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Comparative Analysis of the Implication of Periods Before and During Vaccination of COVID-19 Infection in Some Regional Leading African Countries

Abiola T. Owolabi[a,*], Kayode Ayinde[b], Taiwo J. Adejumo[a], Wakeel A. Kasali[a], Emmanuel T. Adewuyi[a]

[a]*Department of Statistics, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria*
[b]*Department of Statistics, Federal University of Technology, Akure, Nigeria*

Abstract

There has been a high expectation about the efficacy of coronavirus disease 2019 (COVID-19) vaccines. This research investigates and compares the efficiency of COVID-19 vaccines in five (5) African countries and evaluates the risk or preventive factors inherent in COVID-19 spread. Five different COVID-19 leading African countries in their respective regions (Nigeria, Ethiopia, South Africa, Morocco, and Cameroon) were considered in this study. Population sampling proportional to size concept was used to draw data for two periods (before and during COVID-19 vaccination). A sequential analysis approach was adopted, focusing on the estimates of some epidemiological metrics for the two distinct periods. Nigeria (a wet region) has the lowest risk of COVID-19 incidence during vaccination. The risk of being reported COVID-19 positive in South Africa (a high semi-arid region) is approximately 137 times the number in Nigeria. This study suggests that while vaccination has successfully reduced the case fatality rate in most countries considered except Ethiopia, infection and incidence rates increase during vaccination in all countries except Nigeria. Methods other than vaccination like wearing a face mask, washing hands, and avoiding large gatherings should be intensified to curtail incidence and infection rates.

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1. Introduction

Coronavirus 2019 (COVID-19) started in Wuhan, China, in December 2019 [1-3]**.** This virus was investigated to have an origin connected with the kingdom of the Riboviria, the Nidovirales Order, orthocoronavirinae subfamily of the Coronaviridae family, and corona-like Species at 125mn size larger than Influenza, Severe Acute Respiratory Syndrome (SARS), and Middle East Respiratory Syndrome (MERS) [4]. Coronavirus is derived from ”corona,” which implies a ”halo” shape. Under a two-dimensional transmission microscope, the virus exhibits a unique appearance because its surface is covered with a rod-shaped protein tip. The incidence of 1981 Influenza or pandemic smallpox earlier confronted the human race has not been successful as an epidermal viral pathogen of SARS-CoV-2, a member of the family of viruses that severely attack and cause severe diseases in many animals with backbones [5].

*Corresponding author tel. no: +2348062956731
Email address: atowolabi@lautech.edu.ng (Abiola T. Owolabi)

The virulence power of SARS COV-2 remained formidable and has spread exponentially worldwide, with negative effects on the healthcare system, economic, financial, commercial, and social development across the globe [6-8]. About 240,631,670 infected people with COVID-19 and 4,899,169 death tolls were recorded worldwide as of 19th October 2021 [9]. Following the first wave in China, the second wave of COVID-19 hits Iran, South Korea, and Italy. Only about some moments later, the outbreak of COVID-19 swiftly swept through the United States, Africa, and more heavily into European countries [10].

Because of many unknowns, a partial understanding of COVID-19 transmissibility has fueled the level of concern among the public health community, as most modeling suggests that the severity of the illness is more like influenza than SARS [4, 11]. Similar to this is the fold of research affirming semblance of certain flu-like symptomatic features that COVID-19 shares with influenza [12], suggesting in this light the potentiality of mitigating factors on influenza being equally appropriate for quelling COVID-19. The development efforts to curtail the spread from hotspot to hotspot fervently proved abortive. During the first surge on the regional level in Lombardy, Italy, the confirmed cases doubled from 41,035 to 86,498 in just one week (Between 19th March and 27th March 2020), allotting Italy as one country with a large outbreak of COVID-19. In the wake of the U.K. variant emergence (B.1.1.7) that settled the origin lineage (D614G) immensely, Italy encountered a COVID-19 sweep from 1st October 2020 as an indicator of a second surge [13].

