Evaluation of Preventive Measures and Forecasting of COVID-19 Infection: Case Study Egypt.

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Abstract

Background: COVID-19 is a highly infectious disease caused by SARS-CoV-2. This article assessed the effectiveness of preventive measures of COVID-19 infection, including social distancing (SD) and quarantine (Q) of patients and contacts in Egypt.

Methods: A simple model was developed to predict the infection rate without preventive measures. The article utilizes fertile meta-heuristic technique and particle swarm optimization (PSO), to predict the growth of the disease.

Results: A correlation between the predicted and actual infected cases , validated the proposed forecasting algorithm. Preventive measures together with the Egyptian Government stay home order reduced 98% of expected infections. PSO analyses showed that infection and death rates will continue to increase particularly with lifting these restrictive preventive measures.

Conclusions: The advised PSO model could predict COVID-19 infection and death rates with high degree of accuracy. This prediction model could help health authorities in decision making.

Keywords: COVID-19**,** Particle Swarm, Preventive Measures, Egypt.

1. Introduction

COVID-19 is an infectious respiratory illness caused by severe acute respiratory syndrome virus 2 (SARS-CoV-2). The first case of confirmed COVID-19 infection was reported in Nov. 2019 in Hubei, then the World Health Organization (WHO) identified the disease in 31st of Dec. 2019 in Wuhan, China [1-3]. The infection spreads rapidly affecting thousands of people worldwide, thus the WHO declared COVID- 19 outbreak a Public Health Emergency of International Concern on 30 Jan. 2020. On 11 Feb. 2020, the WHO launched a preventive plan to restrain the spread of this highly infectious serious disease, that was adopted by many countries. Furthermore, information about COVID-19 virus infection were made accessible to public through social media, mass media, WHO website and national health websites [4-7]. Eventhough the virus continues to spread, particularly with absence of an effective vaccine and treatment, by 24 Apr. 2020 a total of 2.7 million patients were reported in 185 countries, 190,000 died and 742,000 recovered [8-11].

Preventive measures were adopted by many countries to restrain COVID-19 spread and reduce fatalities. These included social distancing and good respiratory personal and public hygiene, also wearing personal protective equipments particularly for health care workers and at public places. SD aimed mainly to prevent transmission of infection from infected or asymptomatic subjects. SD entails preventing contact among large groups through closure of workplaces and schools, travel restriction, canceling gatherings of large groups. Also people should stay 1.8 meters apart. Instead people can still connected through social media and perform their jobs while at homes. After application of SD and stay home orders many regions had sustained effective rate of transmission rate <1. Those suspected or with confirmed COVID-19 infection should stay home, get out for their medical care and should use face mask before , cover sneezes ,avoid sharing equipments, shaking hands, regularly wash hands with soap and water or hand sanitizers [12].

Egypt is a big transcontinental country; geographically Egypt included 27 Governorates, each Governorate has a considerable number of towns and villages. Egypt has a dry hot sunny weather in Summer with higher temperatures in Southern region, and warm rainy weather in Winter. The Egyptian Ministry of health and University Hospitals offer medical services and immunizations to the population at no or minimal fee [13]. Egypt is the Arabian country that has the highest population census of nearly 95- million inhabitants in 2017 and nearly 97.7% of them are native Egyptians. Eventhough COVID-19 infection and deaths, in Egypt, are very low compared with other countries [14].

The Egyptian health systems responded rapidly to the WHO preventive plan to strain COVID-19, and the Egyptian government announced a curfew as an antivirus preventive plan on 24 of March that began at 7:00 pm until 6:00 am for 2-weeks, that was extended to another 2-weeks till 23-April. But the later begin 1-hour later. At the same time, the Egypt's Orthodox Christian Church and Ministry of Religious Endowments announced temporarily halting of communal prayers. On evening of 25-4-2020 there were 4319 confirmed cases of COVID-19 and 307 deaths in Egypt. Furthermore, Egypt implementing preventative measures and a 14-day quarantine periods in all cases. Egypt announced that it will ease its COVID-19 lockdown for the holy month of Ramadan by shortening the curfew at night-time and allowing more businesses to open [14, 15].

