Environment, Society and Business Review (ESBR) Vol. 1, No. 1 (February 2026) | pp. 66-82
ISSN: 3152-8716 https://doi.org/10.66776/ESBR.2026.1.1.66-82

DIGITAL HEALTH INNOVATIONS IN PANDEMIC RESPONSE: A CASE STUDY OF COVID-19 MANAGEMENT IN SAUDI ARABIA

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Article type: Original Research
Received: 31 August 2025 | Accepted: 05 December 2025 | Published online: 08 March 2026

Abstract

The COVID-19 pandemic drove unprecedented adoption of digital health innovations in the Gulf Cooperation Council (GCC) region, especially in Saudi Arabia. Saudi Arabia's healthcare system leveraged digital technology, transforming its pandemic response. This research examines the impact of digital applications such as Tawakkalna, Tabaud, Sehhaty, Mawid, and Tetamman on GCC healthcare, focusing on Saudi Arabia during and after the pandemic. We analyzed 2020-2023 data from the United Nations Office for the Coordination of Humanitarian Affairs (OCHA), using JAMOVI for statistical analysis and Power BI for data visualization. Results show Tawakkalna effectively monitored and controlled COVID-19 spread in Saudi Arabia. Significant differences were found between Saudi Arabia and other GCC countries ($p < .001$), and between pre- and post-digitalization periods in Saudi Arabia ($p < .001$). The IBM-KSA model estimated that Tawakkalna prevented over 1.3 million cases, nearly 28,000 deaths, and 112,000 hospital days. Tech-health policy integration offers a promising framework for future health challenges. This study contributes to the existing literature on digital innovations in healthcare systems and highlights Saudi Arabia's leadership in digital health transformation.

Keywords: *COVID-19; digitization; pandemic management; GCC; Saudi Arabia; Tawakkalna; technology adoption; healthcare infrastructure*

1. Introduction

The COVID-19 pandemic, an unprecedented global health crisis, accelerated the digital health industry's transformation, driving innovation and adoption of cutting-edge healthcare technology. According to the statistical report from Johns Hopkins University, approximately 248 million individuals were diagnosed with the virus during the first two years of the pandemic, resulting in approximately five million reported deaths globally (CSSE, 2022). The outbreak forced governments to take drastic measures, leveraging technology to reduce infection cases and control its spread.

Nevertheless, the COVID-19 epidemic accelerated digital health adoption, with telehealth mobile applications, playing a key role in patient tracking and healthcare delivery The Kingdom of Saudi Arabia (KSA) was one of the countries that quickly responded to the pandemic, taking proactive measures such as postponing various activities, introducing a digital check on March 5, 2020, restricting travel to neighboring countries, and suspending international flights (Al-Tawfiq & Memish, 2020). In Saudi Arabia, the spread of the virus has been controlled partly through telehealth applications, such as Seha, Mawid, Tawakklna, Tabaud, and Tetamman (Dingel & Neiman, 2020), which played a key role in healthcare delivery and patient tracking. Despite the increasing adoption of telehealth, there is a

ISSN: 3152-8716 https://doi.org/10.66776/ESBR.2026.1.1.66-82

noticeable difference in perceptions and utilization rates of telehealth among Saudi Arabian healthcare professionals (Machkour et al., 2023). Some medical professionals view online healthcare as beneficial and private, but others face challenges like a lack of time or training (Dhingra & Dabas, 2020).

Despite the emergent literature on telehealth and the widespread adoption of telehealth technology during the COVID-19 pandemic, there is a dearth of research exploring specific factors influencing telehealth adoption in Saudi Arabia (Alakhrass et al., 2021). To fill this research gap, this study aims to assess the effectiveness of digital applications in managing COVID-19 in Saudi Arabia and identify best practices by comparing Saudi Arabia's digital response with other Gulf Cooperation Council (GCC) countries.

This study confirms the effectiveness of digital technology in managing the pandemic in Saudi Arabia and advances the literature in several ways: Firstly, it provides statistical evidence for Saudi Arabia and other GCC countries, shifting the focus from perceptions and acceptances to real outcomes. Secondly, it introduces a new concept where digital health applications, such as Tawakkalna, are not only used as tools for service delivery but are also integrated with regulatory mechanisms such as immunity passports. Thirdly, by comparing pre- and post-digitalization phases, it makes an important contribution to digital transformation theory with respect to crisis management.

The paper is organized as follows: Section two presents a review of the relevant literature. Section three outlines the research methodology. The findings and discussions are presented in section four. Sections five and six provide the limitations and conclusion, respectively. Finally, section seven lists the references.

