Assessment of COVID-19 Vaccination Coverage and Its Impact on Disease Spread in Shendi Town- Sudan.

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Abstract:

Background: Since the World Health Organization declared COVID-19 a pandemic on March 11, 2020, the virus has continued to challenge healthcare systems globally, causing significant morbidity and mortality. With the availability of vaccines and increasing vaccination coverage, controlling the disease is becoming increasingly achievable. As of February 28, 2023, over 13 billion vaccine doses have been administered worldwide.

Objective: This study aimed to assess COVID-19 vaccination coverage in Shendi Town and determine the role of vaccines in limiting the disease's spread.

Methods: A descriptive cross-sectional community-based study was conducted in Shendi Town from April 2020 to December 2022, involving 240 participants. The study used a simple random sampling technique to select participants. Based on a 9% margin of error, the sample size was calculated using the formula: $\boldsymbol{n = z^2 p(1 - P)/d^2}$

Results:

- Vaccinated individuals were significantly less likely to contract COVID-19 compared to unvaccinated individuals (p- *value*= 0.000)
- Vaccination coverage was 78.3%.
- 50% of participants were vaccinated with the Johnson & Johnson vaccine, 16.7% with AstraZeneca, and 15% with Pfizer.
- The infection rate among participants was 8.3%, with 80% of the infections occurring before vaccination.
- 90% of respondents adhered to preventive measures, with 66.7% using masks, 13.3% practicing social distancing, and 10% using disinfectants.

Conclusion: COVID-19 vaccination campaigns have significantly increased vaccine acceptance, resulting in a notable reduction in disease incidence, complications, mortality, and an increase in recovery rates in Shendi Town.

Keywords: COVID-19, Vaccination, Shendi, Sudan.

Introduction

On December 31, 2019, 27 cases of pneumonia of unknown origin were reported in Wuhan, Hubei province, China (1). By January 30, 2020, the World Health Organization (WHO) declared the COVID-19 outbreak a Public Health Emergency of International Concern, emphasizing its significant threat to nations with fragile healthcare systems. The WHO emergency committee highlighted that early detection, isolation, prompt treatment, and effective contact tracing could help curb the virus's spread (2).

The COVID-19 pandemic quickly became a major global health crisis, with SARS-CoV-2 spreading more rapidly than its predecessors, SARS-CoV and MERS-CoV, due to its stronger binding affinity to human receptors (3). According to the WHO's situational report, there were over 16 million confirmed cases and nearly 298,000 deaths, with the Eastern Mediterranean Region ranking fourth in the number of COVID-19 cases (4).

By October 9, 2021, Iraq had the highest number of COVID-19 cases in the Arab world, followed by Morocco, Jordan, the UAE, and Tunisia. The highest death tolls were reported in Tunisia, Iraq, Egypt, and Morocco, with 25,028, 22,537, 17,658, and 14,443 deaths, respectively (4). The virus also mutated into several variants, including alpha, beta, gamma, and delta, with each posing additional global challenges (5). In response, numerous countries launched immediate vaccination campaigns (6).

Reports suggest that several African countries have experienced a lesser impact from COVID-19 compared to nations like the United States, Italy, and Peru (7). However, the factors influencing the pandemic's progression in Africa are complex and cannot be generalized. These factors include past experiences with infectious diseases, community interconnectedness, infection fatality rates, limited healthcare access, and low testing rates (7). Given the substantial health, social, and economic consequences of COVID-19, a significant rise in cases and fatalities could prove particularly devastating for African nations with underfunded healthcare systems (8).

Sudan reported its first COVID-19 case in Khartoum on March 13, 2020, involving a man who had recently visited the UAE and passed away just before the confirmation. By July 12, 2020, Sudan had confirmed 10,250 cases and 650 deaths (9). The country's healthcare system, weakened by years of neglect, insufficient government investment, international sanctions, and dwindling global donor support, faces significant challenges in managing the COVID-19 crisis (10).

The problem of insufficient healthcare infrastructure, coupled with ineffective non-pharmaceutical interventions such as social distancing and curfews, highlighted the need for alternative solutions (11). This has led to a global consensus that vaccination

is the most effective strategy to manage the pandemic (12). Unprecedented global collaboration led to the rapid development and distribution of vaccines to combat COVID-19 (13). Since the outbreak, vaccine development has significantly accelerated, with many candidates undergoing pre-clinical trials, and 43 progressing to clinical trials, including some never before licensed for human use (14).