The infection of COVID-19 varies according to different factors. However, until now there are no authenticated vaccines or medications. Thus, the number of COVID-19 cases continues to grow in many countries worldwide [14]. This motivates different researchers to predict the infection rate of COVID-19 in near future. Different approaches are being utilized for near future COVID-19 infection rate prediction as statistical methods, regression analysis and time series technique [16, 17]. These techniques show wide variation in the results. Recently, meta-heuristic optimization algorithms were considered for developing reliable and robust forecasting models in different areas of research as financial and engineering research. These algorithms are probabilistic heuristics nature, with global search properties [18, 19]. They could reach an optimum solution without prior knowledge of the problem.

Particle Swarm Optimization (PSO) search approach simulates the behavior of individuals of the species whom work for the benefit of the entire group. It is based on swarm concept; the particles in the swarm adjust their performance i.e flying speed/ direction according to the experience of their own and the other in the swarm, through robust communication. PSO is a random search algorithm with a parallel structure. It enjoys the advantages of a simple structure and fast convergence [18, 19].

This article could claim to have the following contributions:-

- Assessing qualitatively the preventive measures in action and determining its effectiveness in attenuating the infection rate.
- Advising simple and reliable short-time forecasting for the infection rate of COVID-19, particularly for Egypt. This forecasting would probably help in advising more appropriate preventive measures and help decision making.

2. Methodologies and Forecasting Models

We obtained data from the Egyptian ministry of health website; it included new confirmed cases, cumulative confirmed cases, in the period 5th of Mar-2020 to first of Apr-2020. The infection rate of COVID-19 starts to increase in Egypt from 5th of March 2020. However, only one case tested positive was reported in 14th Feb. 2020. [14]The infection rate of COVID-19 is much higher than other comparable viruses SARS and MERS. It is around 1:5 compared with ordinary flu, of 1: 1. [20] However, it is difficult to identify the actual infection rate, as it depends on different factors, such as incubation period, medical treatment and susceptibility of exposed persons. Therefore, the number of positive COVID-19 in near future N_{i+1} could be related to reported cases N_i by,

$$N_{i+1} = N_i \left(1 + f\left(x_1, x_2, x_3, ...\right) - \alpha_T\right) \qquad (1)$$

where x1, x2, x3 are variable that vary according to geographical location, population density, medical facilities, preventive measures and etc. α_T is the ratio of cured to reported cases.

$$N_{i+1} = \sum_{j=1}^{m} a_j N_j \qquad (2)$$

The parameters $a_1, a_2, \ldots\ldots, a_m$ could be determined through PSO algorithm

2.1. PSO technique

The PSO technique could be summarized in the following four steps as [5-6],

- Uniform distribution is used to randomly create a particle swarm.
- Each particle represents a feasible solution to the problem; the particle swarm refers to the best experience of the individual, and the best experience of the group.
- Transition from a point into another in hyperspace is performed logically according to the fitness function.
- The particle swarm gravitate towards the optimum solution after continuous iterations

These generic steps are interpreted mathematically in the following. Population of particles are placed in d-dimension.al search space, where their initial positions and speeds are chosen randomly. The velocity of each particle is regulated according to the flying experience of its own and that of other particles in the population as [5-6],

$$v_i^{k+1} = w_i v_i^k + c_1 rand\left(pbest_i^k - s_i^k\right) + c_2 rand\left(gbest - s_i^k\right) \qquad (3)$$

where v_i^{k+1}, v_i^k are the updated velocity at k+1 iteration and current velocity at iteration k of i particle respectively. $pbest^k_i$ and gbest are the best position for the particle i at iteration k and the global best position for the group so far. s_i^k is the current position of particle i. w_i is the inertia weight of particle i. The positive parameters of PSO c_1 and c_2 are usually chosen between 0.5 to 2 [5-6]. The updated position of a particle i , s_i^{k+1} is related to the current position s_i^k and the updated velocity v_i^{k+1} by [5-6],

$$s_i^{k+1} = s_i^k + v_i^{k+1} \qquad (4)$$

The value of the fitness function is computed for i particle and compared with the current best position $pbest^k_i$. Also, the $pbest^k_i$ is compared with gbest; this is to improve the flying experience of the particles. The number of the particles with position better than gbest is stored. And gbest is updated accordingly. This process continues until reaching to global best position or the predetermined maximum iteration number.