2. Literature Review

With Internet of Things (IoT) innovations, such as smart homes, smart lamps, and smart security systems that operate via smartphones, technology has become an integral part of our lives. This case study demonstrates how digital tools have revolutionized and integrated human lives, providing convenience in daily life (Machkour et al., 2023; Shaikh et al., 2014). All policies, whether in governments or private companies, must adapt and evolve in line with rapid technological advancements to sustain businesses' and societies' efficiency, longevity, and profitability. The digital revolution is changing the way we work in business and daily life (Baniawwad et al., 2023; Hu et al., 2024). Many companies are digitalizing their daily operations, significantly optimizing costs and manpower needs. Almost all our daily activities involve the use of technology, including connecting with friends, online shopping, sports, working out, using reminders, calendars, and emails, booking travel, and even using applications that aid sleep and enhance driving experiences (Rafiq et al., 2017).

Undoubtedly, despite the pandemic's catastrophic impact on people and companies, a bright spot that underscored the COVID-19-induced acceleration of digitization. Significant changes in digitalization implementation, including remote working, online meetings, and the normalization of the working-from-home concept, have resulted from this. In the United States (US), around 37% of work can be done entirely from home. In fact, 4% of all

ISSN: 3152-8716 https://doi.org/10.66776/ESBR.2026.1.1.66-82

American workers worked "at least half the time" from home, indicating the potential for remote work to become more prevalent not only in the US but also in other countries in the world (Dingel & Neiman, 2020).

2.1. Digital Development in the Medical Industry

Since the COVID-19 pandemic, medical technology (medtech) has grown at an accelerated rate, raising expectations of medtech companies to empower patients with greater authority and flexibility regarding their healthcare information and life expectancy (Aji et al., 2020). The growth of medtech is essential, given the increasing life expectancy, rising number of patients with chronic diseases, and the escalating costs of contemporary therapies. According to the World Health Organization (WHO), a global shortage of health workers persists (WHO, 2022). The 2016 Global Strategy on Human Resources for Health Workforce 2030 predicted a global shortage of 18 million health workers by 2030 (Boniol et al., 2022). However, expansion of medtech and digitization in the health care system can help mitigate this shortage of medical personnel.

The penetration of mobile phones, smartphones, and internet connectivity has been increasing in terms of hardware, alongside emerging medical technologies like virtual and augmented reality, robots, genomics, telemedicine, and artificial intelligence (Ben Dhaou et al., 2021).This continuous process of digital development began in the 19th century, when the use of phone and video calls for medical diagnosis first became apparent and proved effective (Diab et al., 2022; Senbekov et al., 2020).The development of artificial organs, DNA sequencing, and ultrasound imaging techniques commenced in the second half of the 20th century (Senbekov et al., 2020). The technological advancements made between 1950 and 1999 paved the way for the success of digital health, enabling it to advance beyond telemedicine and diagnostics. Furthermore, the 1980s and 1990s are often referred to as the "Golden Times" (Sarantod et al., 2021).

2.2 Digitalization in KSA during the COVID-19 Pandemic

Rapid socioeconomic transformation in Saudi Arabia has led to significant revisions in the country's public focus areas and broad health reform (Moshashai et al., 2020). In 2015, the Kingdom of Saudi Arabia (KSA) unveiled the National Transformation Program (NTP), an executive initiative aimed at enhancing healthcare delivery through technological innovation, as part of Saudi Vision 2030 (Dhingra & Dabas, 2020). Approximately 84% of studies believe that using technology to manage their health is crucial. To manage their health, people utilize websites (44%), apps (40%), social media (41%), and smartwatches (14%), indicating a growing demand for digital health tools in Saudi Arabia (Al Kuwaiti et al., 2018). The public's adoption of digital technology has aided Saudi Arabia in managing the COVID-19 pandemic effectively.

Furthermore, in response to the COVID-19 outbreak on March 3, 2020, the Saudi Arabian government, like other countries worldwide, implemented mobility restrictions and locked down numerous governmental and private enterprises. In this curfew situation, digital technology was an ideal solution for providing essential health services (Hassounah et al., 2020). The Ministry of Health (MoH) launched various digital applications and online services to combat and limit COVID-19 contractions, including the MoH Call (937) Service Center, which responds to COVID-19-related queries. Additionally, in 2020, the Saudi

ISSN: 3152-8716 https://doi.org/10.66776/ESBR.2026.1.1.66-82

Ministry of Communications and Information Technologies initiated the "Move to Tech" program in response to COVID-19, prompting the use of existing digital tools and the development of new ones such as Sehhtay, Mawid, Tawakkalna, Tabaud, and Tetamman in delivering healthcare and tracking COVID-19 patients, as shown in Table 1 below.

