I. Introduction

The unprecedented speed at which coronavirus disease 2019 (COVID-19) was declared a pandemic warranted concerted efforts for dealing with the disease from multiple fronts, including health informatics. COVID-19-related apps were developed from all parts of the globe, coming from both middle-income and developing countries. Silva categorized COVID-19-related apps into five clusters: informational, self-assessment/medical reporting, contact tracing, multi-purpose apps, and others [1]. In the Arabian Gulf countries of Oman, Kuwait, Bahrain, and United Arab Emirates, a total
of six COVID-19-related apps were developed from March 2020 to April 2020. All these apps used global positioning system (GPS) and Bluetooth technology to enhance preventive measures through the inclusion of a feature for tracing positive cases and notifying people nearby of potential exposure to the virus [1]. As with other countries in the Arabian Gulf, Saudi Arabia also took several healthcare initiatives to address COVID-19 [2]. While extensive research has been conducted on the COVID-19 pandemic, there have been no studies of the healthcare informatics sector in the context of the pandemic. The purpose of this paper is to fill this gap in research and, more specifically, to examine the official healthcare informatics applications implemented in Saudi Arabia in light of their role in addressing the COVID-19 pandemic.

II. Methods

This is a case study of official healthcare informatics programs and apps developed in Saudi Arabia before and during the COVID-19 pandemic. The inductive approach of qualitative content analysis (QCA) was the method used [3]. The data used come from a desktop review of documents and actual testing of the programs. Information was retrieved from the Ministry of Health (MOH) website, via published literature, and via the gray literature (such as news items, internal memos, official announcements, etc., in English and Arabic). The Google search terms used to identify other COVID-19-related apps developed elsewhere included “COVID-19 apps” and “Corona apps.”

According to the QCA method, analysis of the data obtained on various software programs was carried out through categorization and compilation [3]. For categorization, we developed a matrix for abstracting information about the different apps and programs.

The compilation of data and discussion were based on information summarized using this matrix. For benchmarking, we reviewed COVID-19-related apps developed elsewhere, paying special attention to apps developed in neighboring Arabian Gulf countries due to their similar socio-economic and cultural contexts.

III. Results

The details of the official apps developed by the government before COVID-19 pandemic are shown in Table 1, and the apps developed to address the COVID-19 pandemic after it had already begun are shown in Table 2. Six apps had been developed before the COVID-19 pandemic: the Health Electronic Surveillance Network (HESN) (2012), 937 (2013), SEHA (2017), Asafny (2017), Mawid (2017), and Sehataty (2019). The apps were all developed by the MOH, except for Asafny, which was developed by Red Crescent. The MOH apps are targeted to all citizens and residents, while the Red Crescent app is a stand-alone app that is targeted only to those seeking emergency care via the Red Crescent. HESN is a special electronic system for public health and disease surveillance. As of 2021, over 47 communicable disease groups are exclusively reported using HESN. The 937 app provides 24/7 telephone-based health services for both medical emergencies and regular health consultations, while the SEHA app is designed to offer online medical consultation services [4]. The Asafny app is used to provide a quick response to people in emergency situations, and the Mawid app is used to book and manage medical appointments. Lastly, the Sehataty app links patients to relevant health information and provides them with medical consultations with a variety of health professionals.

With the advent of the COVID-19 pandemic, in addition to the older MOH apps being modified to address the pandemic, new apps were developed as well. HESN was modified in April 2020 to allow for easy reporting of COVID-19 cases and characteristics related to the case. It is mandatory by law in Saudi Arabia for healthcare centers to report all cases of communicable diseases, including COVID-19, through the HESN system. Both SEHA and Mawid were modified to provide information about COVID-19 awareness. SEHA provides assessment services that employ artificial intelligence methods, while Mawid has a self-assessment survey. In addition, Mawid includes options for accessing 937 or SEHA. Sehataty also allows users to book a COVID-19 test appointment if they have an account with Mawid.