w_i the inertia weight of particle is given by [5],

$$w_i = w_{i\max} - \frac{w_{i\max} - w_{i\min}}{T_{i\max}} T_i \qquad (5)$$

where w_{imax}, w_{imin}, T_{imax} and T_i are maximum weight, minimum weight , maximum iterative time and iterative time respectively. Usually w_i varies within the range 0.4 to 0.9 [5-6]. The maximum value of particle velocity is given by,

$$v_i^{k+1} = \begin{cases} v_i^{k+1} & \left|v_i^{k+1}\right| \text{p } v_{\max} \\ v_{\max} & v_i^{k+1} \geq v_{\max} \\ -v_{\max} & v_i^{k+1} \leq -v_{\max} \end{cases} \qquad (6)$$

where $v_{\max}$ is maximum allowable velocity of a particle.

2.2. Objective function for Daily Forecasting (DF) of COVID-19 infection.

Parameters of DF models, equations (1)-(2), are converted to a constrained optimization problem, where the constraints are the lower and upper limits of the parameters,

$$\text{Minimize } f \text{ subject to } L_{lower} \leq a_{paramters} \leq L_{upper} \qquad (7)$$

Where f is the objective function, L_{lower} and L_{upper} are the lower and upper limits of the parameters respectively. $a_{parameters}$ are the parameters to be optimized.

The objective function in this research is designed to measure the ability of the optimized parameters in predicting the demand accurately. It is based on the Least Square principles [6].

$$f = \sum_{p=1}^{M} \left[\left| N_f(p) - N(p) \right| \right]^2 \qquad (8)$$

2.3. Performance Evaluation

In this research, the visibility of DF models are examined via the Percentage Absolute Normalized Error (PANE) ε, which is given by [5],

$$\varepsilon = \frac{\left| N - N_f \right|}{N} x\, 100 \qquad (9)$$

Where N and N_f are the confirmed and the predicted number of cases respectively.

2.4. Ethical issues and informed consent:

All relevant data and information were obtained from the Egyptian Ministry of Health Website, where we were dealing with recorded numbers and figures and not patients' data, accordingly informed consent was inappropriate.

2.5. Statistics

Micosoft Excel v. 2010 was used to generare figures.

3. Results

Data about COVID-19 infection in Egypt were obtained from the official website of the Egyptian Ministry of Health. **Figure 1** shows the number of COVID-19 cases daily and cumulative, from 5 -Mar-2020 to 1-Apr-2020, with and without using preventive measures as social distance, sterilization of public and private avenues and exposed persons quarantine. The case of without preventive measures is anticipated carried out according to equation (1). However, the infection rate was not assumed as a constant number. Although Figure 1 is developed for an infection rate varying from 1:1 to 1:2, however, the number of cases jumps to 30000 cases. The infection rate of COVID-19 in **Figure 1** was much lower than the reported. [3]

Figure 2 illustrates the confirmed and forecasted number of daily and cumulative COVID-19 cases from 1st of April 2020 until 15th of May 2020. And **Figure 3** shows the confirmed and anticipated number of daily and cumulative COVID-19 death cases from 1st of April 2020 until 15th of May 2020.

Again, the PSO was validated via the sufficient accurate prediction of the COVID-19 deaths.

It could be concluded from **Figures 3 and 4** that the mortality rate for COVID-19 in Egypt until 25 April 2020 is around 7.1%, which is expected to drop to 6.9% by 6 May 2020.

Figure 4 shows the PANE for the COVID-19 confirmed and death cases for 1st of April 2020 until 25th of April 2020. **Figure 4** was developed according to equation (4). It validated the DF model of PSO for COVID-19. The error jumps in some points for deaths forecasting to ± 50%, which is occurred particularly for significant change in reported cases in consecutive days.

4. Discussion and conclusion

Results of the current study proved the effectiveness and feasibility of the preventive measures to control COVID-19 infection in Egypt. Where the confirmed cases, with the preventive measures, were less than 98% for those without them. Thus, until developing the appropriate medication strategy the preventive measures are the only effective tools to face COVID-19. Alternatively, if no SD and other preventive strategies were put into place, we predicted that the epidemic would grow exponentially, and the number of cases would be 31,000 by the first of April 2020. Accordingly for the Egyptian community to be safe and healthy the Egyptians should work together with the health authorities to insure effective application of COVID-19 preventive plan.