These applications, widely used and accepted by the public in Saudi Arabia, rapidly evolved during the COVID-19 pandemic, playing a crucial role in mitigating its spread. A survey conducted by King Saud University revealed that Tawakkalna was the most popular app during COVID, with 96% of users, followed by Tabaud (68.6%), Sehhaty (64.2%), Mawid (61.4%), and Tetamman (54.4%) (Almufarij & Alharbi, 2022). Another study examined users' acceptance of these applications, with key performance indicators (KPIs) covering effectiveness, simplicity, user satisfaction, mission fulfillment, usefulness, and helpfulness. In general, 86.6% of Tetamman respondents, 80.5% of Tabaud respondents, and 90% of Tawakkalna respondents stated that these tools operate in accordance with the aforementioned KPIs (Hidayat-ur-Rehman et al., 2021).

Table 1: Main Health Applications Used in the Kingdom of Saudi Arabia During the Pandemic

App Name	English Meaning	Purpose
Tawakkalna	We trusted	During curfew hours, the system authorizes the public and employees to obtain e-permits.
Tabaud	Distancing	It alerts those in contact with coronavirus-infected individuals so they can request immediate medical assistance from the MoH.
Sehhaty	My Health	Various health agencies in the kingdom use the system to access medical e-services and retrieve their health information.
Mawid	Appointment	Various primary healthcare facilities use it to book, change, or cancel appointments.
Tetamman	Rest assured	During their quarantine period, citizens and residents who are self-isolating use it to protect themselves and speed up their recovery.

Tawakkalna is a requisite immunity passport that controls entry to public places, and only users who had already recovered from COVID-19 or had had two vaccinations were permitted entry to public areas with the immunity passport at the peak of COVID spread. For easy understanding, the Tawakkalna app displays a screen with different colors, each having a distinct meaning. For instance, as shown in Figure 1, the black screen on the far left indicates a lack of internet connection or the need to adjust settings to enable location

ISSN: 3152-8716 https://doi.org/10.66776/ESBR.2026.1.1.66-82

sharing. The green hue signifies an individual's recovery or vaccination status, allowing them to access any facility. The orange color indicates that an individual has been exposed to another COVID-positive case and is required to self-isolate. Lastly, the red color signifies the individual's COVID infection, prohibits them from entering facilities, and advises them to practice self-isolation (Hidayat-ur-Rehman et al., 2021).

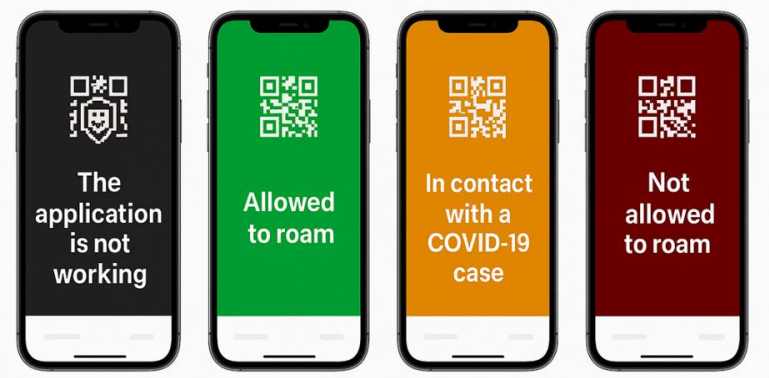

Figure 1: Color Code Indicating the Status of the Tawakkalna App

Furthermore, we used a specific Individual-Based Model (IBM) for Saudi Arabia, called the IBM-KSA model, which simulates how about 34 million people in KSA interact with each other through a contact network. We chose the network structure over an agent model to recreate a population with traits similar to those of the real KSA population, as it reduces computing effort and allows for variability and contacts among people. We created the model using demographic data. The IBM-KSA also explains variations in contact interactions between age groups, specifically those aged 18 to 21, as well as migration flux between cities, a major factor contributing to the spread of COVID-19 across the country. This model concluded that the use of the Tawakkalna passport was able to prevent 1,343,099 cases, 198 hospitalizations, 112,322 hospital days, and 27,967 fatalities (Al-Ansari, 2020).

2.3 GCC Countries' Response to COVID-19

The same unfortunate circumstances forced other GCC countries to take action to stop the spread of COVID-19. As of May 18, 2020, there were 92,171 active cases across the six GCC nations, with 841 (0.6%) fatalities and 54,300 (36.9%) recovered individuals. This quantity translates to 550.4 recoveries, 934.3 active cases, and 8.5 fatalities per million people. In terms of total cases, Saudi Arabia records the highest number, followed by Qatar, the United Arab Emirates, Kuwait, Bahrain, and Oman (WHO, 2022).

