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EMPIRICAL MODELING FOR REPORTED CASES AND DEATHS OF COVID-19 IN EGYPT DURING THE ACCELERATED SPREAD AND PREDICTION OF THE DELAYED PHASE

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This is a newly developed conceivable mathematical model for analyzing the spreading behavior of COVID-19 during the first wave of the pandemic in Egypt. We emphasized the impact of detection and control measures in flattening the spread of disease. This knowledge of the early spread dynamics of infection and assessing the efficiency of control measures is critical for reviewing and evaluating the potential for sustained transmission to occur during the coming waves. This proposed empirical model for the accelerated spread phase is based on non-linear regression technique, interpolations, tangents, least-square, and optimization methods to delimit different phases of the pandemic and predict the delayed phase. We prove that our model is mathematically consistent and present various simulation results using the best-estimated parameter value. The model can be easily updated when restrictions and other issues become changed. These simulation results may guide the local authorities to make timely right decisions.

Keywords: *Accelerated spread; Causal correlation; COVID-19; Delayed spread; Empirical modeling; Mortality.*

INTRODUCTION

During the 1960s, coronaviruses were first known to infect humans[1]. Most of them primarily affect the upper respiratory tract and the lungs[2]. 229E, NL63, OC43, HKU1, MERS-CoV, SARS-CoV-1, and SARS-CoV-2 are the most known subtypes. They are zoonotic, meaning that they were mainly infecting animals then got the ability to attack humans[3]. The severe acute respiratory syndrome coronavirus (SARS-CoV) pandemic came to the scene between 2002–2003 and led to 8,000 infections in humans across 27 countries[4].

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The novel 2019 SARS-CoV-2 that causes the currently circulating COVID-19 pandemic differs from the former viral infection. It spreads significantly worldwide, causing a significant number of deaths. Globally, on March 12, 2020, COVID-19 was proved in 125,048 cases, with a mortality rate of 3.7% compared with less than 1% mortality rate in the case of the influenza virus. Older people, especially those with severe or chronic illnesses, are at higher risk of COVID-19 than younger persons, contrary to the influenza virus[5].

Accordingly, the development of vaccines is a cornerstone in the prevention of COVID-19 spread. Besides, the non-pharmaceutical preventive measures are critical concerns for public health[6]. These include frequent hand washing, face masks, disinfection and ventilation indoors, social distancing, improved detection methods, and other government and public actions. Besides, the introduction of successful mathematical models that could analyze the epidemiological dynamics, transmission behavior, and the in-time quality of intervening approaches[7&8] .

Owing to its novelty, the research just offers partial responses. Such partial findings require distribution as soon as presented to help research progress in this area. The partial but timely and scientifically-based information will support the authorities in making sound decisions during the progression of the outbreak. Ultimately, a complete image of both the virus and its disease will arise, which will help in the coming waves[9].

Everyday estimates of the number of cases and deaths are delivered by the authorities in all countries and circulated globally. From these data, the delicate health systems in many countries were uncovered. We analyzed the official data for Egypt to make empirical modeling of the pandemic transmission of COVID-19 there. The first reported case of COVID-19 in Egypt was revealed on February 15, 2020, and the first mortality was reported on March 8, 2020, with a total number of infected cases of more than 36. The number of cases increased exponentially to more than 82,000 by the end of August 2020, with a similar increase in the mortality rates to reach 3,858 confirmed deaths at the same period. There are likely far more undetected cases due to the limited number of screening tests, public hesitancy to report, and even worse the denial attitudes of some people[10].

Since the onset of the COVID-19 spread in Egypt, the government has allocated isolation hospitals across the country and gradually placed a series of control measures to Detect the first cases of COVID-19 infection in Egypt. The Egyptian government allocated specific hospitals across the country for COVID-19 cases. This action was taken to reduce the community transition of the disease and to flatten the spread curve. Egypt decided to lock down the schools and universities on March 10 after escalating the cases above 100. A curfew was imposed in Egypt, during which all public and private transportation was suspended for specific hours. Air flights, social activities, places of worship, and sports events were also suspended in the same period[11]. These activities were resumed partially since the end of June 2020, with a continued gradual decline in the restrictions. The Egyptian Science, Technology, and Innovation Funding Authority (STIFA) funded many scientific projects that aim to improve the preventive measures, diagnostic procedures, and development of treatment for COVID-19. The ministry of health published the Egyptian protocol for the management of COVID-19 in April 2020 and updated it in November 2020.

Since SARS-CoV-2 causes a contagious respiratory infection, the first wave was lagged for a short period in most countries during the summer, and the second wave was started at the beginning of winter, posing a socioeconomic crisis and a significant burden on the public health for millions of people. From the transmission curve of the virus, there are three phases of the COVID-19 pandemic to be distinguished. First is the latent growth phase, where the number of reported cases is almost constant over time. It started from February 15 to February 28, 2020 (Supplementary Table S1). The second stage of the pandemic corresponds to the accelerated growth phase; it started on February 29. The third phase corresponds to the delayed growth phase; it started on June 19, where a time-dependent exponentially diminishing transmission rate due to the public interventions and the application of social distancing measures.