One of two scenarios are expected in the future, the first that the current preventive strategies should be in place for another month (or more) with effective application and supervision. The other scenario that could happen is setting up moderate

preventive measures. Based on the results of this study the first scenario will lead to reduction in COVID-19 cases, the contrary will happen if Egypt goes with the second scenario. Thus we recommended that Current preventive measures need to be continued for another 1-month (or more) to decrease the number of new infections. Because, if people mix together they will be in contact with symptomatic or asymptomatic infectious persons and attract infection easily. Accordingly if there is a definite need to open up Egypt have to be cautious to avoid epidemic rebound.

This study developed a forecasting approach for COVID-19 infection in Egypt, and revealed the feasibility of this approach. It predicted the number of COVID-19 cases with sufficient accuracy. Figure 2 showed that the infection rate of COVID-19 will continue to increase in near future and the number of cases will experience around 170% increase in only 10 days. This could be attributed to the increased awareness of physicians with COVID-19, advancement of diagnostic techniques of COVID-19, and the recent behavior of COVID-19 to be a hospital acquired infection with affection of health care workers and their relatives. Moreover it could be related to the highly infectious potential of the virus or development of mutation. Again these results ensured the ultimate need for persistence of the current preventive measures with continuous monitoring and effective application [20]. Moreover, health care workers have to ensure proper use of personal protective equipments (PPE) including face masks and gloves, gowns and face shields during these measures. Also authorities have to pay attention to dental and surgical procedures to be conducted under complete aseptic techniques. Furthermore the patient remained infectious from catching infection to even postmortem, which is a long period that facilitates spread of the virus.

On the other hand this study proved that forecasting not only predicted the progression of COVID-19 infection in a community, it could help predict prognosis of the already infected cases. In this study our model showed expected decrement of fatality rate in Egypt by 6th of May. This denoted effective management strategies and in hospital care of patients, despite of lack of effective antiviral or other therapies. [9,10] Another explanation would be the appropriate sunny weather in Egypt that help weaken the virus and affect its potency, accordingly summer cases would be milder than those occurred in colder weather. This assumption was in accordance with other researchers who reported that the SARS corona virus viability was lost (>3 log10) at high temperatures and high humidity. This explained the incidence of outbreaks in subtropical regions as Hong Kong during spring. It also explains the lower number of cases in Asian countries as Malaysia due to higher temperature and humidity [21].

In this work our findings of forecasting COVID-19 infection were concomitant with other researchers in other countries [22]. Also it was in accordance with what was lastly announced by the Egyptian Government that there is a 50% chance that COVID-19 crisis could continue tell next June or septmeber [23].

Conclusions

The main conclusions of this research could be summarized in the following: -

1. The advised PSO near future COVID-19 model predicts the infection rate and death cases with high accuracy for Egypt.
2. This prediction model could help medical and national decision making.
3. If Egypt has to reopen this step should be proceeded by forecasting studies and future expectations

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Competing interests: The authors declared there was no competing interest of the study.

Informed Consent: Inapplicable.

Author Contributions;

Dr. Hafez proposed the research topic. Dr. Khaled and Dr. Hafez constructed the study objectives, plan and collected data. Dr. Hafez did the statistical analysis and optimization work. Dr. Khaled edited the original study draft. Both authors edited and review the article.

Data Availability: The authors declare that data supporting the findings of this study are available from the Egyptian Ministry of Health website.