During the COVID-19, three new official apps were developed in 2020: Tetamman (March), Tawakkalna (April), and Tabaud (June). It is mandatory for all citizens and residents to activate the Tawakkalna app whenever visiting stores and institutions during the pandemic. It has many services, including tools for requesting travel permits when curfews are in place, requesting personal permits, requesting gathering permits, checking the status of a COVID-19 test, accessing education services, and accessing dependent services. The Tetamman app provides COVID-19 test results and allows one to check for symptoms on a daily basis. It also has an educational content library and provides alerts. The Tabaud app notifies individuals if they had been exposed to someone with a confirmed COVID-19 case. It also enables individuals...
|                      | HESN | SEHA          | Asafny       | Mawid        | Sehhaty     |
|----------------------|------|---------------|--------------|--------------|-------------|
| Date of development  | Oct 1, 2012 | May 14, 2013 | Mar 12, 2017 | Aug 17, 2017 | Dec 29, 2017 | Aug 4, 2019 |
| Division that comissions the app | Ministry of Health | Ministry of Health | Ministry of Health | Saudi Red Crescent Authority | Ministry of Health | Lean Business Services Company |
| Linked with national ID/Absher? | Linked with national ID, Iqama, or passport number | No | No | No | Linked with Absher | Linked with Absher |
| **Aims**            | Provide a one-stop platform for all hospitals in Saudi Arabia to detect, respond, and control communicable diseases. | Provide 24/7 telephone call service for emergencies and normal health consultations [4]. | Offer online medical consultation services. | Provide a quick response to people in emergency situations. | Enable users to book, cancel, or reschedule medical appointments and manage referrals. | Link patients with health information and provide them with medical consultation from a variety of health professionals. |
| **Beneficiaries**   | All governmental and private hospitals | All citizens and residents | All citizens and residents | Citizens, residents, and individuals with disabilities | All citizens and residents | All citizens and residents |
| **Services included** | Report all notifiable infectious diseases immediately such as cholera; or weekly, such as chickenpox. | Provide medical consultation by certified physicians. | Receive complaints and feedback related to the Ministry of Health (MOH). | Request emergency help from the Saudi Red Crescent Authority by identifying one’s location on a map. | Book appointments | -Tele-consultation |
|                      | -Clarify the results of COVID-19 swabs. | -Offer advice and guidelines for poisoning cases. | -Identify a list of all health centers, hospitals, and pharmacies nearby. | -Issue a sound and flash warning to alert people nearby. | -Reschedule appointments | -Search for medication and the nearest pharmacies that provide it. |
|                      | -Offer online medical consultation through audio-video by MOH’s certified specialists, or using artificial intelligence technology. | -Request emergency help from the Saudi Red Crescent Authority by identifying one’s location on a map. | -Identify a list of all health centers, hospitals, and pharmacies nearby. | -Issue a sound and flash warning to alert people nearby. | -Manage referrals | -View issued sick leave and prescribed medication. |
|                      | -Request emergency help from the Saudi Red Crescent Authority by identifying one’s location on a map. | -Identify a list of all health centers, hospitals, and pharmacies nearby. | -Issue a sound and flash warning to alert people nearby. | -Book an appointment in primary healthcare centers. | -Registration of vital signs | -School screening results and steps tracker |
Table 1. Continued

| Feature related to COVID-19 added later | HESN | 937 | SEHA | Asafny | Mawid | Sehhaty |
|----------------------------------------|------|-----|------|--------|-------|---------|
| Include a record for all COVID-19 patients who did a swab. | Guide patients 24/7. | Include awareness info about COVID-19. | Provide 4-hour emergency permits that can be used during curfews. | Provide COVID-19 awareness info, conduct self-assessment surveys, and provide options after test results: contact 937 or book test in Tetamman clinics. | Allows users to book an appointment for a COVID-19 test. |

| Estimated monthly global downloads (as of February 27, 2021) | N/A | N/A | Google Play: 8,310  Apple store: 15,762 | Google Play: 1,096  Apple store: 1,692 | Google Play: 46,367  Apple store: 43,915 | Google Play: 254,612  Apple store: 90,974 |

| Required operating system | N/A | N/A | iOS 9.0 or later  4.3 Android and up | iOS 10.0 or later  4.2 Android and up | iOS 10.0 or later  5.0 Android and up | iOS 12.0 or later  5.0 Android and up |