From available data, incidence rate and mortality vary from country to country and from continent to continent. The variation may be due to factors such as dietary habits, climate, social activities, genetic differences, governance structures, the use of chloroquine (C.Q.), and the anti-tuberculosis (T.B.) vaccination (Bacillus Calmette–Guerin, B.C.G.) [14]. Following the first confirmed case report on 14th February in Egypt, the second in Algeria on 25th February 2020, and the third in Nigeria on 27th February 2020, there has been a continuous increment in COVID-19 incidence in Africa.

One of the challenges faced in the fight against COVID-19 is the emergence of new SARS-CoV-2 variants in the latter part of 2020 and the early part of 2021. In July 2020, the EU2 variant (mutation S: 447N) was first observed in Western Europe and increased virus infectivity [15]. Then B.1.1.7 developed firstly in the U.K. in September 2020 [16], B.1.351 in South Africa in December 2020 [17], P.1 in Brazil in January 2021 [18], and the 'Indian' variant B.1.617 reported firstly in Maharashtra in January 2021 [19]. Different countries adopted several preventive measures for the COVID-19 outbreak. Cooperate measures like lock-down, social distancing and mask use, and individual hygiene measures like frequent hand washing and avoiding touching eyes, nose, or mouth [20] were adopted by different countries. Vaccines as part of the exit strategy to enable a return to previous working, schooling, and socializing patterns have been widely considered. Numbers of different vaccines have been developed and analyzed in clinical trials. Clinical trials on vaccine efficacy revealed that Pfizer-BioNTech had 95% efficacy at preventing symptomatic COVID-19 infection in people without prior Infection [21]. 94.1% efficacy was reported for Moderna [22], 70.4% for Oxford -AstraZeneca [23], 66.5% for Johnson & Johnson [24], and 96.4% for Novavax [25]. Regarding the prevention of the disease, 100% efficacy was reported for Pfizer, Moderna, AstraZeneca, and Novavax, whereas 84% was observed for Johnson & Johnson [25].

By 24th September 2020, many vaccines (not less than 200) had been considered for preclinical development, although mixed with some concepts that have not previously been licensed for human vaccines, from which 43 had entered clinical trials. As of 19th October 2021, 6,545,309,084 vaccine doses have been administered worldwide (W.H.O, 2021). There has been a high expectation about the COVID-19 vaccine's efficacy, but this seems to vary from country to country, region to region, and then continent to continent. Many nations have to depend on the development of vaccines when all efforts to cure and eradicate the COVID-19 pandemic proved abortive. However, there are reports of side effects of the COVID-19 vaccine, especially in Africa, which has led to hesitation by some individuals to take the jab. In this light, this study aims at investigating the effectiveness of COVID-19 vaccines, comparing case fatality, incidence, and infection rates caused by COVID-19 in the presence of non-pharmaceutical intervention (Pre-vaccination) and during the inception of pharmaceutical intervention (vaccination) in five regional leading African countries.

2. Method

2.1. Study Location

Nigeria is located on the western coast of Africa, bordered to the north by Niger, to the east by Chad and Cameroon, to the south by the Gulf of Guinea of the Atlantic Ocean, and to the west by the Benin Republic. Nigeria has a warm desert climate in the northeast, a tropical savannah climate in the southwest and middle belt, a warm semi-arid climate in some parts of the north, and the monsoon climate in the Niger Delta. Nigeria is a major player in sub-Saharan Africa with its large human population [26]. Nigeria is the most populous African country, with an estimated population of about 200 million people.

Ethiopia is another African country on the Eastern coast, bounded by Somalia to the east, South Sudan and Sudan to the west, Kenya to the south, and Djibouti to the northeast. Due to its varied topography, its climate is tropical in the north-eastern lowlands and south-eastern lowlands, while it's temperate and cool in the highlands. The country shares 1.47% of the world population, making it the second-largest African country.

South Africa is in the southern part of Africa, surrounding Lesotho in the east, bordered by Zimbabwe, Swaziland, Namibia, and Botswana. The country is a climate patchwork of warm coastal subtropics with humid highlands, hot deserts, and Mediterranean weather in the southwest. South Africa has about 60 million people, sitting 25^{th} in the world population ranking.