Mathematical models proved to perform a significant part in studying infectious disease dynamics[12&13]. The SIR model divided the population into three groups; susceptible (**S**),

infectious (**I**), and recovered (**R**), and neglected the incubation period of the disease. The susceptible–exposed–infectious–recovered (SEIR) model was introduced to include the exposed stage (**E**). Thence the SEIAR model was introduced to involve the asymptomatic (**A**) individuals. The main limitation of these models is that they do not consider the change in the population numbers over time[14]. Far away from these traditional models, this paper will expose a semi-empirical study for the pandemic spread behavior in Egypt in a simplified exponential form over time with three adjustable parameters to offer an accurate prediction and estimation.

Data of reported cases and deaths

Data collection

The investigation data of reported cases and deaths of COVID-19 in Egypt were collected for about eight months (February 14, 2020, to October 10, 2020) depending on three principal electronic resources. The first was the COVID-19 dashboard of Johns Hopkins University (https://systems.jhu.edu/). This was followed by the COVID-19 world meters (https://www.worldometers.info/coronavirus/). The third was Github (https://github.com/owid/covid-19-data/tree/master/public/data).

Data are illustrated graphically in Fig. 1and are presented in Supplementary Table S1. Given the adequate empirical expressions, we propose to divide the time range into three domains according to the different trends of curvatures shown in Fig. 1. Table 1indicates the three main phases (I): latent phase, (II): accelerated phase, and (III): delayed phase.[15]has considered that the two phases (0) and (I) in Table 1 constitute the pre-pandemic intervals and can be assigned as the two stages of *Investigation* and *Recognition*, while phases (II) and (III) constitute the pandemic intervals and can be assigned as the four stages of *Initiation*, *Acceleration*, *Deceleration*, and *Preparation*.

Table 1 :Different spread phases and identification of the accelerated phase for the reported cases and deaths.

Phase 0		Phase I		Phase II		Phase III
Reported cases						
Absence	$t=t_{c0}$	Latent	$t=t_c$	Accelerated	$t=t_{c1}$	Delayed
Deaths						
Absence	$t=t_{d0}$	Latent	$t=t_d$	Accelerated	$t=t_{d1}$	Delayed

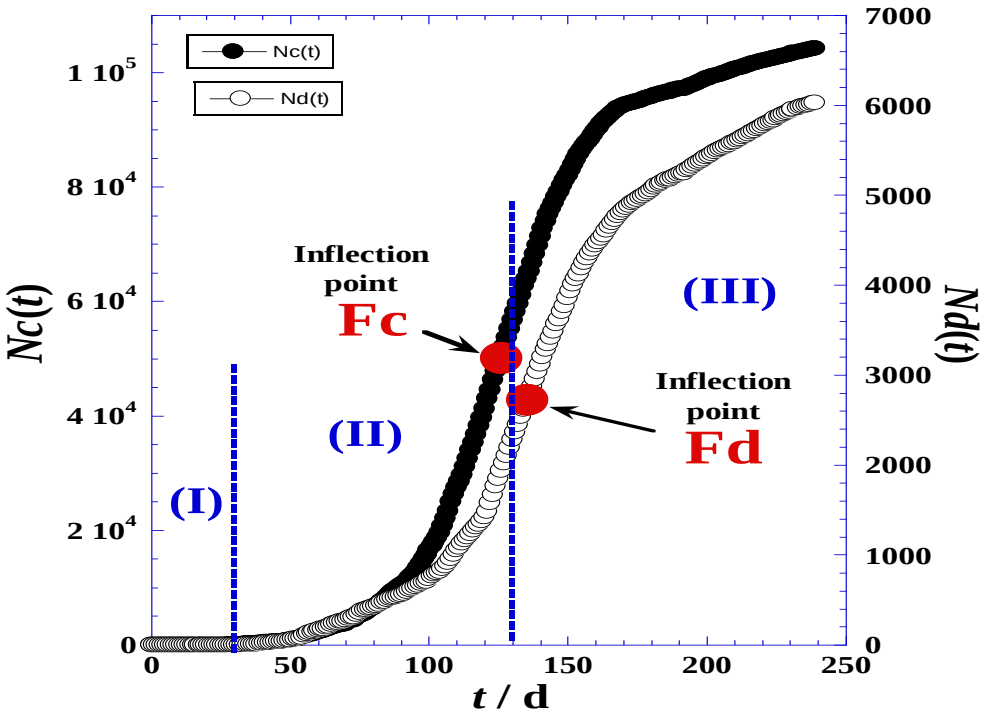

Fig. 1: The total reported cases *Nc*(t) (-●-) and the total recorded deaths *Nd*(t) (-○-) for the first 240 days of the pandemic in Egypt.

Delimitation of phases' domains

The delimitation of the three domains mainly resides on the precise determination of the coordinate of the inflection points indicated in Fig. 1 and Table 1, such as Fc(t_{c1}, N_{c1}) and Fd (t_{d1}, N_{d1}) for the reported daily cases and daily deaths, respectively. However, the times (tc1) and (td1) of the inflection points (Fc) and (Fd) in Fig. 1 can be determined by two techniques, such as the derivations method and tangents method, which will be detailed below. It is observed that the initial times (tc0) and (td0) of phase (I) related to the day before the first non-null occurrence of a new case (Table 2 and Supplementary Table S1). On the other hand, the final times of the latent phase (I), which are the initial times (t_{c1}) and (t_{d1}) of the accelerated phase (II), are obtained by optimization techniques using the least square methods and the non-linear regression of the proposed model for the accelerated phase (II) presented in Section 3.