The GCC responded to COVID-19 by implementing strategies such as lockdowns and travel restrictions. Bahrain was the first country to act promptly to stop the spread of COVID-19. The UAE also reacted swiftly to the pandemic in February, treating all cases as emergencies just two days after the discovery of the first COVID-19 case on January 29, 2020. Additionally, the UAE government chose to treat COVID-19 patients free of charge. School closures, flight cancellations, curfews, and the opening of drive-through COVID-19 testing centers followed. To effectively combat COVID-19, the Ministry of Health (MoH)

ISSN: 3152-8716 https://doi.org/10.66776/ESBR.2026.1.1.66-82

developed a chatbot service named "Virtual Doctor for COVID-19." People could also access the "Doctor for Every Citizen" app for information and services relating to COVID-19. During the pandemic, the National Crisis and Emergency Management Authority (NCEMA) utilized the "Weqaya" platform to raise public awareness (Hidayat-ur-Rehman et al., 2021). Behavioral interest in using mobile devices correlated significantly and positively with perceived utility, perceived ease of use, and perceived COVID-19 risk (Nair et al., 2024).

The GCC countries initially implemented mitigating measures, but suppression measures, such as curfews and complete lockdowns, quickly followed. In the meantime, Bahrain and the UAE introduced apps called "BeAware" in Bahrain and "ALHOSN" in the UAE, similar to "Tawakkalna" in Saudi Arabia. People used these apps to check their COVID-19 status, schedule appointments, and view their ID cards (Alanezi et al., 2021). From a digital governance perspective, digital health applications are instruments of social regulation and compliance, not just technology. Tawakkalna immunity verification features shift voluntary technology adoption to digital governance. Crisis management theory emphasises coordination, transparency, and compliance. The Saudi case provides empirical evidence of digital infrastructures operationalizing these theories through combining technology innovation with policy regulation to combat health crises effectively.

1. Research Methodology

The methodology used in this research is the best fit for its objective, leveraging objectives, abundant, and readily available quantitative COVID-19 data to drive insights, rather than relying on subjective interpretation. This methodology compares COVID-19 trends in Saudi Arabia and GCC countries using quantitative data, involving the following steps: First, identify trustworthy data sources that provide information on COVID-19 cases, deaths, and recoveries for Saudi Arabia and the GCC nations. The World Health Organization (WHO), the Saudi Arabian Ministry of Health, and the Ministries of Health in the GCC nations are among the most trustworthy sources. Second, we need to collect information about the chosen period, which could include a specified date range or the full pandemic's lifespan. We need to gather each country's data independently and enter it into a database or spreadsheet. Next, we must eliminate duplicates, discrepancies, and missing data points to ensure the data's accuracy and consistency. Finally, we should statistically evaluate the data to identify trends and patterns.

To allow comparability across countries with various population sizes, we normalized counts of cases and deaths by per million-population adjustment. Such an approach ensured better cross-national comparability. The next step involves computing crucial metrics to compare Saudi Arabia's COVID-19 trends with those of the GCC countries. We present charts, graphs, and tables to statistically compare the trends and clearly illustrate the results. Finally, we interpret the results to highlight significant findings about COVID-19 in the targeted countries of this study. The conclusion is based on the statistical significance of the results, taking into account any limitations of the analysis.

ISSN: 3152-8716 https://doi.org/10.66776/ESBR.2026.1.1.66-82

3.1 Data Collection

The United Nations Office for the Coordination of Humanitarian Affairs (OCHA), which previously monitored and documented daily data from 2020 to 2023, forms the basis of the research's methodology (OCHA, 2023). Note that the dataset includes the number of COVID-19 cases for all Asian and Middle Eastern countries; however, this research focuses on Saudi Arabia (SA) and the GCC countries. To account for the differences in population numbers between Saudi Arabia and the GCC countries, we used Saudi Arabia's cases per million. Table 2 below demonstrates a sample of the data set used (number of cases per million) in our analysis.

Table 2: Important COVID-19 Dataset Elements

Country	Date	Total Number of Cases	New Cases per Million	Total Deaths	Total Deaths Per Million
Saudi Arabia	2022-02-27	744374	632	8996	247.083
Saudi Arabia	2022-02-28	745027	653	8998	247.138
Saudi Arabia	2022-03-01	745590	563	9001	247.22
Saudi Arabia	2022-03-02	746066	476	9002	247.248

This study utilized pre-recorded data to establish the efficacy of digital tools in reducing COVID-19 infections by generating comparisons between COVID-19 pandemic cases in KSA and the other GCC countries. We obtained the information from several sources, both locally in Saudi Arabia and in other GCC countries. To analyze the situation, we examine a critical timeline during the pandemic, specifically the introduction of digital applications (Tawakkalna) and the vaccine. These two events significantly impacted the management of the COVID-19 pandemic. Our goal was to analyze the trend of COVID-19 cases in each targeted country in relation to milestones during the time, as shown in Table 3 below (Alanezi et al., 2021; Assiri et al., 2021).

