**Are we on the right track? Forecasting the trends and probable impact of COVID-19 on Low and Middle Income Countries based on the publicly available data**

**Abstract**

The COVID-19 pandemic becomes a public-health threat globally exerting a devastating impact on patients, healthcare providers, systems, and financing. Both developed and developing countries are struggling to control the pandemic, though situation is alarming in Low-and-Middle-Income-Countries (LMICs). Lack of social-distancing, higher population, health-inequalities, adequate health infrastructure is placing tremendous challenge to control COVID-19. Present study was undertaken to forecast the trends in outbreak of COVID-19 in LMICs (40 countries) based on the publicly-available-case-data drawn from the<https://ourworldindata.org/coronavirus-source-data>. An auto-regressive-integrated-moving-averages (ARIMA) model was used to predict the trends in total confirmed and death-cases caused by COVID19. Findings reveal the highest point-forecast of confirmed cases for Zambia (8.36%) and death cases for Senegal (5.72%). Tunisia recorded lowest point-forecast (0.27%) for confirmed cases and Morocco (0.75%) for deaths across LMICs.Keeping in view the limited healthcare resources in LMICs, accurate forecasting and detection, stronger disease-surveillance, and avoidance of acute-care for infected-cases is indispensable.

**Keywords**  COVID-19, Low-and-Middle-Income-Countries, ARIMA, Forecasting, Healthcare.

**Introduction**

Worldwide, over the past two decades, a larger number of individuals and animals have been affected with three epidemics caused by the family of coronavirus (Severe Acute Respiratory Syndrome (SARS)-2003, Middle East Respiratory Syndrome (MERS)-2012, and Coronavirus Disease (COVID-19) [1]. However, significant genetic dissimilarities have been documented between pathogens of these three epidemics, particularly amid MERS and COVID-19. Initially, the hotspots for these epidemics were the Middle East, Saudi Arabia, and China. They transmitted from animal to human, and later transmissions of pathogens were reported from humans to humans in other countries as well. Epidemiological evidence of the COVID-19 outbreak began from Wuhan, China from December 12, 2019 [2].

The World Health Organization (WHO) declared COVID-19 a pandemic on March 11th, 2020 as more than 118,000 cases had been reported in 110 countries with a sustained worldwide risk of further spread [3]. The most common symptoms associated with the COVID-19 are fever, tiredness, and dry cough, though few people may also experience symptoms such as aches and pain, nasal congestion, running nose, sore throat, and diarrhoea which is very much similar with the common cold conditions. Symptoms may develop in two days to two weeks period following the exposure to the virus.

A pooled analysis of 181 confirmed cases of COVID-19 estimated the mean incubation period to be between 5.1 days and a majority of the individuals (about 98%) will develop the symptoms within 11.5 days of infection [4]. The majority of these patients have a self-limiting infection, and they do recover over time. However, in some severe cases, about 10% of these infected cases may require admission in the intensive care units (ICUs), and unfortunately, some of them may die also. The population in the older age brackets, along with the people with low immunity, and prior medical conditions such as cardiovascular diseases/hypertension, diabetes, and other chronic underlying conditions are more prone to COVID-19.

There are two important stages of COVID-19 i.e. stage II and III. In stage II, the transmission takes place due to human contact, while in stage III, there is community spread. As COVID-19 is a viral infection, and no medicines or vaccines have yet been developed, prevention of virus transmission is crucial, and confirmed cases may require treatment of symptoms. As per the estimates by the Imperial College London, in the absence of interventions, Covid-19 would have resulted in 7 billion infections and 40 million deaths in 2020 globally. As of May 05, 2020, the spread of COVID-19 since the first case in December 2019, has reached 3,582,469 confirmed cases including 2, 51,365 deaths globally [5, 6]. It is argued that developed countries have greater expertise in the investigation and management of such cases than low- and middle-income countries (LMICs).

The spread of COVID-19 in the LMICs is a major concern because of the extreme resource constraints, poor quality of healthcare, lack of awareness, compliance, human resource and expertise, and vulnerable supply chains. Controlling the spread in these countries would be critical as these LMICs are accommodating about 6.3 billion people. As of May 05, 2020, LMICs are hit severely causing 1,40,211 confirmed cases which are around 39.13 percent of the global cases worldwide and 5009 deaths which are 19.92 percent of the global cases [7, 8]. Many stringent measures were promptly instigated by these countries including city lockdown, suspension of travel by air, train, and highways to contain the spread of the pandemic.

The COVID-19 pandemic continues to create an acute shortage of essential supplies, personal protective equipment, diagnostics, and medical supplies among the LMICs [9]. Due to delays in monitoring the symptoms, and need for critical care, the ventilator support required by the patients suffering from COVID-19 has outnumbered the available number of beds in the Intensive care units (ICUs). Further, the health system needs to be provided with accurate expected numbers to meet the demand for healthcare in terms of emergency training and transferring the doctors and nurses along with other healthcare workers to the severely affected areas in these LMICs.