| Available languages (as of February 27, 2021) | 3 languages (Arabic, English, and Urdu) | 2 languages (Arabic and English only) | 9 languages (Arabic, English, Bengali, Filipino, French, Indonesian, Malay, Turkish, and Urdu) | 1 language (English only) | 2 languages (Arabic and English only) |

| Features related to COVID-19 added later | HESN | 937 | SEHA | Asafny | Mawid | Sehhaty |
|----------------------------------------|------|-----|------|--------|-------|---------|
| Include a record for all COVID-19 patients who did a swab. | Guide patients 24/7. | Include awareness info about COVID-19. | Provide 4-hour emergency permits that can be used during curfews. | Provide COVID-19 awareness info, conduct self-assessment surveys, and provide options after test results: contact 937 or book test in Tetamman clinics. | Allows users to book an appointment for a COVID-19 test. |
|                  | HESN                  | 937                  | SEHA                  | Asafny                  | Mawid                  | Sehhaty                  |
|------------------|-----------------------|----------------------|-----------------------|-------------------------|-------------------------|--------------------------|
| **Advantages**   | - Each patient has one record only. | - Available 24/7. | - Schedules appointments at any nearby primary care centers. | - Records the patient's history, diseases, and prescribed medications once downloading the app to help healthcare providers when care is needed. | - User-friendly. | Linked with health app in iPhone. |
|                  | - Enable checking patients' history before admission or outpatient visits. | - Does not require a smart phone. | - Can schedule consultations for another person. | - High accuracy at identifying the patient's location. | - Free self-assessment. | - Uses location only if you want to know the nearest clinic. |
|                  | - Includes all notifiable infectious diseases. | - Provide direct advice to any citizens in all sectors. | - Indicates the expected wait time for a virtual consultation. | - Supports individuals with disabilities. | - Survey can be completed once per day. | |
|                  | - Mandatory for all hospitals. Carries a 100,000 SAR penalty for failure to report cases. | | - Provides options for receiving consultations immediately or by booking an appointment within 2 days. | | | |
|                  | | | - Cannot submit more than one consultation until the process is finished. | | | |
|                  | | | - The number of consultations will not be reduced until one receives a consultation, even if a booked consultation is canceled. | | | |
During the COVID-19 pandemic, Saudi Arabia used several healthcare informatics apps among the multiple tools to mitigate the effects of the pandemic. Some of the apps were developed specifically to address different aspects of the COVID-19 pandemic, while other were developed before the pandemic. Our examination of the role of healthcare informatics in Saudi Arabia’s COVID-19 response uncovered both positive and negative points. The adaptation of HESN for reporting COVID-19 cases is a positive decision as it helps to standardize data collection for rapid analysis. Similarly, the adaptation of older apps designed before the COVID-19 pandemic to address certain aspects of the pandemic was also a positive decision as existing resources were able to be used. The development of three apps during the COVID-19 pandemic was very successful. The Tawakkalna app was broader and highly inclusive, while the Tatamman and Tabaud apps had more specific functions. Tabaud is comparable to other similar apps developed in the Gulf region, such as BeAware (Bahrain) and Shlonik (Kuwait). Unlike these apps, Tabaud relies on Bluetooth technology rather than GPS technology, which is an advantage of the Saudi Arabia-developed COVID-19 apps. The emergence of the Saudi Red Crescent Authority (SDAIA) as a developer of and stakeholder in Saudi Arabian healthcare informatics is a merit. This similar to the way that COVID-19-related apps were developed in Bahrain, where the BeAware app was developed by the Information and eGovernment Authority, and in Kuwait, where the Shlonik app was developed by the Kuwait Central Agency for Information Technology.

A few shortcomings were observed as well. The HESN system was only adapted to address factors related to COVID-19 in April 2020. Prior to this, data related to COVID-19 from the HESN system were unstructured and disorganized. Tabaud was launched in June 2020, 2 months after the launch of the Gulf Cooperation Council apps. There is a technical issue with the Tawakkalna app that results in a delay of several days before a user infected with COVID-19 is shown as being infected in the app using the color-coded system. This delay can have a potentially damaging effect, as the infected person might expose others to the virus during this time before a user infected with the COVID-19 app that results in a delay of several days before a user infected with COVID-19 is shown as being infected in the app using the color-coded system. This delay can have a potentially damaging effect, as the infected person might expose others to the virus during this time.