Ultimately, 14 vaccines received emergency use authorization across various countries, with Sudan becoming the first nation in the Middle East and North Africa to receive the COVAX vaccine, obtaining over 800,000 doses of the AstraZeneca vaccine. The country's immunization supply chain included a national store, 18 state stores, 183 locality stores, and 2,421 service points (15).

Sudan initially focused on reducing morbidity and mortality while restoring essential services. This strategy later expanded to include controlling disease transmission and preserving social and economic functions. Immunization efforts initially aimed to vaccinate 3% of the population, prioritizing frontline healthcare workers and elderly individuals with co-morbidities. The first vaccination phase targeted 4% coverage, later adjusted to 16% to maximize the benefits from the COVAX facility, with plans to increase coverage to 20-60% through cost-sharing mechanisms (16).

In response to the COVID-19 pandemic, Sudan launched several vaccination campaigns using multiple vaccines that received emergency use authorization from the World Health Organization (WHO). The vaccines administered in Sudan include the AstraZeneca COVID-19 vaccine, which uses a modified adenovirus to deliver the SARS-CoV-2 spike protein to trigger an immune response. It has been widely distributed and is known for its cost-effectiveness and easier storage requirements compared to mRNA vaccines. It demonstrated around 70% efficacy in preventing symptomatic COVID-19 in clinical trials (17). Over 800,000 doses of the AstraZeneca vaccine were delivered to Sudan through the COVAX initiative to aid in vaccination efforts, with priority given to healthcare workers and high-risk individuals (18).

Another vaccine used in Sudan is Sinovac-CoronaVac, developed by the Chinese company Sinovac. It uses an inactivated form of the SARS-CoV-2 virus to stimulate an immune response. This vaccine is traditional and has been used globally for other diseases, such as polio and hepatitis. Clinical trials reported an efficacy of around 50-80% in preventing symptomatic COVID-19, depending on the population and conditions of the trial (19). The Sinovac vaccine was also part of Sudan’s vaccination strategy, with the country receiving significant quantities to help control the spread of the virus (20).

The Johnson & Johnson Janssen COVID-19 vaccine, which is a single-dose vaccine, uses a modified adenovirus to deliver the SARS-CoV-2 spike protein to trigger an

immune response. It was authorized for emergency use in several countries, including Sudan, as part of the global effort to control the pandemic. This vaccine has shown around 66% efficacy in preventing moderate to severe COVID-19 infection and 85% efficacy in preventing severe disease (21). The single-dose feature of the Janssen vaccine makes it a practical option for mass vaccination campaigns, especially in resource-limited settings like Sudan (22).

Pfizer-BioNTech's COVID-19 vaccine, which uses mRNA technology, was one of the first vaccines authorized for emergency use. It instructs cells to produce the spike protein of SARS-CoV-2, triggering an immune response. This vaccine has demonstrated more than 95% efficacy in preventing symptomatic COVID-19 in clinical trials (23). Although it has been less widely used compared to AstraZeneca and Sinovac in Sudan, the Pfizer vaccine has been administered in smaller quantities through the COVAX program and other international aid initiatives (24).

Sudan faced significant challenges in combating COVID-19, given its underfunded healthcare system and the socio-economic impact of the pandemic. However, vaccination campaigns, aided by the COVAX initiative and bilateral agreements, have provided hope for controlling the spread of the virus. Sudan's vaccination strategy initially focused on high-risk groups, such as healthcare workers and the elderly with comorbidities. The first phase of the vaccination drive aimed to vaccinate 3% of the population, a figure later adjusted to 16% through international support (25). The vaccination efforts have included significant logistical work, with vaccines being distributed across the country through the national immunization supply chain. This includes over 800,000 doses of the AstraZeneca vaccine and several doses of the Sinovac vaccine (26). As the vaccination rollout progresses, Sudan plans to expand coverage, aiming to reach 20-60% of the population through cost-sharing mechanisms (27).

This study aims to evaluate the immunization coverage of various COVID-19 vaccines authorized for emergency use and assess their effectiveness in limiting the disease's spread in Shendi Town. The justification for this study lies in the need to address the significant challenges Sudan faces due to its underfunded healthcare system and to explore how vaccination efforts could mitigate the health, social, and economic consequences of the pandemic. The findings of this study will help inform national vaccination strategies and improve the efficiency of public health responses in Sudan and similar contexts.