Table 3: Date and Important Events for Dealing with COVID-19 in Saudi Arabia

Date	Event
May 2020	The public first saw the Tawakkalna application as a tool for issuing curfew permits.
January 2021	To guarantee that citizens receive two doses of vaccination, the Ministry of Health launched the "Health Passport" feature in Tawakkalna.
January 2021	Saudi Arabia approved the COVID-19 vaccine for administration.

ISSN: 3152-8716 https://doi.org/10.66776/ESBR.2026.1.1.66-82

3.2 Data Analysis

We used JAMOVI statistical tool for data analysis and Power BI to visualize timeline comparison. This aimed to evaluate and compare the patterns in GCC countries (Bahrain, UAE, Oman, Qatar, and Kuwait) during COVID-19 and compare them to Saudi Arabia.

Independent sample t-tests compared new COVID-19 cases per million between Saudi Arabia and each of the GCC country, and between pre- and post-digitalization periods in Saudi Arabia. This assesses statistical differences between two independent populations. With large daily data over years, the Central Limit Theorem assumes approximate normality. Levene's test checked variance homogeneity; Welch's correction adjusted degrees of freedom when variance were unequal ($p < .05$).

We applied independent sample t-tests to statistically compare mean differences in new cases per million for Saudi Arabia as compared to every GCC state. We can use this test to determine the statistical significance of differences between two independent groups. Saudi Arabia also uses the same test to identify differences before and after applying digital applications (Creswell & Clark, 2017). These tests allow us to assess whether the noted differences are likely to be significant rather than a result of random variation.

The methodology's accuracy is likely high due to reliance on historical data, which is more stable than unpredictable future data. The analysis focuses on narrating results that support the research claim. Given that the goal was comparative mean evaluation, not causal interferences, the independent samples t-test was suitable for identifying significant differences. Future research could use regression models for a more in-depth analysis.

4. Results

To provide a more nuanced perspective of the pandemic's impact, we normalized the data using the number of cases per million people, ensuring a more accurate comparison across countries with different population sizes. Compared to the GCC countries, Saudi Arabia has the highest population, approximately 34.85 million as of 2023. The UAE has the second-largest population, approximately 9.5 million, followed by Oman (4.6 million), Kuwait (4.3 million), Qatar (2.7 million), and Bahrain (1.4 million). Bahrain, Qatar, and Kuwait have the highest population density, with an average of 1,108/km² (Javed et al., 2022).

Despite having the largest population, Saudi Arabia reported 525,730 cases overall, compared to 1,869,857 cases for the GCC as a whole. During the same period, Bahrain recorded 269,145 cases, Kuwait recorded 397,786, Oman recorded 295,851, Qatar recorded 226,238 cases, and the UAE recorded 680,837 cases, respectively. Figure 2 below provides an overview of the trends in the number of cases in Saudi Arabia and other GCC countries from March 2020 to July 2021 (Ali, 2022).