Derivations method

The ideal and precise technique consists in the modeling by smoothing some small portions of the curve with similar curvatures using simple non-linear regression such as a polynomial with a low degree and then making a derivative of each part (Eq. 1) with the precaution of ensuring continuity and derivability for each boundary. Then, the derivative function reaches its maximum at inflection times (t_{c1}) and (t_{d1}).

$$n_i(t) = \frac{dN_i(t)}{dt} \qquad (1)$$

Nevertheless, due to the irregularities of curvature, we encountered some difficulties in the modeling by part. We used the relative variation for a minimal interval of time (Eq. 2) or squarely the daily reported cases given from the provided data.

$$n_i(t) = \frac{\Delta N_i(t)}{\Delta t} \qquad (2)$$

In practice, we can also determine the approximate inflection times (t_{c1}) and (t_{d1}) when the daily reported cases reach the maximum of the smoothed peak (Fig. 2). Indeed, the inflections points (Fc) and (Fd) occur at the daily highest cases t_{c1} and the daily highest deathst_{d1}. So, we have the corresponding coordinates: $N_{c1} = N_c(t= t_{c1})$ and $N_{d1} = N_d(t= t_{d1})$ respectively (Table 1).

Tangents Method

The tangents method can also be applied if the provided data exceed the inflection point (Fig. 1) and necessarily the strong curvature characterized by a maximum absolute value (Fig. 1 and Supplementary Fig. S1) of the second derivative of *Nc*(t) or *Nd*(t). The details of the method are presented in Supplementary Figs. S1, S2, and S3).

Accelerated phase modeling

Once the two inflection times (t_{c1}) and (t_{d1}), as the second boundary of the accelerated phase (II) are determined, the first limit of times (t_c) and (t_d) can be only recognized by non-linear regression by optimizing the standard deviation (σ) and the relative error (*Erel*) between the experimental values (Supplementary Table S1) and the values estimated by the proposed model.

The pseudo-Gaussian shape of the derivative function d$N(t)$/d(t) plotted in Fig. 2 a and b inspired us to consider an exponential form for the reported case-time dependence. Therefore, we suggested the following expressions with three independent adjustable parameters for the reported cumulative cases *Nc*(t) and the recorded cumulative deaths *Nd*(t) in the accelerated phase (II).

$$N_c(t) = N_{c0}\left(e^{\frac{(t-t_c)}{\tau_c}} - 1\right) + \delta N_c \qquad (3)$$

$$N_d(t) = N_{d0}\left(e^{\frac{(t-t_d)}{\tau_d}} - 1\right) + \delta N_d \qquad (4)$$

Where the increments (δNc) and (δNd) are dependent parameters and can be assimilated to the values of the reported cases *Nc*(t_c) and the deaths *Nd*(t_d) at the beginning of the accelerated phase (II). It is preferable to be determined by the optimization methods even if it differs slightly from the experimental values given in Supplementary Table S1.

$$\delta N_c \approx N_c(t_c) \qquad (5)$$

And

$$\delta N_d \approx N_d(t_d) \qquad (6)$$

Table 2 reported the optimal values of the adjustable parameters of the accelerated phase (II) for the reported cases and deaths determined by the non-linear regressions for Eq. 3 and 4. We noted that (A_{c0}) and (A_{d0}) denote the cases' activity and the deaths' activity, which expressed as follows:

$$A_{c0} = \frac{N_{c0}}{\tau_c} \qquad (7)$$

And $$A_{d0} = \frac{N_{d0}}{\tau_d} \qquad (8)$$

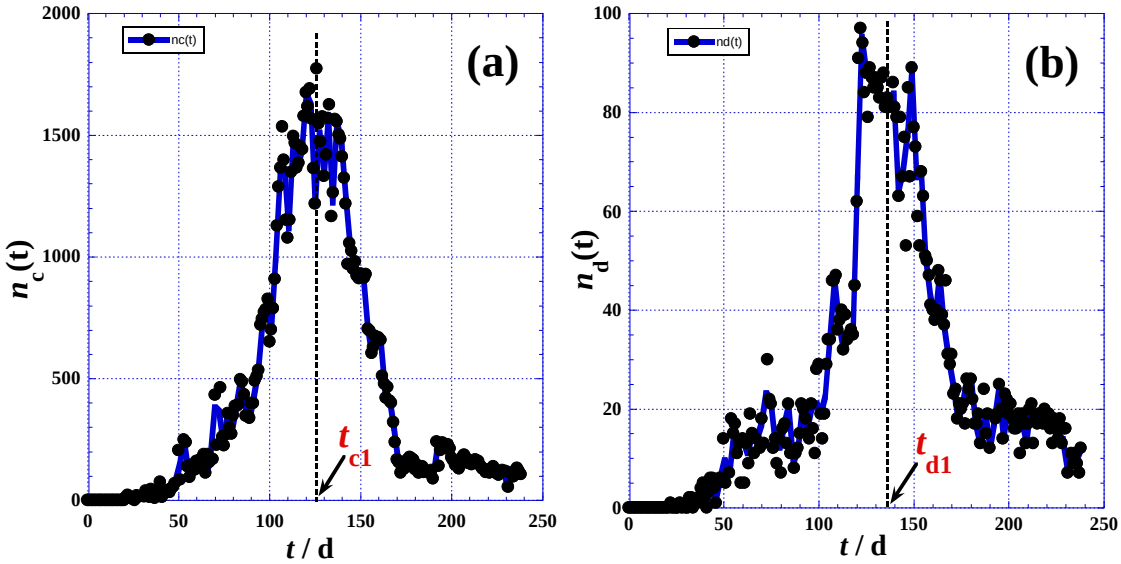

Fig. 2: The new daily reported cases (a) and the new daily deaths (b) in the locus area