Materials and methods:

The study was a descriptive cross-sectional, community-based research conducted from April 2020 to December 2022 in Shendi town, located in the River Nile State of Sudan. The primary goal was to assess the immunization coverage provided by the

different types of COVID-19 vaccines that were authorized for emergency use, as well as to evaluate their role in limiting the spread of the disease in Shendi town.

The total population of Shendi town is approximately 50,446 people, of which 12,316 individuals are above 18 years of age and were the target group for this study (14).

A sample of 240 individuals was selected using simple random sampling to ensure that every eligible individual had an equal chance of being included in the study. Simple random sampling was chosen because it minimizes selection bias and ensures the representativeness of the sample. To determine the appropriate sample size, the following formula for calculating the sample size for a population was used:

$$\boldsymbol{n = z^2 p(1 - P)/d^2}$$

Where:

n = required sample size

Z = Z-value (1.96 for a 95% confidence level)

p = estimated proportion of the population (0.5 is used for maximum variability when no prior estimate is available)d

d = margin of error (0.09 for 9% error)

Using this formula, the sample size is calculated as follows:

n= 119 individuals. Thus, the required sample size is approximately 119 individuals. However, to account for potential non-responses, data omissions, or other risks associated with the sample's accuracy and representativeness, the sample size was increased to 240. This adjustment was made to ensure that the sample would still be sufficiently robust to support the study's objectives and yield reliable results. Therefore, 240 individuals were selected to participate in the study.

The study utilized multiple data sources, including health records, to determine critical indicators such as the case-fatality rate, mortality, and morbidity related to COVID-19 within the community. Participants were then interviewed using pre-tested questionnaires.

The pre-tested questionnaire was designed to gather detailed information on:

Socio-demographics: This section collected data on age, gender, education, occupation, and other relevant demographic factors to assess potential factors influencing vaccine coverage and awareness.

Vaccination Status: Questions aimed at understanding if individuals had received the COVID-19 vaccine, which vaccine they received, the timing of their vaccination, and any factors that may have influenced their decision to vaccinate.

Occurrence of Disease: This section focused on gathering information about whether participants had contracted COVID-19, including the severity of their symptoms, hospitalizations, and outcomes.

Awareness: The questionnaire included questions related to participants' awareness and knowledge of COVID-19, preventive measures, vaccine benefits, and potential side effects. This was essential for understanding public perception and the effectiveness of educational campaigns.

The data were then entered and analyzed using the **Statistical Package for Social Sciences (SPSS), version 22**. Descriptive statistics were employed to summarize demographic characteristics, vaccination rates, disease occurrence, and the awareness levels of participants. Additionally, inferential statistics were used to determine the relationships between vaccination coverage and the spread of COVID-19 in Shendi Town, helping to evaluate the impact of vaccination efforts on the local population's health outcomes.

Results:

Table 1: Distribution of cases and deaths of COVID-19 according to years, in Shendi town

Reported Years	Status	
	Cases	Deaths
2020	62	7
2021	170	21
2022	48	8

Source; epidemiology department records (morbidity and mortality report, Shendi locality, River Nile state, 2022)

This table presents the total number of reported COVID-19 cases and deaths in Shendi town from 2020 to 2022. The data shows that in 2020, there were 62 cases and 7 deaths, in 2021, 170 cases and 21 deaths, and in 2022, 48 cases and 8 deaths. This reflects the overall trends in morbidity and mortality over the three years.

Table 2: Distribution of cases and deaths of COVID-19 according to the months of three years (2020 – 2021 - 2022), in Shendi town

Status	Months & Quarters												Total
	Quarter (1)			**Quarter (2)**			**Quarter (3)**			**Quarter (3)**			
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Cases	23	9	20	22	13	22	35	2	1	34	64	35	**280**
Deaths	2	2	3	2	1	0	4	0	1	9	8	4	**36**

Source; epidemiology department records (morbidity and mortality report, Shendi locality, River Nile state, 2022)

This table provides monthly breakdowns of COVID-19 cases and deaths over the three years (2020-2022). The data shows that the highest number of cases occurred in the fourth quarter of 2021 (64 cases in November), while the highest number of deaths was also in the last quarter of 2021 (9 deaths in October). The total reported cases over the period were 280, and the total deaths were 36.

