 04, 2021].

40. Oliver N, Lepri B, Sterly H, et al. Mobile phone data for informing public health actions across the COVID-19 pandemic life cycle. Sci Adv. 2020;6(23):eabc0764-eabc0764. PMID: 32548274.

41. Du L, Raposo VL, Wang M. COVID-19 contact tracing apps: a technologic tower of babel and the gap for international pandemic control. JMIR mHealth and uHealth. 2020; 8(11): e23194-e23194. doi: 10.2196/23194.

42. Chan EY, Saqib NU. Privacy concerns can explain unwillingness to download and use contact tracing apps when COVID-19 concerns are high. Computers in human behavior 2021;119:106718-106718. PMID: 33526957.

43. Cho H, Ippolito D, Yu YW. Contact tracing mobile apps for COVID-19: Privacy considerations and related trade-offs. ArXiv. Preprint posted online on 30 March, 2020 arXiv:2003.11511v2.

44. Wottrich VM, van Reijmersdal EA, Smit EG. The privacy trade-off for mobile app downloads: The roles of app value, intrusiveness, and privacy concerns. Decision Support Systems. 2018;106:44-52. doi: 10.1016/j.dss.2017.12.003.

45. Zwitter A and Gstrein OJ. Big data, privacy and COVID-19–learning from humanitarian expertise in data protection. Int J Humanitarian Action. 2020; 5(1): 4. doi: 10.1186/s41018-020-00072-6.

46. Taiwan Mistry of Health and Welfare. Quarantine system for Entry: Quarantine measures required for incoming passengers 2021. https://hdhq.mohw.gov.tw/Default1?openExternalBrowser=1 [accessed Sep 05, 2021].

47. Chen B, Marvin S, While A. Containing COVID-19 in China: AI and the robotic restructuring of future cities. Dialogues in Human Geography. 2020; 10(2): p. 238-241. doi:10.1177/2043820620934267.

48. Chang R, Varley K, Munoz M, Tam F, Makol MK. The Covid Resilience Ranking: The Best and Worst Places to Be as Delta Wrecks Reopening Plans. Bloomberg. https://www.bloomberg.com/graphics/covid-resilience-ranking/ [accessed Sep 05, 2021]