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Table 2.: Different spread phases and identification of the accelerated phase for the reported cases and deaths (Times are expressed in days).

t_{c0}	t_c	t_{c1}	τ_c	N_{c0}	*Erel*	σ	N_{c1}	A_{c0}
0	15	125	23.6779	477.2175	6.25%	763.30	49219	20.1556
t_{d0}	t_d	t_{d1}	τ_d	N_{d0}	*Erel*	σ	N_{d1}	A_{d0}
22	27	135	28.2521	60.5208	6.77%	55.20	2708	2.1422

Fig. 3 shows an excellent agreement among the experimental values and the estimated ones in the accelerated phase (II), while the observed discrepancy in the delayed phase (III) for which prompts us to slightly modify the model of Eq. 3 to predict this slower phase (see Sections 5 and 6).

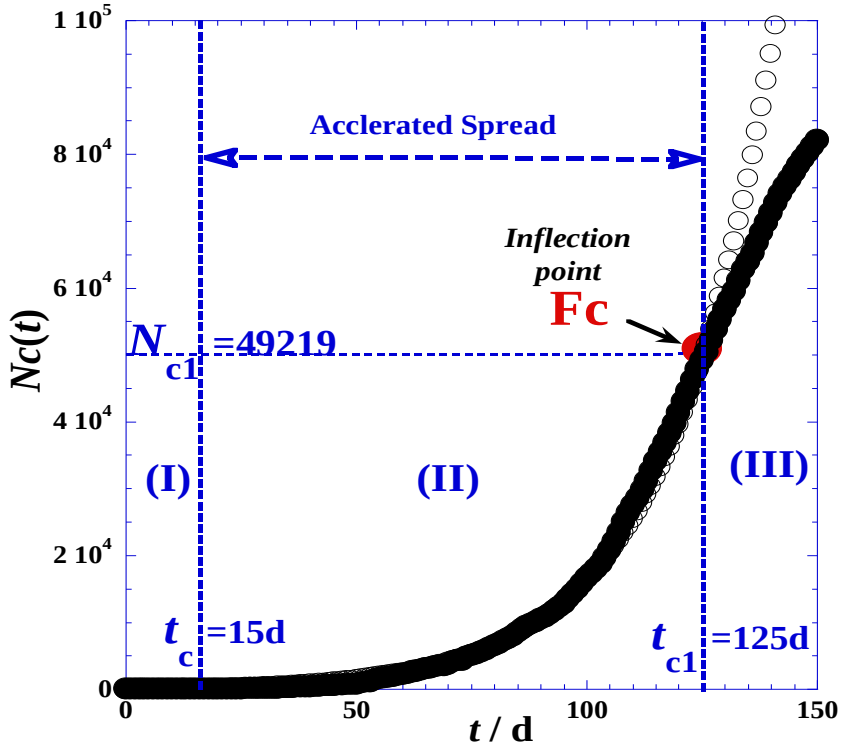

Fig. 3 : The total reported cases *Nc*(*t*) for the first 150 days. (-●-): the experimental data; (-○-): the estimated values for the accelerated phase II) using Eq. 3

Nevertheless, Baldwin (2020) stated that tremendous errors would occur if there is a belief that the spread of COVID-19 will occur in an exponential curve. The number of new cases rises rapidly, reaches a peak, and then declines, which is a hypothesis called “the epidemiological curve."It is not a theory or hypothesis". We agree if we describe the phenomenon with a simple exponential form. Several causes interfere together, giving such complicated propagation, which needs to be expressed by an exponential function whose argument is a non-simple function with time. Given that what we are proposing is empirical, we have suggested the simplest possible form with a minimum of optimal adjustable parameters (Eq. 3). Supplementary Fig S4 justifies our choice, where the linearity of the logarithm can be seen in a wide range of time in the accelerated phase (II), objects of the model proposal.

Besides, the peak height of Fig. 2a and estimated by Eq. 9 is characterized by the global maximum of the derivative function of $Nc(t_{c1})$ occurring at the highest day (t_{c1}) and an inflection point (Fc) for the $Nc(t)$-curve (Fig. 1). The observed quasi-symmetrical shape in Fig. 2a indicates very feeble containment policies and negligible interventions (Baldwin, 2020), and the curve takes various shapes, depending on the infection rate of the virus and the health system capacity.

$$n_{c,max}(t = t_{c1}) = A_{c0} e^{\frac{(t_{c1} - t_c)}{\tau_c}} \qquad (9)$$

We can add that, N_{c0} is mathematically a proportionality's constant, and it plays the role of modulation rate in Eq. 3 (i.e., attenuator or amplificatory). At the same time, the reciprocal ($1/\tau_c$) is a multiplicative scaling factor playing the role of change of the scale of the variable time (t) in the exponential function (i.e., rapidity or slowness of the variation of the values of the exponential function).