Morocco is located in the northern part of Africa, bordered by the Mediterranean Sea to the north, Algeria to the east and southeast, Western Sahara to the south, and the Atlantic Ocean

to the west. The climate is humid temperate at a higher elevation, dry and hot in the south-western part, and the Mediterranean on the coasts. Morocco's equivalence is 0.47% of the global population.

Cameroon is situated in the central part of Africa. The Central African Republic borders its triangular structure to the east, the Republic of the Congo to the southeast, Nigeria to the northeast, Gabon and Equatorial Guinea to the south, and the Atlantic Ocean to the southwest. Cameroon takes number 52 in the list of countries by population.

2.2. Data extraction

Datasets on daily new cases and death cases of COVID-19, including population size, cardiovascular death rate, diabetes prevalence, and people vaccinated for 5 (five) different COVID-19 leading African countries in their respective regions, were surveyed for 2 (two) periods. These were extracted from the official website of "our world in data" [27]. The world annual averaged temperatures and precipitations data were sourced from the World Bank data catalog [28].

2.3. Analysis of Data

Conceptualizing the sampling strategy for relative efficiency under a super population model, the approximated 0.05% confirmed cases of the total population of each country in this study were sampled for "before-vaccination period" and data for 5 (five) months after the intervention of COVID-19 vaccines were surveyed. This study estimates the *infection rate* (IRR) according to its definition by [29], *incidence rate* (I.R.), and *Relative Risk* (R.R.) for the two periods using equations 1, 2, and 3.

$$\text{IRR} = \frac{\text{a}}{\text{b}} \tag{1}$$

where a is the number of people infected and b is the days of infection.

$$\text{IR} = \frac{\text{m}}{\text{n}} \tag{2}$$

where m is the number of persons who develop the disease over time and n is the number of persons initially without the disease who were followed for the defined period.

$$RR = \frac{\text{Disease incidence in group 1}}{\text{Disease incidence in group 2}} \tag{3}$$

where RR = 1 means that exposure does not affect the outcome, RR < 1 means that the risk of the outcome is decreased by the exposure, which is a "protective factor," and RR> 1 means that the risk of the outcome is increased by the exposure, which is a "risk factor."

The case fatality rate (CFR) was obtained using the regression model approach [29]. The equation is given as:

$$\text{death cases} = \beta_0 + (\beta_1 \times \text{confirmed cases}) + \varepsilon_i \tag{4}$$

An aridity index (AI) is a numerical indicator of the degree of dryness of the climate at a given location as classified by De Martonne [30], [31] and denoted I. For $I < 5$ is classified as Hyper-Arid, Arid when $5 < I < 10$, Semi-Arid when $10 < I < 20$, Mediterranean when $20 < I < 24$, Semi-Wet when $24 < I < 28$, wet when $28 < I < 35$, very wet when $35 < I < 55$ and extremely wet when I > 55. The Index (I) is obtained as:

$$I = \frac{P}{T + 10} \tag{5}$$

Where P is the average annual precipitation (mm), T is the average yearly temperature (^0C), and I is the De Martonne aridity coefficient. In equation (5), evaporation is indirectly considered. The availability of the factors and the classification of this method which can define diverse climates made this method more widely used in Iran [32].

3. Results

This study examined the daily behavior of COVID-19 in incidence, spread, and fatality rates in association with the level of vaccines efficacy when there was no vaccination and during vaccination in the aggregation of risks associated with the exposure to a climatic condition of five Sub-Saharan African countries having recorded high COVID-19 cases in their respective regions.

3.1. Descriptive Statistics and estimated cases

The descriptive statistics of COVID – 19 outcomes on daily confirmed and death cases in the analysis explains the sampling technique and measures of the data surveyed in the period before vaccination as the sampling revolved from the day of the first reported COVID-19 case till when the case reached 0.05% of the total population of every country under study. At the same time, the sampling during vaccination lasted for the first five months of vaccination, as presented in Table 1. The sample for each country was taken in proportion to its size, as used by [33]. Right before the infected people with COVID-19 in Cameroon summed up to about 15,000 on 7th August 2020 [9], the lowest and highest daily confirmed cases recorded were 0 and 2,324, respectively, while the lowest and highest ever recorded death cases were 0 and 64 respectively. The average within the pre-vaccination period is 119 and 3 for confirmed and death cases, respectively. Within the first five months of vaccination, 22,479 cases were reported from amongst uninfected populations of 27,162,531 that made it to the vaccination period in Cameroon. Between 12th April 2021 and 12th September 2021, the average daily reported confirmed cases and death cases were 146 and 3, respectively.