Figures

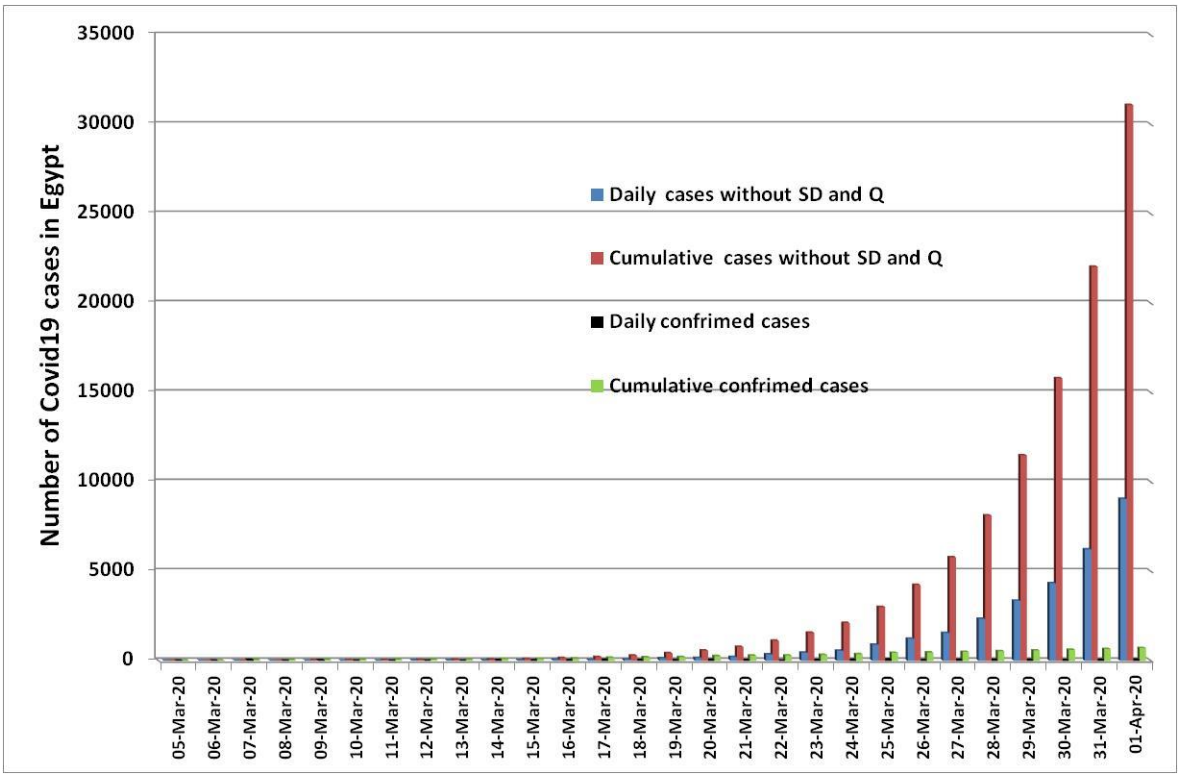

Figure 1: COVID- 19 daily and cumulative cases with and without using preventive measures from 5 -Mar-2020 to 1-Apr-2020.

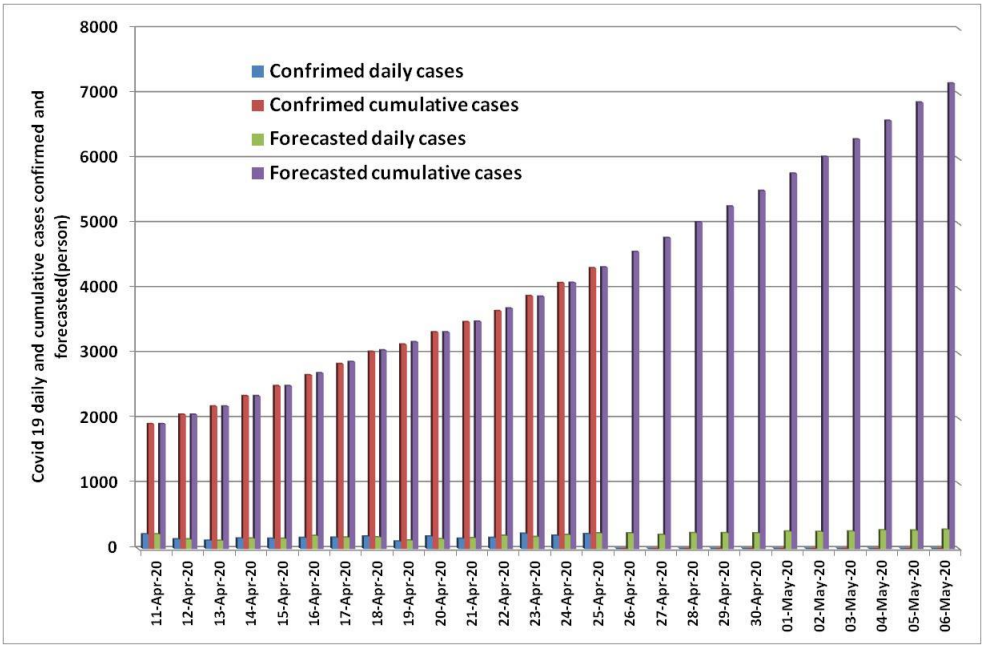

Figure 2 : COVID-19 daily and cumulative cases confirmed and forecasted from 1st of April 2020 until 15th of May 2020.