Reported cases-deaths correlation

As the present work is an empirical investigation, this section just introduces empirical comparisons to allow the theoretical researchers to invest in more details in their investigations of the handled theoretical parameters. As the first ascertainment from Table 2, we can write the following inequality equations:

$$\begin{cases} t_d > t_c \\ N_{d0} < N_{c0} \\ \tau_d > \tau_c \end{cases} \qquad (10)$$

It must be taken as necessary mathematical conditions and main constraints in optimization problems. We can add the following derived parameters necessary for future discussions and interpretations:

$$\begin{cases} \Delta t = t_d - t_{dc} \\ \Delta N = N_{c0} - N_{d0} \\ \Delta \tau = \tau_d - \tau_c \end{cases} \qquad (11)$$

Where for example, Δt is the effective delay until death. We can also add another exciting criterion for discussion, the activity (Eq. 7 and 8), such as:

$$A_{d0} < A_{c0} \qquad (12)$$

One of the ways to check the mutual correlation between the reported cases $Nc(t)$ and the deaths $Nd(t)$ is to eliminate the time variable and plot $Nd(t)$ as a function of $Nc(t)$ in Fig. 4. We observe an interesting linear dependence in a domain stretched between the two accelerated and delayed phases. nnnnAfter that, the positive deviation to the linearity (with greater slope) indicates that each reported phase always precedes in time the similar phase related to death cases.

Another manner of comparison consists of introducing the mortality rate $T(t)$ expressed as follows:

$$T(t) = \frac{N_d(t)}{N_c(t)} \qquad (13)$$

The plot of the percent of mortality rate $T(t)$ shown in Fig. 5 indicates distinct behaviors of the three spread phases. The maximum occurring in the accelerated phase at ($t = t_{dc}$) about 64 days is mathematically due to the sign conflict between the two logarithms and(t) and ln$Nc(t)$ (Supplementary Fig. S5). We can benefit from this feature by following this variation over the time since the beginning of the spread, and when the mortality rate $T(t)$ reaches the maximum, we can predict that the highest day (t_{c1}) is very close. The pandemic is preparing to move from the accelerated phase I to the delayed phase II if there are no significant changes in the precautionary measures and the peoples' behaviors towards the pandemic.

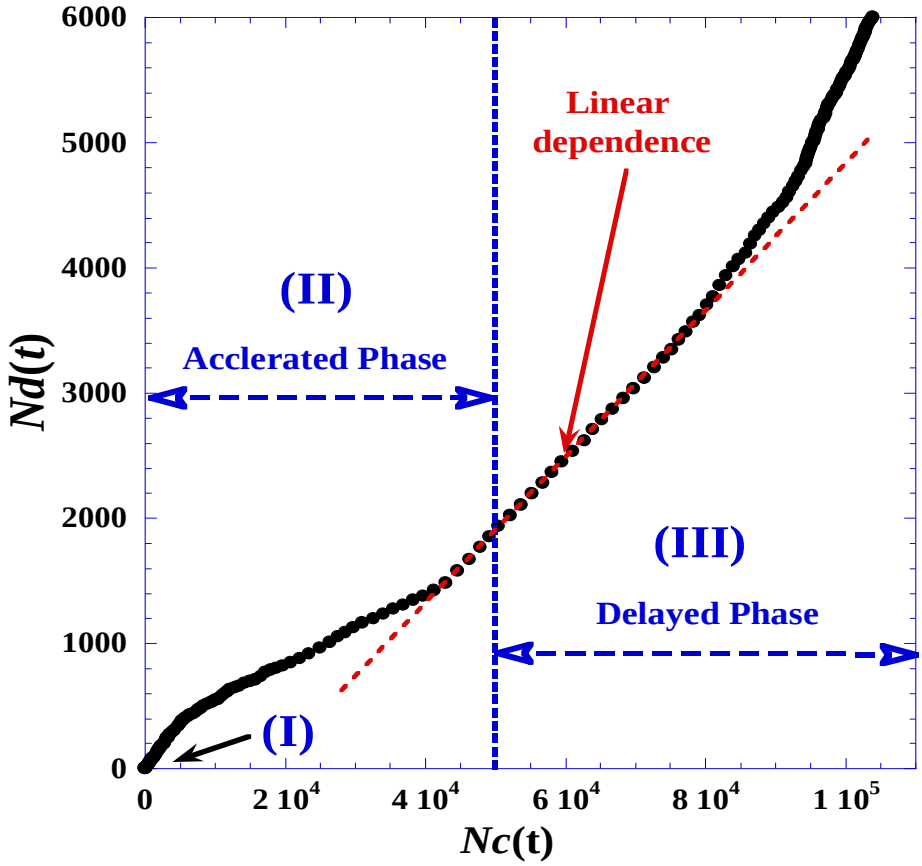

Fig. 4: Cumulative deaths *Nd*(*t*) versus the total reported cases *Nc*(*t*).