Focusing on the realistic patterns of figures, South Africa recorded a shock in the daily average confirmed cases of 5,289 and death cases of 122 during vaccination when Infection was observed in larger people than in any other population on the list. According to De Martonne's global classification [30], Cameroon falls within "Very wet region," Ethiopia within "Semi-wet regions," Morocco within "Semi-arid regions," Nigeria within "Wet regions," and South Africa within "Semi-Arid regions," all measured by an index that characterizes climate.

Table 1: Descriptive statistics of the Datasets

Countries	**Period**	**Total population**	**Sample**	**Temp. (^{O}C) Prec. (mm)**	**De Martonne (I)**	**CONFIRMED/DEATH CASES**			
						Min	**Max**	**Mean**	**Std dev**
Cameroon	*Before*	27,224,262	14,916	17.60	46.72	0/0	2324/64	119/3	279/9
	During	27,162,531	22,479	474.78		0/0	6252/116	146/3	650/12
Ethiopia	*Before*	117,876,226	59,648	17.23	25.66	0/0	1829/28	333/6	481/8
	During	117,654,682	97,557	322.27		39/0	2149/47	633/12	585/10
Morocco	*Before*	37,344,787	18,834	26.78	11.84	0/0	570/12	130/2	115/6
	During	36,864,731	78,729	1138.53		35/0	2853/18	521/6	469/4
Nigeria	*Before*	211,400,704	107,345	22.37	30.95	0/0	1867/31	332/5	331/5
	During	21,124,0047	21,846	830.51		0/0	790/28	142/1	181/3
South Africa	*Before*	60,041,996	30,967	24.53	17.20	0/0	1837/52	356/10	441/12
	During	58,545,557	798,656	1613.07		0/0	26485/63	5289/122	6398/109

Table 2: Behavioral expression of rates of COVID-19 Infection with and without vaccines

Countries	Case Fatality Rate		Infection Rate		Incidence Rate	
	Before	During	Before	During	Before	During
Cameroon	0.024(R^2= 0.958)	0.022(R^2=0.982)	*119.328*	*145.97*	0.000562	0.0008276
Ethiopia	0.016(R^2= 0.996)	0.020(R^2=0.928)	*333.23*	*633.49*	0.000519	0.0008292
Morocco	0.014(R^2 = 0.806)	0.013(R^2=0.977)	129.89	*511.23*	0.00051	0.0021356
Nigeria	0.015 (R^2=0.948)	0.009(R^2=0.890)	*332.33*	*141.86*	0.000521	0.000103
South-Africa	0.021 (R^2=0.994)	0.019(R^2=0.921)	*355.94*	*5,186.09*	0.000522	0.013642

3.2. Health indicators

The proportion of Cameroon people who died of COVID-19 among 14,916 diagnosed with the disease within the defined time-interval for the study is 2.4% before vaccination (See Table 2). Within the first five (5) months of vaccination, 22,479 people diagnosed with the disease were sampled. The fatality rate dropped to 2.2%. Before vaccination, it took 125 days for Cameroon to reach 0.05% of the total population, making an approximate 119.328 infection rate. During the first five (5) months of vaccination, the Infection rate rose to 145.97 within 154 days, with 22,479 individuals diagnosed with the disease. However, the incidence rate (the number of new cases in Cameroon within the defined time-interval for this study before vaccination as a proportion of the 27,224,262 people at risk) is 0.562 per one-thousand people. This rate increases to 0.828 per one-thousand among 27,162,531 people at risk during the first five (5) months of vaccination.