ISSN: 3152-8716 https://doi.org/10.66776/ESBR.2026.1.1.66-82

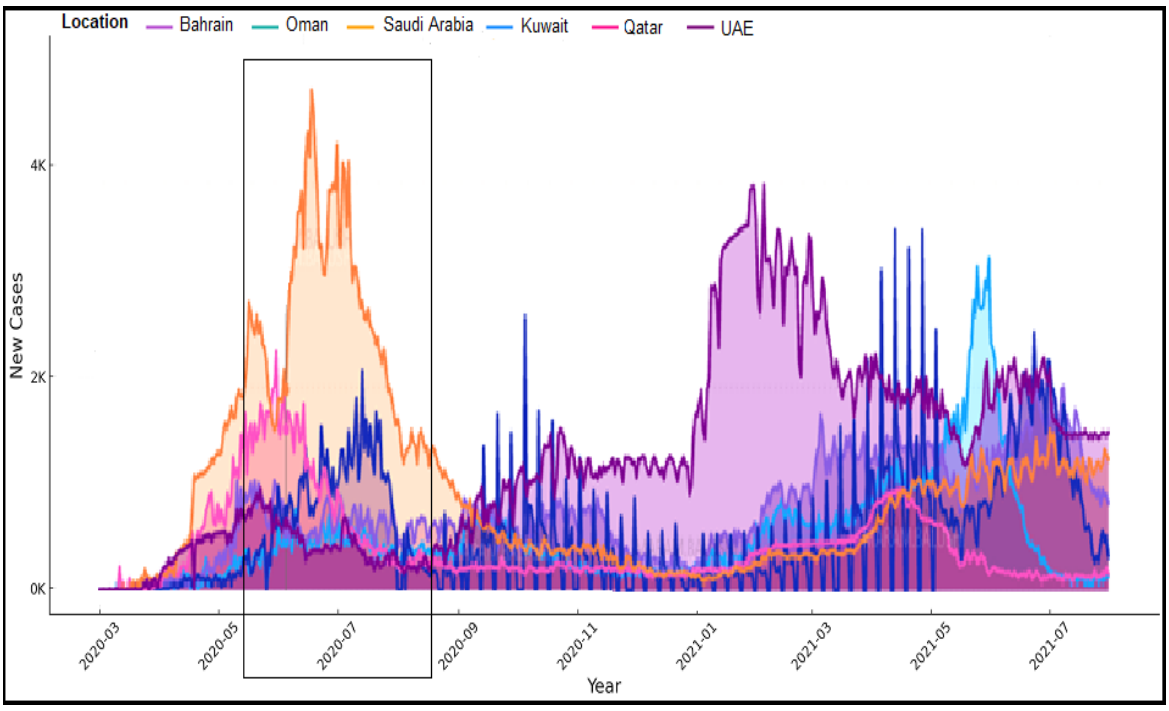

Figure 2: COVID-19 Case Trend In Saudi Arabia And GCC Countries Between March 2020 And July 2021

4.1 Comparison between KSA and GCC Countries

We used the independent sample T-test to compare the results of Saudi Arabia and other GCC (Gulf Cooperation Council) countries. This statistical analysis is suitable for measuring or observing two samples under different circumstances or at different times (Alandijany et al., 2020). This research categorizes the countries into two independent groups: the GCC (UAE, Oman, Qatar, Kuwait, Bahrain) and Saudi Arabia, as shown in Table 4 below.

Table 4: Comparison Between Saudi Arabia and GCC Countries

			Statistic	df	p
Saudi Arabia	Bahrain	Student's t	-19.6	1075	<.001
	Kuwait	Student's t	-19.7	1075	<.001
	Oman	Student's t	-13.1	1071	<.001
	Qatar	Student's t	-25.2	1075	<.001
	UAE	Student's t	-27.2	1075	<.001

ISSN: 3152-8716 https://doi.org/10.66776/ESBR.2026.1.1.66-82

The result indicates that the P value is less than 0.001, which indicates a significant difference between Saudi Arabia and the other GCC countries. Various health measures implemented by the governments, such as lockdowns, travel limits, social distancing rules, and vaccination campaigns, may contribute to this significance. Additionally, variations in testing and reporting, the number of tests performed, and the method employed to record cases can impact the number of cases. The reported number of new cases may vary between countries if they use different testing and reporting methods. Other factors, including population density, the frequency of pre-existing medical disorders, the population's demographics, and the transmission of various viral strains, also play a role. This study compares new cases per million between Saudi Arabia and the GCC countries, as shown in Table 5 below.

Table 5: New Cases Comparison Between Saudi Arabia and Independent Samples T-Test

		Statistic	df	p
New_cases_per_million	Student's t	14.2[a]	6464	<.001

Note. H_a $\mu_{Gulf} \neq \mu_{Saudi\ Arabia}$

[a]Levene's test is significant ($p < 0.05$), suggesting a violation of the assumption of equal variances.

The results indicate that the P value is less than .001, which indicates that there is a significant variance between the two groups. It is important to note that the p-value by itself does not reveal the magnitude or direction of the difference. To determine whether Saudi Arabia has more or fewer cases per million people than other GCC countries, as well as to investigate the causes and effects of this disparity, further investigation and interpretation are required. It is vital to take into account the practical or clinical importance of the observed difference. While the p-value suggests a substantial difference, it is important to carefully consider the context, real-world consequences, and other factors that may have contributed to this discrepancy to gain a full picture of the situation.

4.2 Saudi Arabia before and After Digitalization

We applied the independent sample T-test to examine the cases in Saudi Arabia both before and after digitalization efforts to manage the widespread COVID-19 pandemic. The results, shown in Table 6 below, are important when looking at the two time periods: March 2020, before digitization and vaccination, and July 2021, after the vaccine was released and Tawakkalna was used as a digital passport and proof of immunity.