Due to the limited budgetary allocations on health, the LMICs are currently managing the additional cost of critical care from other sources, putting them further into a deeper economic crisis. The literature points out the fact that due to higher socio-demographic and economic inequalities among these countries, high pressure of the population, poor sanitation, and hygiene practices, these countries may act as a breeding ground for the spread of the virus.

According to real-time data, confirmed cases of COVID-19 are growing exponentially. Therefore to contain the spread of coronavirus, it is important to forecast the precise increase in the expected number of cases to comprehend what is required to control the perturbing trends in COVID-19 [9-11]. The accuracy in the predictions will play a critical role in managing the health emergency and preparedness of the respective governments of these LMICs to tackle the COVID situation. Accurate forecasting can play a critical role in apprising the governments and healthcare professionals what to expect and which measures to impose to motivate the public to adhere to them. In this paper, we aimed to assess the spread of coronavirus (COVID-19) in the LMICs from publicly available data and to assess the quality of official case records trends by using the ARIMA method. We assume that publicly available data of total confirmed cases and deaths is a legitimate subject to certain reporting biases if any. The objective is not to attempt for meticulous precision but to merely provide useful insights on COVID-19 in the LMICs.

**Material and methods**

The data were collected from the publicly available sources i.e. Our World in Data (https://ourworldindata.org/coronavirus-source-data) on COVID-19 total confirmed and death cases [12]. The data were collected and analyzed from December 31, 2019, to May 10, 2020. We used the Auto-Regressive Integrated Moving Average (ARIMA) forecasting model, a popular statistical method for time series forecasting [13]. In this method, we use weighted averages of past observations to forecast new values. Here, the idea is to give more importance to recent values in the series. Thus, as observations get older (in time), the importance of these values get exponentially smaller. A univariate time-series analysis method has been used to model and forecast the COVID-19 daily confirmed, and death cases in LMICs. The information was available for only 40 LMICs, which has been used in the present study. The regressive forecast curves were consistent with the pattern of actual values. The ARIMA model fitting was adequate for the data.

Steps to implement Arima are: first loading the data, and pre-processing it, along with making the time series stationary. Later, we determine the d-value and create an autocorrelation function (ACF) and partial autocorrelation function (PACF) plots. After determining the p and q values, we fit the ARIMA model. Lastly, we predict the values on the validation set and calculate the root mean square error (RMSE). However, ARIMA makes the task easier as it eliminates the steps from 6 to 3, which were time-consuming. Steps for ARIMA are: Loading the data and pre-processing it to fit the ARIMA model. Then we predict the values on the validation set and calculate the RMSE.

An autoregressive (AR(p)) component is referring to the use of past values in the regression equation for the series Y. The auto-regressive parameter p specifies the number of lags used in the model. The equation for the model is:

Yt=c+ ∅1Yt-1+ ∅2Yt-2+ et

Where *φ*1, *φ*2 are parameters for the model.

The *d* represents the degree of differencing in the integrated (*I(d)*) component. Differencing a series involves simply subtracting its current and previous values *d* times. Often, differencing is used to stabilize the series when the stationary assumption is not met, which we will discuss below. A moving average (MA(q)) component represents the error of the model as a combination of previous error terms *et*. The order *q* determines the number of terms to include in the model

Yt=c+ 1et-1+ 2et-2+…+ qet-q+ et

Differencing, autoregressive, and moving average components make up a non-seasonal ARIMA model which can be written as a linear equation:

Yd=c+ ∅1ed t-1+ ∅2ed t-2+…+ 1et-1+ ∅qet-q+ et

Where *yd* is *Y-differenced* *d* times and *c* is constant.

ARIMA methodology does have its limitations. These models directly rely on past values and therefore work best on long and stable series. Also, note that ARIMA simply approximates historical patterns and therefore does not aim to explain the structure of the underlying data mechanism. The parameters for the tentative model from the identification step were estimated using the ARIMA module in R Software [14].

**Results**

The study estimates show the highest point forecast for confirmed cases of COVID-19 in Zambia across the LMICs. The confirmed cases in Zambia could be around 1102 (95% CI: 823.31, 1380.39) and death cases could be highest for Senegal i.e. around 36 (95% CI: 30.00, 42.04) as on May 20, 2020. As a result, the confirmed rate of disease for Zambia as a whole will increase approximately at the rate of 8.36% for confirmed cases and 5.72% for death cases in Senegal daily. The base data has been taken from December 31, 2019, to May 10, 2020, for daily confirmed and death cases. Based on this data, these confirmed and death cases have been predicted from May 11 to May 20, 2020, and presented in Table 1. Among these 40 LMICs, the lowest number of confirmed cases has been estimated for Tunisia while lowest death cases were forecasted in Morocco. The rate of increase in confirmed cases in Tunisia was 0.27% (1060.58 with 95% CI 929.03, 1192.13) and for death cases in Morocco; it was 0.75% (200.98 with 95% CI 173.10, 228.87), mentioned in Table 2.