In Ethiopia, the percentage of people who died of COVID-19 among 59,648 diagnosed with the disease within the defined time-interval for the study is 1.6% before vaccination. Within the first five (5) months of vaccination, 97,557 people diagnosed with the disease were sampled. The fatality rate also increased to 2.0%. The infection rate that expresses the spread power among the population was estimated to be 333.23, with the infection taking 179 days to reach 0.05% of the total population of Ethiopia before vaccination. In comparison, within the first five (5) months (154 days) of vaccination, the infection rate almost doubled to 633.49. The incidence rate for 117,876,226 people at risk was 0.519 per one-thousand people before vaccination. This rate among 117,654,682 people of Ethiopia at risk during the first five (5) months of vaccination increased to 0.829.

The proportion of Morocco people who died of COVID-19 among 18,834 diagnosed with the disease within the defined time-interval for the study is 1.4% before vaccination. Within the first five (5) months of vaccination, 97,557 people diagnosed with the disease were sampled. The fatality rate dropped to 1.3%, leaving behind an indication that the vaccine has a significant mitigating influence on the case fatality rate. However, the COVID-19 spread rate was estimated to be 129.89 within 145 days of the period before vaccination, and this rate increased to about 4-times during vaccination for 154 days of people receiving COVID-19 vaccines. Moreover, the incidence rate taking
37,344,787 of Morocco people at risk before vaccination into consideration gives 0.51 per one-thousand people, and this rate during the vaccination period of five months accounted for 2.41 per one-thousand people of 36,864,731 in the population at risk, meaning that the incidence is five-times more of what it was before vaccination. This suggests that vaccination had less effect

on reducing the incidence rate. However, the tendency of these rates to behave differently in the period before and during vaccination can be explained by climate phenomenon, containment measures, the population in dominance, cardiovascular death rate, and diabetes prevalence in the country, even though the Morocco vaccination campaign had been claimed as rapid and effective compared to other African countries.

The Nigerian people who died of COVID-19 among 107,345 diagnosed with the disease within the defined time-interval for the study is 1.5% before vaccination. Within the first five (5) months of vaccination, 21,846 people diagnosed with the disease were sampled, and the fatality rate was 0.9%. This indicates that vaccine has a mitigating influence on the case fatality rate. Also, within 323 days after Nigeria recorded its first case, the infection rate had reached about 0.05% of the total population, making 332.33 spread rate, similar to that of Ethiopia before vaccination, while this reduced its spread drastically during the first five (5) months of vaccination. This implies COVID-19 spread rate in Nigeria is being affected positively by vaccines. A similar inflow is the incidence rate before vaccination taking 211,400,704 people at risk into consideration. The estimated 0.521 per one-thousand reduces among 211,240,047 people at risk during vaccination to 0.103 per one-thousand. These results make Nigeria a benchmark for vaccine efficacy among the African countries considered in this study.

The proportion of South Africa people who died of COVID-19 among 30,967 diagnosed with the disease within the defined time-interval for the study is 1.5% before vaccination. Within the first five (5) months of vaccination, 798,656 people diagnosed with the disease were sampled, and the fatality rate appeared to be 0.9%. This indicates that vaccine has a mitigating effect on the case fatality rate. Before vaccination, the case dispersed across 0.05% of the total population within 87 days, making its spread the fastest compared to other countries in the study with a 355.94 infection rate. The spread becomes about 15-times faster during the first five (5) months of vaccination, estimating 5,186.09 as the value of infection rate. This implies COVID-19 vaccines show no efficacy on the behavioral spread of the infection. However, the incidence rate taking 60,041,996 of South African people at risk into consideration gives 0.522 per one-thousand people, as this rate during the vaccination period of five months accounted for 13.642 per one-thousand people of 58,545,557 in the population at risk meaning that the incidence is by 26-times more of what it was before vaccination.