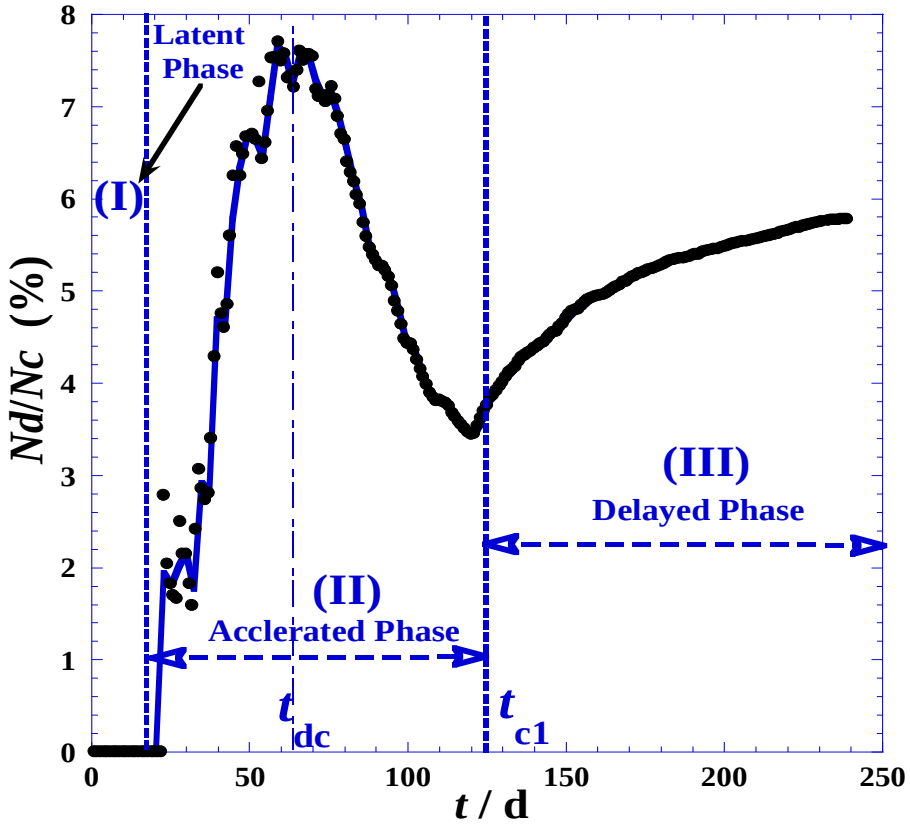

Fig. 5: The mortality rate *T*(*t*) as function of the time.

Prediction of delayed phase for symmetric behavior

To predict the delayed phase (III) from the accelerated phase (II), we consider, at the first approximation, the kinetic process of the pandemic is the same before and after the highest day ($t = t_{c1}$). This symmetric behavior occurs when there are no changes in the environments of the pandemic, such as the precautionary measures and the peoples' behaviors towards the pandemic, etc. On the other hand, the symmetric behavior is translated mathematically by the fact that the inflection point (Fc) will be a center of symmetry of the curve (Fig. 1). So, when we respect the continuity and the derivability at the inflection point Fc ($t = t_{c1}$), we can easily give the equation predicting the delayed phase (III) as follows:

$$N_c(t) = N_{c1}\left(2 - e^{\frac{-(t-t_{c1})}{\tau'_c}}\right) \qquad (14)$$

With

$$\tau'_c = \frac{\tau_c N_{c1}}{N_{c0}} e^{\frac{-(t_{c1}-t_c)}{\tau_c}} \qquad (15)$$

In our case, (τ'_c = 23.4512 days). We note that the precedent values are close to (τ_c) given in Table 2 for the accelerated phase (II). We can conclude that, in a good approximation, we can simplify the problem and put the value of (τ_c) in Eq. 14 in place of (τ'_c) without any imprecision (Fig. 6). The feeble discrepancy between experimental values and estimated ones is due to the asymmetric spread phenomenon due to the little changes in the precautionary measures and the peoples' behaviors towards the pandemic.