ISSN: 3152-8716 https://doi.org/10.66776/ESBR.2026.1.1.66-82

Table 6: Independent Sample T-Test Between Saudi Arabia Before and After Tawakkalna Implementation

		Statistic	Df	p
New_cases_per_million	Student's t	13.6[a]	1067	<.001

Note. H_a $\mu_{before} \neq \mu_{after}$

[a]Levene's test is significant ($p < 0.05$), suggesting a violation of the assumption of equal variances.

The test result shows $p < .001$, indicating that Saudi Arabia made attempts to stop the COVID-19 virus from spreading. The statistical results are consistent with our data visualization for Saudi Arabia, which further supports the idea of successfully using digital tools to combat the pandemic, as in Figure 3 below.

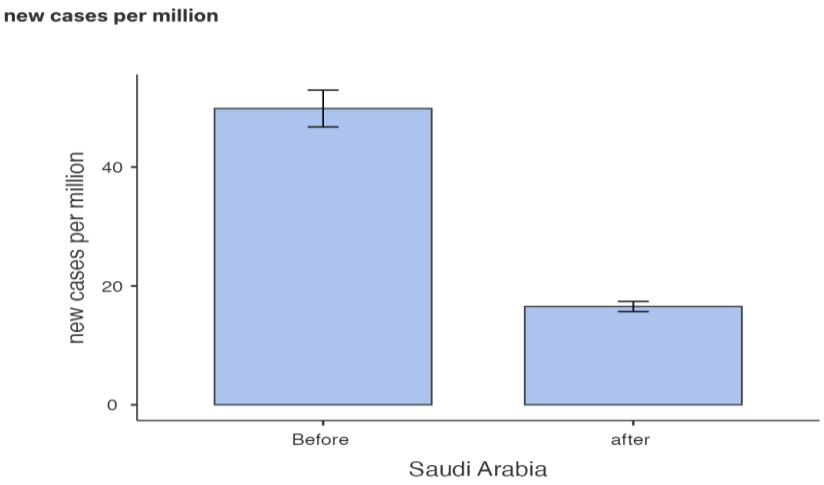

Figure 3: Saudi Arabia's New Cases Per Million Before and After The Tawakkalna App Implementation

These findings address the first research objective by empirically testing the effectiveness of digital applications in mitigating COVID-19 transmission in Saudi Arabia. The significant differences between Saudi Arabia and other GCC countries support the second research objective, identifying best practices in digital applications use for pandemic management.

4.3 Discussion

The discussion of the results is divided into two parts, aligning with the research objectives. Firstly, it examines whether digital applications, particularly Tawakkalna, were effective in the mitigation of COVID-19 transmission in Saudi Arabia. Secondly, it interprets Saudi Arabia's performance relative to other GCC countries to identify distinctive elements of its digital health strategy.

ISSN: 3152-8716 https://doi.org/10.66776/ESBR.2026.1.1.66-82

4.4 Objective 1: Effectiveness of Digital Applications

Saudi Arabia was one of the first countries to take precautionary measures, starting on February 2, 2020, by evacuating Saudi citizens from China and suspending flights to and from China. By February 27th, 2020, Saudi Arabia had suspended the holy practice of Umrah for foreigners, and by March 4th, it had locked down Umrah for citizens. Most other countries had initiated their measures by February 28th and March 1st, 2020, with Bahrain and the UAE being the first to respond, followed by other countries (Alandijany et al., 2020). This visualization shows that the implementation of Tawakkalna in May 2020 led to a significant decrease in COVID-19 cases in Saudi Arabia, with cases continuing to decline until the end of 2021.

The Ministry of Health, starting on May 27th, 2020, relaxed the curfews, causing the COVID-19 case epidemic to peak in July 2020 as people resumed their normal life activities [35]. During this period, the Ministry of Health introduced Tawakkalna and other applications to increase awareness among individuals about the need to avoid areas with potential infections. Consequently, a significant decrease in cases was observed between July 2020 (2,474 cases) and August 2020 (1,143 cases). Since its launch, Tawakkalna has surpassed 20 million users, demonstrating Saudi Arabia's residents' compliance with digital innovations (Gazette, 2021).

In addition to digitization, other elements, such as the lifting of curfew and quarantine regulations by early 2021 and a mandatory vaccination requirement for all citizens, also contributed to its high significance. But the number of symptomatic people who didn't get tested for COVID may affect the results. In the context of the dataset used in this research, one can see that the use of digital solutions in Saudi Arabia has led to a substantial decrease in COVID-19 cases, revealing the crucial role that technology has played in reducing the spread of the virus.