49. University of Oxford. Digital contact tracing can slow or even stop coronavirus transmission and ease us out of lockdown. Fraser Group, Oxford University's Big Data Institute. https://www.research.ox.ac.uk/article/2020-04-16-digital-contact-tracing-can-slow-or-even-stop-coronavirus-transmission-and-ease-us-out-of-lockdown [accessed Jun 21, 2021].
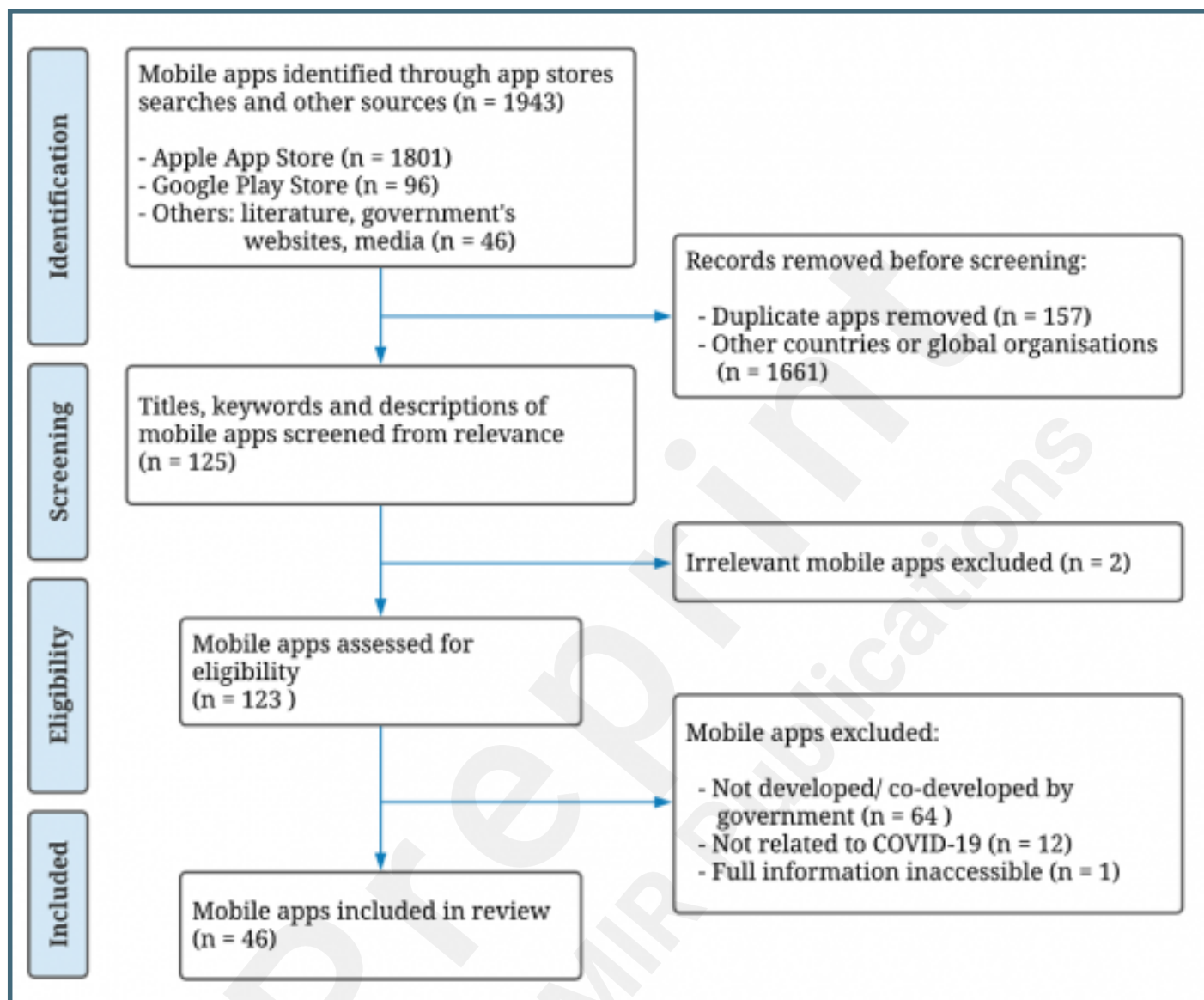
18

50. Hart V, Siddarth D, Cantrell B, et al. Outpacing the virus: Digital response to containing the spread of COVID-19 while mitigating privacy risks. Edmond J. Safra Center for Ethics. https://ethics.harvard.edu/outpacing-virus [accessed Jun 21, 2021].

51. O'Neill PH. No, coronavirus apps don't need 60% adoption to be effective. MIT Technology Review. https://www.technologyreview.com/2020/06/05/1002775/covid-apps-effective-at-less-than-60-percent-download/ [accessed Jun 21, 2021].

52. Beaunoyer E, Dupéré S, Guitton MJ. COVID-19 and digital inequalities: Reciprocal impacts and mitigation strategies. Computers in human behavior. 2020 Oct;111:106424. PMID: 32398890.

53. Lee C, Rogers WA, Braunack-Mayer A. Social justice and pandemic influenza planning: The role of communication strategies. Public Health Ethics. 2008;1(3):223-234. doi:10.1093/phe/phn031.