3.3. Test of association

The challenges of climatic and environmental changes and other events amidst the pandemic have been a dominating involution facing the social development and evolution of human civilization epidemics [3, 15, 34]; however, this shows dynamism in intensity from area to area. South Africa, Ethiopia, and Nigeria, in the fresh spread of COVID-19, reported a mean of 330 confirmed cases per day; this waved exponentially in South Africa and mildly in Ethiopia amidst vaccination. Prevalent health issues among patients hospitalized are hypertension, diabetes, and other cardiovascular diseases [3, 35]. Morocco has a cardiovascular death rate of 419.146 and a diabetes prevalence of 7.14, and there is a possibility of these rates depending on some influencing components of epidemics factors. Spearman-rank correlation test was used to establish the relationship's strength and direction of some of the features relative to the rates estimated in this study, as presented in Table 3. Combinative analysis of this trend from Table 3 shows that only the case fatality rate is significantly correlated with the covid-19 incidence rate before vaccination ($r=0.9$; $p < 0.05$), while only the infection rate is significantly associated with the incidence rate during vaccination ($r=0.9$; $p < 0.05$). The finding affirms the undaunted input of the COVID-19 vaccine in reducing the case fatality rate in Africa.

3.4. Test of significant differences between the periods

Due to the social upheaval of the pandemic, vaccine development was aimed to achieve direct certainty of vaccine efficacy in protecting humans against COVID-19 & SARS-CoV-2 Infection so that manufacture of efficacious vaccines could reach its peak [36]. The most important efficacy endpoint of the vaccine against this severe disease is evaluated by comparing cases when it wasn't within the population and when endorsed for use by citizens.

Some complex behavioral variables are constituted in the diversity of understanding efficacy in the use of vaccines. Independent t-test conducted shows there is no statistically significant difference in the means of Case fatality rate before vaccination and during the first five months of vaccination at (90% and 95% confidence levels, $p > 0.1$ and 0.05, respectively), while there are significant differences in the means of infection and incidence rates across the two periods (before and during vaccination) with ($p < 0.1$ and 0.05) as it can be demonstrated in the vaccine's licensure of outcomes that include consequences attributable to the reduction in Infection, transmission dynamics, lowered severity [37] and duration of infectivity [38] all defining vaccine efficacy.

3.5. Association of exposure to Aridity and COVID – 19 outcome

The *control* column in Table 4 for "before vaccination" expresses the difference in the total population and confirmed cases of the region (country) in concern when there was no intervention of actual COVID-19 vaccines globally accepted, while *control* for "during vaccination" demonstrates the population size that had not received vaccines during the first five (5) months of their vaccines distribution as *cases*-column describes the number of cases reported within these time intervals.

For the period before vaccination, the assumption is made that every patient confirmed with COVID-19 case and reported was under treatment with a specific vaccine, meaning that the population without infection is the control. While for the period "during-vaccination," it is explained through the control column, the population size that did not receive treatment (COVID-19 vaccine) during the first five (5) months of its distribution, through the difference of total people vaccinated and the total country population taken, *as cases-column* shows the number

Table 3: Spearman rank correlation of the rates across the periods of no-vaccination & vaccination

	Vaccination period	Case fatality rate	Incidence rate	infection rate
Case fatality rate	*Before*	-	ρ = 0.90, (p=0.037)	ρ = 0, Absent
	During	-	ρ = -0.1, (p=0.873)	ρ = 0.3, (p=0.624)
Incidence rate	*Before*	ρ = 0.90, (p=0.037)	-	ρ = -0.1, (p=0.873)
	During	ρ = -0.1, (p=0.873)	-	ρ = 0.90, (p=0.037)
Infection rate	*Before*	ρ = 0, Absent	ρ = -0.1, (p=0.873)	-
	During	ρ = 0.3, (p=0.624)	ρ = 0.90, (p=0.037)	-

Table 4: Relative Risks table for pairwise severity of the incidence in different aridity zones