Figure 1(a) and 1(b) shows the highest number of confirmed and death cases for COVID-19. The figure shows a trend line depicted in red and blue colors, where the red color curve indicates the number of confirmed and death cases from December 31, 2019, to May 10, 2020, based on the actual data. The blue colour curve indicates the predicted values for both confirmed and death cases. The Y-axis represents the number of confirmed cases and the X-axis represents days. This data was the base for the predicted values of confirmed cases in Zambia and death cases in Senegal. It is predicting the number of confirmed cases in Zambia and death cases in Senegal from May 11 to May 20, 2020. Similarly, the lowest rate of confirmed cases which were estimated for Tunisia and the lowest rate of deaths in Morocco were depicted in Figure 2(a), and 2(b).

Based on the size of the population, India has the highest number of confirmed cases when compared to other LMICs. The total number of cases in India by May 20, 2020 will be 94258.73 (95% CI: 90740.42, 98317.05). After India, Pakistan may have the highest number of confirmed cases which will be around 46853.60 (95% CI: 44725.56, 48981.63). Pakistan is followed by Ukraine (19420.85 cases), Bangladesh (20260.20 cases), Indonesia (18084.12 cases), Philippines (12785.73 cases), and other remaining LMICs as of May 20, 2020.

Similarly, it was estimated that India had the highest number of deaths which will be 3235.30 (95% CI: 3078.97, 3391.64) by May 20, 2020. India is followed by Indonesia with 1114.96 (95% CI: 1046.74, 1183.18). Other countries such as the Philippines, Pakistan, Egypt, Ukraine, Bangladesh, Moldova, Morocco have total deaths 852.57, 941.73, 658.28, 539.03, 288.39, 219.95, 200.98, 154, and other remaining LMICs respectively by May 20, 2020.

**Discussion**

Having the highest share of the population, who are struggling for daily sustenance and living in the poor socio-economic environment, the spread of the disease is far easier in LMICs than that of the developed countries [15]. The present paper forecasts the spread of COVID-19 among the 40 LMICs in terms of confirmed and death cases by May 20, 2020. Though the data was not available on the death cases among 9 out of 40 LMICs, predictions were not possible for them in terms of deaths. The study highlights that if we go by the highest rate of point forecasts for confirmed cases, Zambia will outnumber other LMICs till May 20, 2020 [16].

As per the records, Infections have just begun to accelerate in the African continents from April. As of 11th May 2020, Zambia has recorded 337 confirmed cases and 7 deaths. What makes this pandemic particularly difficult for countries like Zambia are; the structural constraints that already exist in their economies; notable socio-economic inequalities, and highest labour force in the informal sector, the country may face severe challenges to handle the pandemic [16, 17].

In terms of the highest rate of point forecast for death cases, Senegal may be at the top of the list of all 40 LMICs. The country is already facing concerns about basic hygiene needs, health infrastructure, and people living in unfavourable conditions [18, 19]. If the pandemic spreads to these areas, then not only the host nation but also the other international agencies need to take serious measures.

However, if we go by the numbers and in terms of the size of the population, then India will outnumber other countries in terms of both confirmed and death cases. The country is accommodating the second-largest share of the population, having varied socio-economic and demographic conditions, facing tremendous challenges in terms of the COVID-19 outbreak [20]. Further, the health system readiness and other challenges in terms of required health infrastructure, and health-seeking behaviour of its population are among the few mentioned factors which are posing it at the risk of the higher burden of the disease [21, 22].

The confirmed and death cases by the numbers indicate that Nicaragua may record the lowest numbers of confirmed cases and similarly, the lowest death will be observed for Djibouti. Nicaragua, which falls in Central America, has the lowest number of confirmed cases of COVID-19. There was a lack of massive testing and official records released by the country officials. However, no community transmission has been reported to have taken place, which can be a reason for lower reporting for COVID cases [23]. In Djibouti, the Horn of Africa Nation, people do not understand the seriousness of the disease and unfortunately, confinement measures were not respected by its population [24, 25]. The country has recently witnessed a huge rise in coronavirus cases, though the rate of death is less in the country, and expected to be low till May 20, 2020.

Lowest confirmed cases will be recorded in Tunisia, and the lowest deaths have been forecasted in Morocco. However, few records have mentioned that it may be due to the very nature of the virus that a lot of people may be traveling around with the infection without any symptoms [25, 26]. Under detection may be another factor for a lesser number of incoming cases along with limited monitoring capacity and active surveillance.