54. Van Lancker W, Parolin Z. COVID-19, school closures, and child poverty: a social crisis in the making. The Lancet Public Health 2020;5(5):e243-e244. PMID: 32275858.
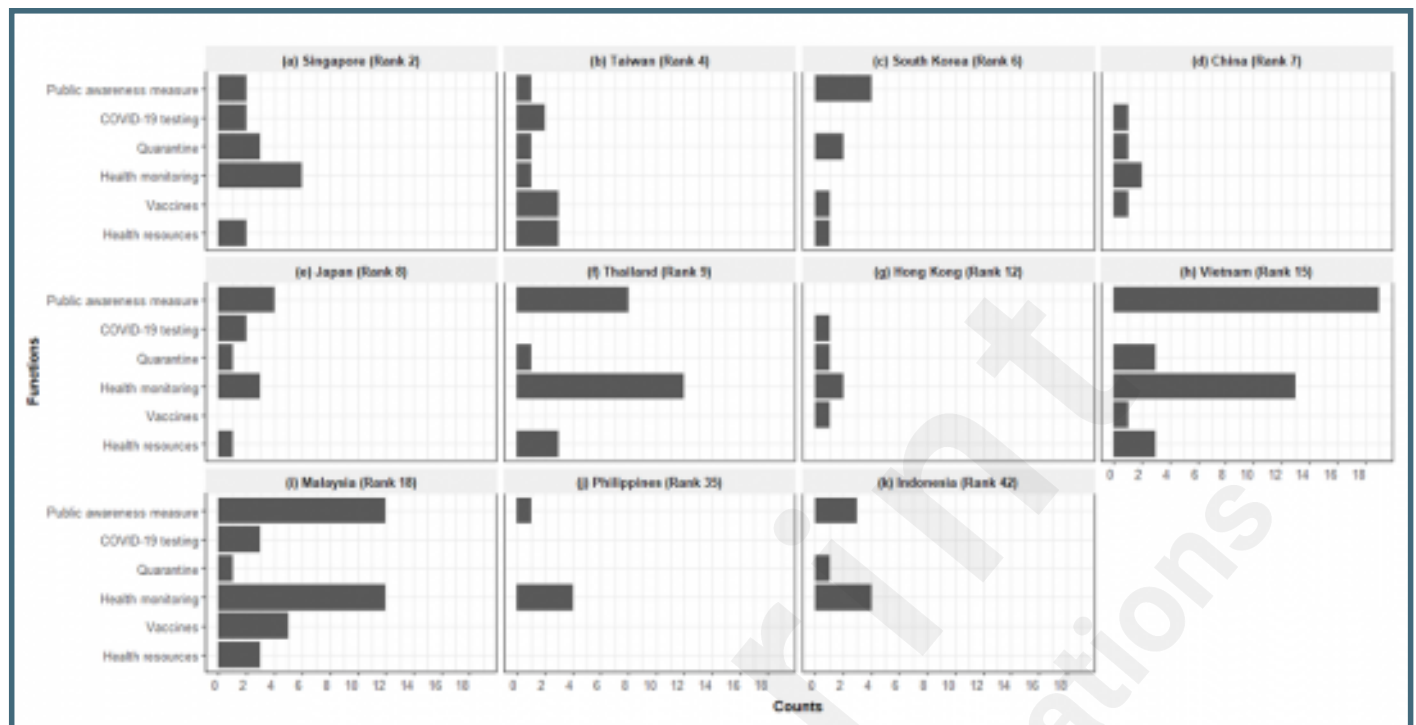
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Supplementary Files

Figures

PRISMA flowchart of the search process.

Identification	Mobile apps identified through app stores searches and other sources (n = 1943) - Apple App Store (n = 1801) - Google Play Store (n = 96) - Others: literature, government's websites, media (n = 46)	Records removed before screening: - Duplicate apps removed (n = 157) - Other countries or global organisations (n = 1661)
Screening	Titles, keywords and descriptions of mobile apps screened from relevance (n = 125)	Irrelevant mobile apps excluded (n = 2)
Eligibility	Mobile apps assessed for eligibility (n = 123)	Mobile apps excluded: - Not developed/ co-developed by government (n = 64) - Not related to COVID-19 (n = 12) - Full information inaccessible (n = 1)
Included	Mobile apps included in review (n = 46)	

Overview of the key functions of included apps by governments.