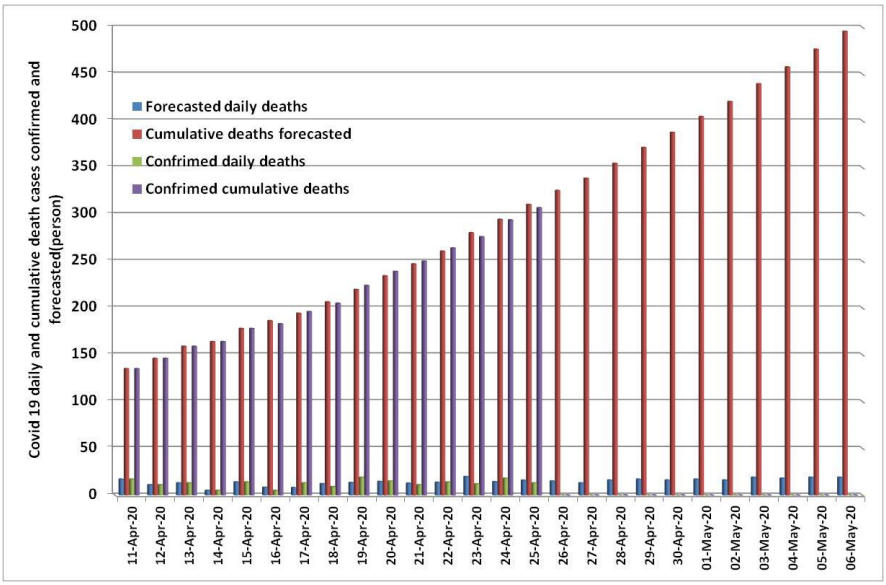

Figure 3: COVID-19 daily and cumulative deaths confirmed and forecasted from 11 of April 2020 until 6th of May 2020.

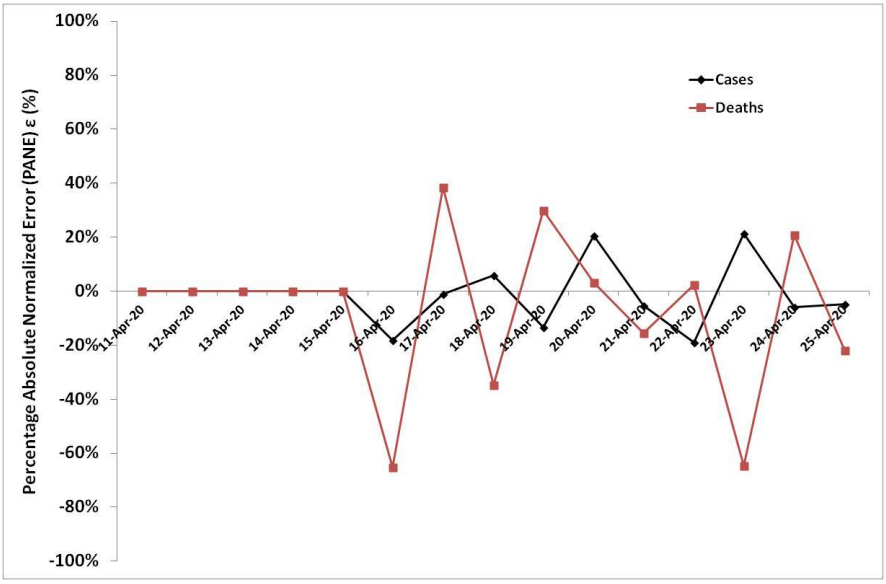

Figure 4 : PANE for Covid 19 cases in the range from 1st April 2020 until 25th April 2020.

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