Another major challenge along with the disease itself is; lack of properly trained healthcare providers, financial burden, the level of awareness about the disease, and inadequate compliance to prevention and mitigation approaches. So, what would be the possible way out for the LMICs, if the developed countries are facing significant challenges in the prevention and management of COVID-19? The LMICs are facing a struggle in terms of the medical preparedness and limited testing capacity. There is a lack of accurate and precise forecasts, which are a must to boost the readiness of the healthcare system to face this public health emergency. A health emergency can happen any time and it has a devastating effect on the normal pattern of existence.

There are also concerns in terms of the disease surveillance, including a case database that is instantly accessible to relevant organizations, and rules requiring sharing information.

It’s essential to help LMICs in strengthening their primary health care systems along with the community workers. They should be considered as first responders and are easily accessed and trusted by the local people. Trained health care workers not only deliver basic minimum services in rural and remote areas; they can also monitor the spread of disease, by serving as part of the early warning surveillance teams.

It is time for the LMICs to get ahead of the curve and respond to the emergency. For the long term effectiveness of the prevention and management strategies, the governmental resources and support are mandatory. It’s time to take a whole-of-government approach to strengthen testing at various entry points along with the institute level mass testing’s for controlling the spread of the epidemics. Further, there is a need for stronger coordination between the local, state, and central government organizations and healthcare institutions.

Better management of COVID‑19 is comparatively more difficult than other medical emergencies, so effective preventive measures are the best way to protect people from it. These measures such as social distancing, quarantine of suspected and vulnerable people; setting up isolation wards and ICUs in hospitals need to be monitored stringently. The LMICs are having a higher population share, where the average household size is bigger than that of the developed countries. The majority of the LMICs are also facing challenges in making its population aware of the symptoms and conditions associated with the COVID-19. Available evidence indicates that incorporating good sanitary practices such as washing the hands frequently with soap and water or using the hand sanitizers especially after touching any surface in public places, covering the mouth and nose by using face masks during coughing and sneezing; avoiding frequent contact with face and nose with the unclean hands, and strict social distancing practices can be helpful in disease management. Further, there are various myths associated with it that need to be addressed with due care by conducting public awareness with the scientific facts. Evidence-based scientific information needs to be provided to the public, as people are of the view that using traditional food items such as ginger, honey, garlic, food rich in vitamin C, and consuming more hot fluids and saltwater gargling can fully cure of COVID-19. However, these traditional means may provide temporary relief from the common cold conditions but their effectiveness in controlling COVID-19 still needs to be scientifically established. Awareness campaigns with pamphlets and brochures, preferably in the native language; sharing information via audio-visual and social media to educate people.

The health information system in the majority of the LMICs is underfunded and weak. There is a need to improve the decision support system in these countries by using digital tools to manage real-time data. The available data needs to be strongly representative of any application based analysis and taking adequate actions based on them. If the data is representative and strong it could be used to send communication messages and prepare for rapid response. The organizations managing the data in LMICs need to focus on improving data governance, real-time analysis, data analytics, and modelling support and accurate forecasting’s by using various technologies. Forecasting and accurate predictions by using the publicly available daily and weekly data for quick action to predict potential coronavirus outbreaks may limit the spread of COVID-19 and associated illnesses and deaths. This information can be used to plan and direct resources for updating the health professionals and community workers in identifying the population at risk, availability of medical supplies, manpower, health infrastructure, and analysis of localized outbreaks in managing the spread of the virus. The private sector can be actively involved along with the government organization in managing the spread and any corrective action.

The insufficient healthcare resources, inadequate financing mechanisms, and constrained health infrastructure in LMICs have resulted in the escalated rate of infections followed by a higher incidence of mortality. These countries understand the association between the healthcare resources and any possible fatalities resulting due to any medical emergencies, which should be used in the future for addressing any local outbreaks. Historical data can be also used from past outbreaks such as severe acute respiratory syndrome coronavirus (SARS-CoV) outbreak, 2003 for strengthening the public health systems. The LMICs must prioritize evidence-based preventive measures in the pre-crisis phase and require preventive measures along with treatment and counselling during and after the crisis. It needs to be recognized that prevention and overall management of such health crises may be more difficult in LMICs than in developed countries.

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**Table legends**

Table 1: Higher forecasting rate of confirmed cases in Zambia and death cases in Senegal across the LMICs by using Auto ARIMA method

Table 2: Lower forecasting rate of confirmed cases in Tunisia and death cases in Morocco across the LMICs by using Auto ARIMA method

**Figure legends**

Figure 1: Higher rate of forecasting confirmed and death cases through ARIMA method

Figure 2: Lower rate of forecasting confirmed and death cases through ARIMA method