Table (3): Demography characteristics of respondents

Variable	Frequencies	Percentage
Age		
From 18 to 30	140	58.3%
From 31 to 45	60	25%
More than 45	40	16.7%
Gender		
Male	160	66.7%
Female	80	33.3%
Education level		
No formal education	20	8.3%
Primary	28	11.7%
Secondary	64	26.7%
Higher education	128	53.3%

This table presents the demographic breakdown of the study respondents. The majority of the respondents (58.3%) were aged 18-30, followed by 25% in the 31-45 age range. The gender distribution shows that 66.7% were male, and 33.3% were female. Regarding education, 53.3% had higher education, 26.7% had secondary education, and 8.3% had no formal education.

Table (4); Covid-19 vaccination services; accessibility, availability and utilization

Availability, accessibility and utilization of vaccination services	Frequencies	Percentage
Facility of vaccine admittance		
Health center	140	74.5%
Hospital	16	8.5%
Mobile team	32	17%
availability vaccine in Shendi town		
Yes	232	96.7%
No	8	3.3%
Vaccination status among respondents		
Vaccinated	188	78.3%
Unvaccinated	52	21.7%
types of Vaccine used among respondents in Shendi town		
Janssen &Jonsson	120	63.8%
AstraZeneca	40	21.3%
Pfizer	24	12.8%
Sinopharm	4	2.1%
the respondents' had vaccination card in Shendi town		
Yes	184	97.9%
No	4	2.1%
the presence of side effects on participants in Shendi town		
Yes	132	70.2%
No	56	29.8%

This table outlines the accessibility and utilization of COVID-19 vaccination services. The majority of respondents (74.5%) accessed the vaccine through health centers, and 96.7% reported that the vaccine was available in Shendi. Regarding vaccination status, 78.3% of the respondents had been vaccinated. The most commonly used vaccine was Janssen & Jonsson (63.8%), followed by AstraZeneca (21.3%). A large percentage (97.9%) of vaccinated individuals reported having a vaccination card. However, 70.2% of vaccinated participants experienced side effects.

Table (5): Prevalence of COVID-19 among respondents in Shendi town

prevalence of covid-19	Frequencies	Percentage
Infection by COVID-19		
Yes	20	8.3%
No	220	91.7%
Infection time		
Before vaccination	16	80%
After vaccination	4	20%
Family member infected by COVID-19		
Yes	36	15%
No	204	85%
Vaccination status		
Vaccinated	4	11.1%
Unvaccinated	32	88.9%

This table shows that 8.3% of respondents had been infected with COVID-19, with 80% of those infected reporting that they contracted the virus before being vaccinated. Additionally, 15% of respondents had a family member infected by COVID-19, and 88.9% of those unvaccinated reported family infections, compared to just 11.1% among vaccinated respondents.

Table (6): Awareness about the preventive measures of COVID-19among respondents

The Response	Frequency	Percentage
The knowledge		
Yes	224	93.3%
No	16	6.7%
Used		
Yes	216	90%
No	24	10%
Applied prevention measure;		
Wearing a mask	160	66.7%
Social distancing	32	13.3%
Using sanitizers	24	10%

This table demonstrates the high level of awareness among respondents about COVID-19 preventive measures, with 93.3% of respondents knowing about the preventive measures and 90% using them. Among the preventive actions, wearing a mask was the most commonly applied (66.7%), followed by social distancing (13.3%) and using sanitizers (10%).

Table 7: Association between COVID-19 Infection and Vaccination Status

Vaccination Status	Infected (Observed)	Not Infected (Observed)	Chi-Square (χ^2)/ P-value
Vaccinated	4	184	$\chi^2 = 43.81$
Unvaccinated	16	36	P-value = 0.000
Total	20	220	

In this table P-value = < 0.001 (Significant)**,** indicate that the Vaccinated individuals were significantly less likely to contract COVID-19 compared to unvaccinated individuals. This highlights the effectiveness of vaccination in reducing the spread of the virus.

Discussion;

The findings of the current study regarding COVID-19 in Shendi town reflect the significant health, social, and economic impacts of the pandemic, as well as the critical role of preventive measures and vaccination in controlling its spread. The number of COVID-19 cases and deaths showed varying trends over the years 2020, 2021, and 2022, with the highest fatality rate recorded in 2022 at 16%, despite the decrease in total cases. This result aligns with findings from other studies, where increased fatality rates were attributed to new viral variants and challenges in healthcare systems during later stages of the pandemic (1, 3).