Furthermore, Saudi Arabia has effectively utilized technology to improve its public health response and achieve remarkable results in reducing COVID-19 transmission through the use of artificial intelligence (AI), machine learning, and various digital tools and platforms, such as contact tracing apps, online symptom reporting systems, and virtual healthcare services (Gazette, 2021). It is evident from the results that the implementation of the Tawakkalna application played a pivotal role in reducing COVID-19 transmission, and this effect was further reinforced by the commencement of the national vaccination campaign in January 2021.

Thus, by enforcing stringent quarantine regulations and requiring the presentation of the Tawakkalna application to enter any public facility, Saudi Arabia has managed to control the trend. As previously demonstrated, a Tawakkalna with a green screen signifies complete immunization and virus-free status.

4.5 Objective 2: Comparative GCC Performance

In contrast to other countries in the GCC, Saudi Arabia is believed to have consistently controlled matters, despite having the largest number of cases. Furthermore, the social

ISSN: 3152-8716 https://doi.org/10.66776/ESBR.2026.1.1.66-82

behavior of people in Saudi Arabia and their acceptance of government rules and guidelines during the pandemic were admirable compared to the GCC. For example, in Kuwait, there was a wave of resistance to vaccination, with 50% of people unwilling to take the vaccine and 23.5% uncertain about it (Al-Ayyadhi et al., 2021). Similarly, strict lockdowns and the deployment of immunization campaigns have significantly reduced COVID-19 transmission in GCC countries, especially in Saudi Arabia, where more than 50% of the population has received vaccination (Khan et al., 2021).This research supports the arguments made by previous researchers that the use of digital tools has successfully contributed to controlling the spread of COVID-19 (Al-Ayyadhi et al., 2021).

4.6 Contribution to Theory and Practice

Theoretical Contribution: The current study contributes to the digital health and digital governance literature by empirically proving digital ecosystems can serve as regular mechanisms during health crises. Unlike existing literature focusing on health application acceptance, this study provides macro-level longitudinal evidence linking digital policy integration to statistically significant epidemiological outcomes. Practical Contribution: This case study shows digital health applications are more effective when integrated into a broad policy framework covering technology deployment, vaccination, mobility, and compliance. The Saudi model may serve as a framework for other countries to enhance their pandemic readiness through digitalization.

4.8 Limitations and Future Research

This study uses secondary data obtained from international and governmental sources, which are generally reliable, but limit control over measurement consistency, accuracy, and revisions. Differences in testing rates, reporting standards, and case definitions across GCC countries may introduce bias. Asymptomatic or unreported cases might also be missed in official statistics. Therefore, findings show statistically indicative trends rather than definitive causal estimations. One of the limitations of this research is that, during the pandemic, a large number of people with symptoms would quarantine themselves, reaffirm that they were COVID-19 positive, and refuse to be tested to avoid being listed as a "reported case." This resulted in the inconsistent reporting of cases at different points in time. Other factors, such as gender, age, education level, and medical disorders like diabetes and heart disease, also influenced the results and general trends in the country. Furthermore, the medical sector's collection, storage, and transmission of sensitive patient data through digital means raised major concerns about privacy and security. Future research can address all of these limitations by providing more insights and reasons for cases that were not reported on time and investigated later. Future research can also segregate cases based on demographic information such as gender, age, and chronic disease. Finally, future research may also investigate privacy and security issues related to the use of digital tools during the COVID-19 pandemic in Saudi Arabia. Despite limitations, using longitudinal data, standardized per-million normalization, and statistical methods improves internal validity and cross-national

ISSN: 3152-8716 https://doi.org/10.66776/ESBR.2026.1.1.66-82

comparability. These approaches boost results robustness and reliability, supporting the comparative conclusion drawn.

5. Conclusion

This study aimed to: (1) evaluate the efficacy of digital health applications in managing COVID-19 in Saudi Arabia, and (2) compare it with other GCC countries to identify best practices. Results showed a significant reduction in new COVID-19 cases per million after implementing Tawakkalna and other digital health interventions ($p < .001$). The IBM-KSA model estimated 1.3 million averted infections and 28,000 deaths, highlighting the impact of digital health enforcement. Compared to other GCC countries, Saudi Arabia showed statistically significant differences ($p < .001$), suggesting that strict enforcement of regulations and digital health interventions contributed to better public health outcomes. This study implies digital health applications are more effective when integrated with governance, enforcement and vaccinations. It contributes to existing literature by linking digitally enforced governance to epidemiological outcomes, shifting focus to digital health regulations and integration with existing policies. The Saudi Arabia case shows that rapid digital identity, immunity verification, and data coordination can improve crises response. Governments should institutionalize digital health platforms for pandemic preparedness. Saudi Arabia's model provides a practical example for improving future pandemic responses.

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