ARIDITY	PERIOD	CASES	CONTROLS	SEMI-ARID (H)	SEMI-ARID(L)	SEMI-WET	WET	VERY WET
SEMI-ARID (H)	Before	*30,967*	*60,011,029*	-	0.9778	0.9812	0.9845	1.0623
	During	798,656	55,706,479	-	0.2129	0.0589	0.0073	0.2129
SEMI-ARID(L)	Before	*18,834*	*37,325,953*	1.0227	-	1.0034	1.0069	1.0864
	During	78,729	25,788,817	4.6962	-	0.2766	0.0343	0.2741
SEMI-WET	Before	*59,648*	*117,816,578*	1.0192	0.9966	-	1.0035	1.0828
	During	97,557	115,549,695	16.981	3.6157	-	0.1239	0.9912
WET	Before	*107,345*	*211,293,359*	1.0157	0.9932	0.9965	-	1.079
	During	21,846	208,850,314	137.0621	29.1855	8.0715	-	8.0007
VERY WET	Before	*14,916*	*27,209,346*	0.9413	0.9204	0.9235	0.9267	-
	During	22,479	26,860,489	17.1314	3.6479	1.0088	0.125	-

of cases reported within this time interval. Between 12th April 2021 and 12th September 2021, Cameroon recorded 22,479 cases, while the total number of people vaccinated was 363,773 (1% of the total population). In the same vein, Ethiopia progressed with 2,326,531 (2% of the total population) vaccinated people, and 97,557 cases were confirmed between 08th April 2021 and 08th September 2021. In Morocco, the entire case confirmed was 78,729, and 11,555,970 (31% of the total population) people were vaccinated between 19th February 2021 and 19th July 2021. Nigeria vaccinated 2,550,390 (1% of the total population) and recorded 21,846 confirmed cases between 15th Marc^h 2021 and 15th August 2021. The vaccination in South Africa reached 4,335,517 (7% of the total population), while 798,656 cases were confirmed between 18th February 2021 and 18th July 2021.

The odd ratios table for the regions in a pairwise manner is shown in Table 4, indicating that the individual estimate ranges between 0.9 and 1.0; meaning that exposure to aridity (temperature and precipitation) either served as a protective factor or did not affect the outcomes during the spread of COVID-19 among the 0.05% of the total population of each of the countries in the study during the period of no-vaccination.

The WET region in De Martonne's aridity index [30] has the lowest risk of having COVID-19 disease during vaccination. The part that falls under the wet region in this study is Nigeria. The risk of being reported COVID-19 positive for Semi-Arid (High) region people (South-Africa) is approximately 137 times the number of people in the WET region (Nigeria). The risk of being reported COVID-19 positive for the Semi-Arid (Low) region (Morocco) is approximately 29 times more for the people living in the wet area (Nigeria). The risk of being reported COVID-19 positive for the people living in the semi-wet region (Ethiopia and Cameroon) is approximately eight times more for those living in the wet region (Nigeria).

4. Discussions

Even though different countries adopted several preventive measures for the COVID-19 outbreak; while corporate and clinical measures were adopted by various governments, South Africa recorded a shock in the daily average confirmed cases of 5,289 and death cases of 122 during vaccination when infection was observed in larger people than in any other population on the list. This is closely followed by Ethiopia, which recorded daily average confirmed cases of 633 and death cases of 12. However, Nigeria of the five countries recorded the least daily average confirmed cases of 142 and 1 death case. The surge in South Africa even during vaccination may be consistent with the report that one of the popular vaccines adopted by the South African government which is the Oxford-AstraZeneca covid-19 vaccine in South Africa, is not efficient against the 501Y.V2 variant, which accounts for around 90% of cases in South Africa [39, 40]. Violation of social distancing guidelines in many parts of South Africa may also be responsible for the spike in the infection rates. In the Eastern Cape Province, 80% of all infections in the province resulted from burial ceremonies [41].

This study suggests that the climatic classification of the countries considered relates to the incidence rate. The wet region in De Martonne's aridity index [26] has the lowest risk of having COVID-19 disease during vaccination. The part that falls under the wet region in this study is Nigeria. The risk of being reported COVID-19 positive for semi-arid (High) region people (South Africa) is approximately 137 times the number of people in the wet region (Nigeria). The risk of being reported COVID-19 positive for the semi-arid (Low) region (Morocco) is approximately 29 times the number of people living in the wet region (Nigeria). The risk of being reported COVID-19 positive for the people living in the semi-wet region (Ethiopia and Cameroon) is approximately eight times of those living in the wet region (Nigeria). This agrees with the report of [36], who pontificated that transmission of viruses can be affected by many factors, including climate conditions such as temperature and humidity. Although visual inspection of world maps describes that (COVID-19) is less common in countries closer to the equator, where humidity & heat seem to be higher, the relationship between COVID-19 and climatic conditions may be confounded by many factors. Temperature and absolute humidity were reported as crucial weather indices associated with the spread of COVID-19 [42, 43].