The study also highlights the importance of preventive measures, such as social distancing and mask-wearing, in reducing the transmission of COVID-19. In Shendi town, mask-wearing (66.7%) and social distancing (13.3%) were practiced, which is consistent with findings from other regions. For example, a study conducted in Italy showed that mask-wearing, along with social distancing, significantly reduced the transmission of COVID-19 (16). Similarly, in the United States, social distancing and face masks were found to be effective in controlling the spread, particularly in the early stages of the pandemic (28). These results emphasize that while vaccines are crucial, behavioral interventions remain key to reducing transmission.

Vaccination played a crucial role in controlling the disease spread, as evidenced by the reduction in infection rates among vaccinated individuals in this study. The findings in Table 5 show that 80% of those infected with COVID-19 had contracted the disease before being vaccinated. The statistical analysis presented in table 7 demonstrates a significant association between vaccination status and COVID-19 infection, with a P-value < 0.001. This strong significance indicates that vaccinated individuals were substantially less likely to contract COVID-19 compared to those who were unvaccinated. The findings clearly support the role of vaccination as an

effective public health measure in reducing both the risk of infection and the overall spread of the virus within the community. These results align with global evidence confirming the protective impact of COVID-19 vaccines, especially in settings with limited healthcare infrastructure. In line with our findings, studies in other regions have shown that vaccination leads to a substantial reduction in the number of cases and hospitalizations. For example, a study in the UK reported that vaccines reduced hospital admissions by up to 80% and significantly decreased the number of severe cases (30). Furthermore, the study's observation of high vaccine uptake, particularly the Johnson & Johnson vaccine (63.8%), mirrors trends seen in other countries, where single-dose vaccines were preferred for their convenience and effectiveness (31).

Additionally, vaccine accessibility and availability in Shendi town were pivotal in the vaccination campaign's success. As shown in Table 4, the widespread availability of the vaccine, with 96.7% of respondents reporting its availability, is consistent with findings from other countries where increased vaccine accessibility was correlated with higher vaccination rates (29). The initial vaccine hesitancy observed in Shendi also aligns with studies conducted globally, which reported skepticism toward COVID-19 vaccines, particularly in the early phases of vaccination campaigns. However, the impact of awareness campaigns in overcoming vaccine hesitancy was evident, as vaccination uptake increased over time, which is supported by findings from other studies that highlight the importance of public health campaigns in addressing vaccine-related fears (30, 31).

Preventive measures beyond vaccination were also explored in this study. While 66.7% of participants reported wearing masks, only 13.3% practiced social distancing, and 10% used sanitizers. These numbers suggest that while mask-wearing was widely adopted, other preventive measures such as social distancing were less emphasized. This is in line with findings from a study in Brazil, which observed that while mask-wearing was universally adopted; social distancing was less consistently followed (31). This highlights the importance of reinforcing multiple preventive strategies, as no single approach is sufficient in controlling the spread of the virus. A comprehensive strategy, as advocated in other studies, is necessary for controlling pandemics effectively, combining vaccination with public health measures like mask usage, social distancing, and hygiene practices (31).

Conclusion:

The results of this study are consistent with the global body of research, which suggests that COVID-19 vaccination campaigns significantly reduce infection rates, complications, and mortality, and those preventive measures such as mask-wearing and social distancing play crucial roles in controlling disease spread. The success of these interventions in Shendi town supports findings from other studies conducted in various regions worldwide. Continued efforts to enhance vaccine coverage and public

awareness, as well as the promotion of comprehensive preventive measures, will be vital in managing the ongoing pandemic and preparing for future outbreaks. The study's findings align with global trends, suggesting that vaccination and preventive behaviors remain fundamental to controlling the spread of COVID-19.

❖ **Ethical approval and consent to participate:**

The study was firstly approved by ethical committee of the faculty of public health (institution research board) at Shendi University. Permission was also taken from ministry of health – River Nile State, and the directors of community to be studied. Names and personal data were completely secured.

❖ **Consent for publication:**

Not applicable

❖ **Availability of data and materials;**

The datasets used and analyzed during this study are available from the corresponding author or reasonable request.

❖ **Competing interests**

The authors declared no conflict of interest.

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The research did not receive any fund from any source.

❖ **Authors' contributions**

All authors contributed significantly to this work, Alhaj Saad Mohamed Ahmed Ali; conceiving the idea of the research, Wiaam Hassan Awad; collection and analysis of data , HaghamadAllzain, Omran Musa Ahmed, Mazin Babekir Musa Bashir; writing and editing of the manuscript. All authors read and approved the manuscript.

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