Table 1. Continued 3

| App     | Drawbacks                                                                 | SAR | Mawid       | Sehhaty       |
|---------|---------------------------------------------------------------------------|-----|-------------|---------------|
| HESN    | Technical issues, including freezing and errors.                         | 937 | -Does not show COVID-19 test results or other test results. | -Must have an account with the Mawid app. |
| 937     | Provides service only to patients eligible to be treated according to the MOH. | SEHA| -Linked to Saudi Red Crescent Authority only. | -Tele-consultation and COVID-19 testing are not available. |
| SEHA    | -Limited consultations per month (3 consultations maximum).               | Asafny | -Not linked to any files in MOH hospitals. | |
| Asafny  | -Not linked to any files in MOH hospitals.                                | Mawid | -If a person has symptoms related to COVID-19, the person will be provided with only a suggestion, to contact 937 or SEHA, or go directly to the nearest clinic; full responsibility rests on the individual. | |
| Mawid   | -Does not show COVID-19 test results or other test results.               | Sehhaty | -Must have an account with the Mawid app. | |
| Sehhaty | -Tele-consultation and COVID-19 testing are not available.                | - | |

COVID-19: coronavirus disease 2019, HESN: Health Electronic Surveillance Network, SAR: Saudi Arabian Riyal, SRCA: Saudi Red Crescent Authority.

*Data from https://42matters.com/app-market-data.

Table 1. Continued 3

| Drawbacks                                                                 | SAR | Mawid | Sehhaty |
|---------------------------------------------------------------------------|-----|-------|---------|
| Technical issues, including freezing and errors.                         | 937 | -Does not show COVID-19 test results or other test results. | -Must have an account with the Mawid app. |
| Provides service only to patients eligible to be treated according to the MOH. | SEHA| -Linked to Saudi Red Crescent Authority only. | -Tele-consultation and COVID-19 testing are not available. |
| -Limited consultations per month (3 consultations maximum).               | Asafny | -Not linked to any files in MOH hospitals. | |
| -Not linked to any files in MOH hospitals.                                | Mawid | -If a person has symptoms related to COVID-19, the person will be provided with only a suggestion, to contact 937 or SEHA, or go directly to the nearest clinic; full responsibility rests on the individual. | |
| -Does not show COVID-19 test results or other test results.               | Sehhaty | -Must have an account with the Mawid app. | |

COVID-19: coronavirus disease 2019, HESN: Health Electronic Surveillance Network, SAR: Saudi Arabian Riyal, SRCA: Saudi Red Crescent Authority.