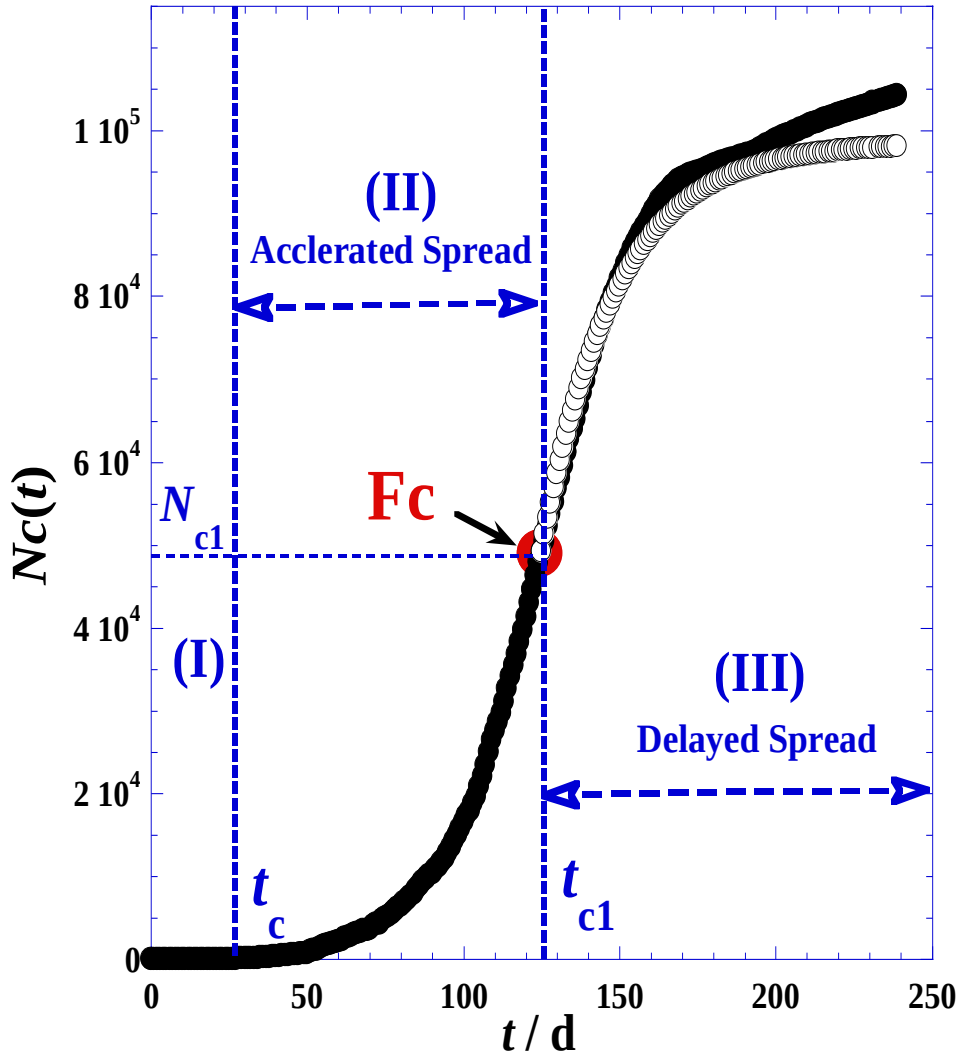

Fig. 6: Total reported cases *Nc*(*t*) for the first 250 days. (-●-): experimental data; (-○-): estimated values for delayed phase (III) in symmetric behavior using Eq. 14.

Prediction of delayed phase for asymmetric behavior

In general and in real situations, we cannot observe the symmetric behavior abovementioned. So, respecting the continuity and the derivability at the inflection point Fc(t= t_{c1}), the equation predicting the delayed phase (III) becomes as follows:

$$N_c(t) = N_{c1} + \frac{\tau'_c N_{c0}}{\tau_c}\left(1 - e^{\frac{-(t-t_{c1})}{\tau'_c}}\right) e^{\frac{(t_{c1}-t_c)}{\tau_c}} \quad (16)$$

Where we only have one adjustable parameter (τ'_c) to be determined using the usual optimization methods. The downside of this situation is that we cannot apply any non-linear regression if we do not have enough data points after the highest day (t= t_{c1}). Nevertheless, a successful prediction should also agree with the limiting value (Nc_∞) of the reported cases at the end of the pandemic (Eq. 17).

$$N_{c\infty} = N_{c1} + \frac{\tau'_c N_{c0}}{\tau_c} e^{\frac{(t_{c1}-t_c)}{\tau_c}} \quad (17)$$

Fig. 7 showed a clear improvement relative to the precedent prediction (i.e., symmetric behavior) when we applied it in Eq. 17, an optimal value (τ'_c = 26.6 days) determined by the least square method of non-linear regression.

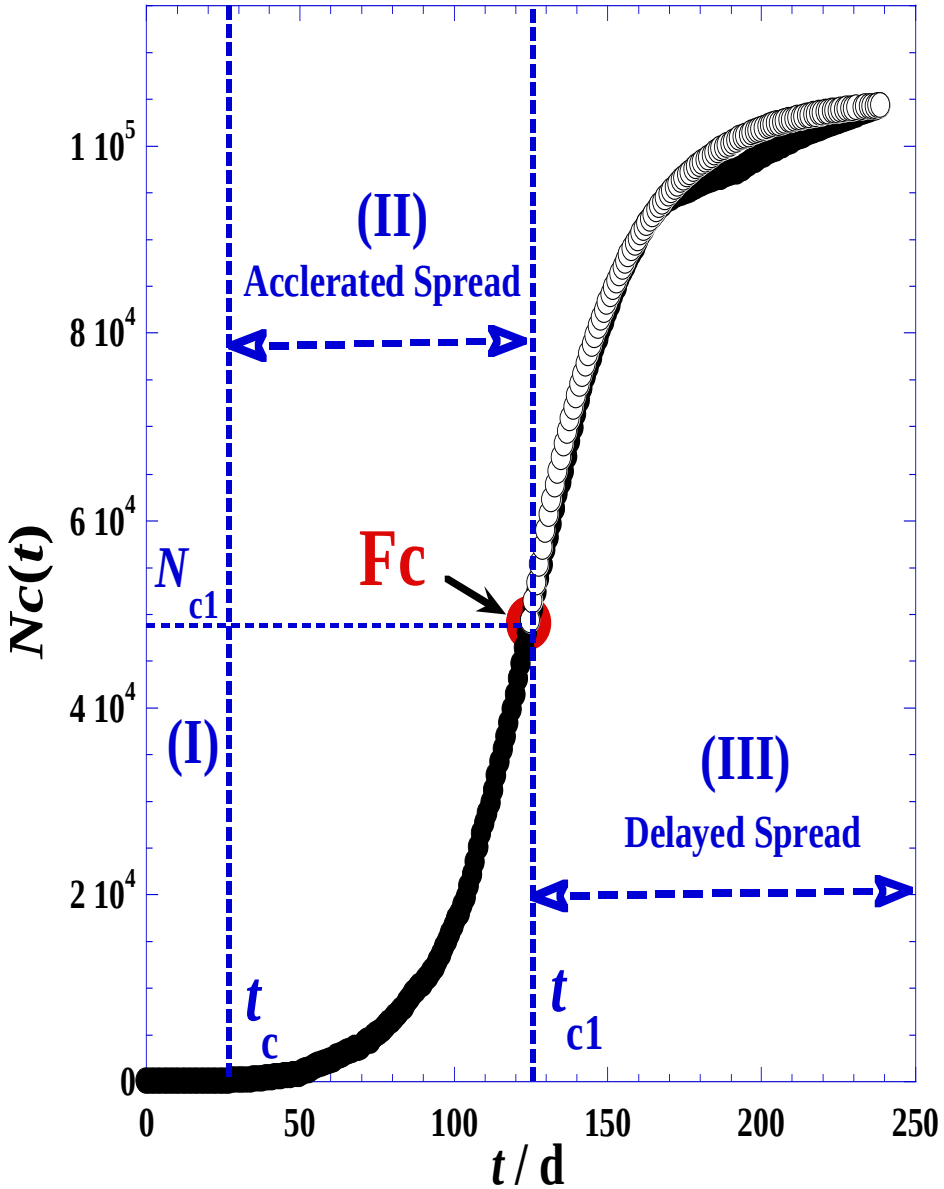

Fig. 7: Total reported cases $Nc(t)$ for the first 250 days. (-●-): experimental data; (-○-): estimated values for delayed phase (III) in asymmetric behavior using Eq. 16