Governments COVID-19 policy commencement dates and release dates of the included apps.
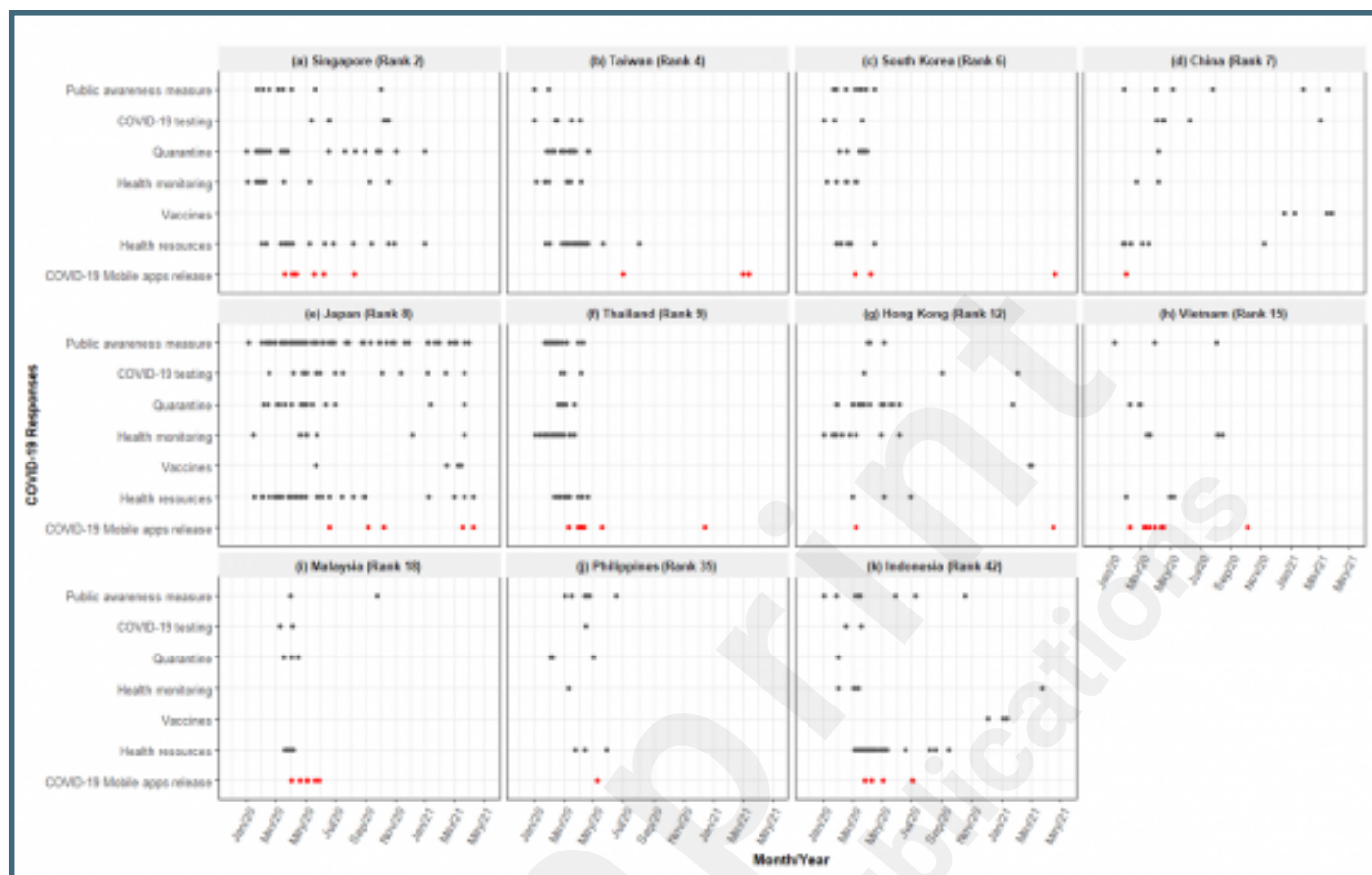
Multimedia Appendixes

Bloomberg's COVID-19 Resilience Ranking (March 2021).
URL: http://asset.jmir.pub/assets/a9aabbe8e6383817fe4263b074a7dab0.docx

List of included mobile apps and their associated characteristics.
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List of included mobile apps with their associated functions.
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