*Data from https://42matters.com/app-market-data.
| Date of development     | Tetamman       | Tawakkalna                              | Tabaud (COVID-19 KSA) |
|-------------------------|----------------|----------------------------------------|-----------------------|
| Mar 25, 2020            |                | Apr 6, 2020                             | Jun 12, 2020          |
| Division that commissioned the app | Ministry of Health | The National Information Centre (NIC) and the Saudi Data and Artificial Intelligence Authority (SDAIA) | The National Information Center (NIC) and the Saudi Data and Artificial Intelligence Authority (SDAIA) |
| Linked with national ID/Absher? | Linked with national ID | Linked with Absher | Linked with Absher |
| Aims                     | To provide protection and healthcare for citizens and residents who were advised to isolate or quarantine to ensure a good recovery. | To manage curfews and to contain the spread of COVID-19. | To preserve the health and safety of citizens and residents from the danger of the spread of COVID-19, and to support the government in tracking COVID-19 cases. |
| Beneficiaries            | -People who have contact with positive cases. -Suspected cases. -Arrivals from abroad. -Confirmed cases in home or domestic quarantine. | Citizens and residents; mandatory to enter any of the public places. | Citizens and residents; mandatory to enter any of the MOH’s buildings. |
| Services included        | Services provided in the application: -COVID-19 test results. -Direct contact with 937 to ask for help. -Daily symptoms check-up. -Ability to add data about contact with positive cases. -Educational content library. -Countdown indicator for isolation days. -Alerts through notifications, text messages, and automated calls. | -Request permits for freedom of movement during curfews (4 hours per week): Supplies, Temporary permit for a driver, Emergency medical permit request, and Jogging permit. -Report suspected cases for the individual himself or for another person by providing the name, location, and phone number, and answering five health questions related to COVID-19 symptoms. | -Notify individuals if they previously came into contact with a positive case of COVID-19. -Links one’s health forms with the MOH to provide them with the needed medical support. -Enable individuals to voluntarily share test results with people they previously contacted in the past 14 days. |
| Estimated monthly global downloads (as of February 27, 2021)* | Google Play: 78,552 Apple store: 39,983 | Google Play: 3,365,543 Apple store: 492,781 | Google Play: 811,996 Apple store: 140,463 |
| Required operating system | iOS 11 or later 5.0 Android and up | iOS 10 or later 6.0 Android and up | iOS 13.5 or later 6.0 Android and up |
| Available languages (as of February 27, 2021) | Tetamman | Tawakkalna | Tabaud (COVID-19 KSA) |
|-----------------------------------------------|----------|-----------|---------------------|
| 2 languages (Arabic and English)              |          | 7 languages (Arabic, English, Bengali, Filipino, Hindi, Indonesian, and Urdu) | 22 languages (Arabic, English, Bengali, Filipino, Hindi, Indonesian, Urdu, Amharic, Burmese, French, German, Japanese, Kazakh, Korean, Malay, Russian, Portuguese, Spanish, Simplified Chinese, Sinhalese, Swahili, and Turkish) |
| Advantages                                    |          |           |                     |
| -User friendly.                               | -User friendly. | -User-friendly. |                           |
| -Uses location all the time.                 | -Easy to learn. | -Provides access to MOH COVID-19 dashboard. | -Provides COVID-19 awareness info. |
| -Provides COVID-19 awareness info.           | -Provides COVID-19 awareness info. |                     |                     |
| Drawbacks                                     |          |           |                     |
| -Uses location, but if one moves from the desired location, the alert notifies one to return. | -Only limited to people with Absher account. | -Sharing results with previously contacts is voluntary. |                           |
| -There is a place for results with poor functionality, and if one wants to change the location, one must ask for help to change it. | -Limited permit options. | -Only effective if all citizens download the app. |                           |
| -Quarantine countdown and the daily survey are the only services that work as-is when you open the app. | -Technical issues: cannot identify some people's phones due to them having been jailbroken. | -Mandatory only within MOH buildings. |                           |
| -The survey is more of a satisfaction survey than one that reflects actions. | -Temporary permits for drivers are limited to students and workers who already have a permit from the Ministry of Interior. | -Reporting results are the sole responsibility of the individual; not connected with MOH system. |                           |
| COVID-19: coronavirus disease 2019, MOH: Ministry of Health. |

*Data from https://42matters.com/app-market-data.
without being officially deemed “infected.” Lastly, while some of the apps include interconnected features, one integrated app would be more effective than several loosely connected apps. In Qatar, Bahrain, Kuwait, and Oman only one app was used for COVID-19 surveillance, assessment, and awareness.

In conclusion, the purpose of this paper was to examine the official healthcare informatics in Saudi Arabia in the context of their role in addressing the COVID-19 pandemic. Overall, we found that there were more strengths than shortcomings in the role played by healthcare informatics in Saudi Arabia’s handling of COVID-19. While six apps were developed from 2012 to 2019, three apps were developed within a span of only 3 months during the COVID-19 pandemic, and all of the different apps served different needs. With the emergence of COVID-19, old apps were adapted to address factors related to the pandemic. While most of the apps developed during the pre-COVID-19 era were commissioned by the Ministry of Health, a new stakeholder, the SDAIA, has entered the field with the emergence of COVID-19. We see this as a positive development that is similar to the approach adopted by other Arabian Gulf countries. One study limitations is the frequency with which apps are updated, which may result in differences between the present-day status of apps and the status of apps as described in this study and the lack of centrality for accessing information about the apps discussed in this study.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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