From this study, the ability of vaccines to curb the Infection (Spread) and incidence rates of the COVID-19 pandemic is highly doubtful. Although there is a scarcity of literature that has compared the effect of the vaccine on infection and incidence rates of COVID-19, four (Cameroon, Ethiopia, Morocco, and South Africa) of the five countries considered in this study consistently show that infection and incidence rates increased (rapidly in some cases) during vaccination compared to what was obtainable before vaccination. Only Nigeria has reduced infection and incidence rates during vaccination. An increase in infection and incidence rates might be due to relaxing the preventive measures observed in all these countries before vaccination during the advent of vaccines. From the results of this study, the case fatality rate representing the proportion of cases that eventually die from the disease was mitigated through vaccination. Four (Cameroon, Nigeria, Morocco, and South Africa) of the five countries considered in this study consistently show that the case fatality rate decreased during vaccination compared with the pre-vaccination period. Analysis, however, shows no statistically significant difference in the means of Case fatality rate before and during the first five months of vaccination. From this study, only Ethiopia experienced an increase in case fatality rate during vaccination. This result is in tandem with [37], who suggest that vaccination against seasonal influenza (though nor COVID-19 vaccine) might beneficially impact on incidence and severity of the novel coronavirus epidemic. Also, according to Miller [38] *et al.*, Bacillus Calmette-Guérin (BCG) vaccination correlates with COVID-19 case fatality rates and offers protection against severe cases of SARS-CoV2.

The differences in the behavior of vaccines among the population for the studied rates across the periods before-vaccination and during vaccination might have resulted from effects in stringency index by the government, diabetes prevalence, cardiovascular death rate, population-class in dominance & climatic condition as the study covered beyond a period [43, 44]. From Spearman rank correlation, it was established for the five African Countries that before introducing the COVID-19 vaccines, the case fatality rate and incidence rate rose together as incidence rate and infection rate also show direct variation during the vaccination period.

The reports of this research should be limited because the data collected for the five countries involved in this study are datasets for five months into the vaccination period. This can still be referred to as the early period into the vaccination period. Although the climatic condition of the countries considered, which is one of the factors that could affect case fatality, incidence, and infection rates, was considered in this study; many other factors could influence the results like the level of strictness in preventive measures for the COVID-19 from country to country. Another factor is comorbidities that will affect the case fatality rate from COVID-19.

5. Conclusion

From this study's findings, vaccines effectively reduce the proportion of cases that eventually die from COVID-19 in Cameroon, Nigeria, Morocco, and South Africa. However, vaccines seem not to affect the case fatality rate in Ethiopia during the period of this study. It was observed that the vaccine is ineffective in curbing infection and incidence rates as there are increases in Cameroon, Ethiopia, Morocco, and South Africa. However, these two rates decrease in Nigeria during vaccination compared with before vaccination. This implies that methods other than vaccination should be considered to curtail the incidence and infection (spread) rates.

There is no yet observed ability of vaccines to produce a desired effect on the Infection (Spread) rate of COVID-19 as the disease spread faster in South Africa in this study than in any other country during the vaccination period. There should be more awareness on reporting every infected individual whenever observed.

Climatic condition is an important factor contributing to the risk of being infected. Based on the categories of countries into regions, other countries have a higher risk of being reported COVID-19 positive when compared to Nigeria, which has the lowest risk of having COVID-19 disease. The risk of being reported COVID-19 positive for South Africa and Morocco is approximately 137 and 29 times the number of people in Nigeria. However, the risk of being infected in Ethiopia and Cameroon is about 8 times more than those living in Nigeria.

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