DISCUSSION AND CONCLUSION

Estimating and predicting the number of people affected by COVID-19 and its evolution through time is crucial in deciding which public health policies to follow. Analyzing the spreading behavior at the initial stages of chain transmission during a pandemic plays a crucial role in its management. Accordingly, government agencies and public health organizations can take in-time decisions. Mathematical models produce measurable information in epidemiology by presenting necessary outbreak management and decision-making regulations. To enhance the prediction accuracy during the subsequent waves, we established an empirical mathematical model to numerically analyze the transmission of SARS-CoV-2 in Egypt during the first wave. This model links the Egyptian governmental efforts to limit COVID-19 spread in Egypt and reduce mortality in infected cases with the real-life situation of the first wave.

After the appearance of the first case of COVID-19 in Egypt on February 15, there were no public restrictions to prevent the disease from the spread. The Egyptian government depended mainly on spreading awareness about the importance of wearing masks, hand hygiene, and social distancing. This action was quite enough until the end of February 2020, the end of the latent phase. According to this analysis, the Egyptian authorities responded adequately to the beginning of the accelerated phase.

About ten days after the accelerated phase's onset, Egypt started gradual public lockdown procedures. The accelerated phase continued for about 110 days despite governmental actions. This may be attributed to the lack of public commitment to the imposed restrictions and/or the weak health infrastructure. Although there is no curative medication for SARS-CoV-2 until now, the reported high mortality rate in Egypt compared to other countries reflects a defect in the Egyptian health system and a delay in seeking medical aid due to the fear of stigma. We propose to use the mortality calculations carried out in most countries to establish an index of the actual number of cases at a given time. The number of days between the declaration of illness and death varies between 12 to 18 days ($t_d - t_c$ in Table 2). The mortality rate in Egypt until October 10 has reached 5.8% (Fig. 8), which is one of the highest reported death values worldwide.

The proposed analytic model can improve the management of the subsequent waves of COVID-19 in Egypt by shortening the duration of the accelerated phase in the next waves. Based on this model, we suggest hastening the lockdown procedure in response to any increase in the daily number of cases. Emphasis on implementing the established restrictions and on imposing sanctions non-conformists may also abbreviate the accelerated phase. Besides, the Egyptian authorities should encourage people to seek medical advice as early they feel any symptoms of COVID-19 infection. This may decrease the mortality rates in Egypt as the earlier medical intervention was shown to abate the mortality rates in SARS-CoV-2 infected cases[16]-.

Section 2 represents the data set and estimates the actual number of confirmed cases in Egypt based on the 23-day effect from infection to death. Data information includes the cumulative number of reported cases, as shown in Fig 1. Section 3 introduces two deterministic compartmental models based on the clinical progression of the disease and the epidemiological status of the individuals[5].

Many mathematical models such as the SEIR models have been used in analyzing the spread and control measures of infectious diseases. Generally, these models assume that the incubation period of microbes is zero. The calculated cumulative number of reported symptomatic infectious cases at time t, is indicated by CR(t). Then numerical simulations and comparing them with data are constructed.

Our suggested empirical model is based on the non-linear regression technique and interpolations, tangents, least-square, and optimizations methods to delimit different phases of the pandemic and predict the delayed phase. It considers the generic framework of SEIR models and incorporates the effect of interventions through a multi-valued parameter, a step-wise constant varying during different phases of the interventions, designed to capture their impact in the model. Nevertheless, modifying these developed models is necessary to help optimize the discrepancy between estimated and observed values yielded an improvement in the prediction of different phases. Moreover, the inconvenience of the theoretical models is that they do not take into account the changes in the precautionary measures and peoples' behaviors as well as the eventually updated decisions of the authority

responsible. Theoretical models neglect the incubation period following infection until the symptoms are observed, while with our proposed model, we found a present latent phase ($t_c \neq 0$, Table 2) the existence of the non-null incubation period. The theoretical methods generally give results with appreciate discrepancy with actual data in the accelerated phase to the best of knowledge. This is due to the introduction of many theoretical parameters; generally, they are not independent of each other. At the same time, our proposed model used a few optimal adjustable parameters (N_{c0}, t_c, and τ_c, Eq. 3), presenting a global description of theoretical parameters with clear and simple mathematical significance. In addition, it can be helpful for investigations in theoretical modeling. Theorists can inject our model as a particular solution in their systems of equations and use some approximations methods to give results that are more reliable than obtained by purely theoretical assumptions. To give a physical meaning to the three parameters in our suggested model, we will investigate the probable causal correlation with some factors like the infected, recovered, hospitalized, and severe cases in future works.

Authors' conflict

The authors have no conflict of interest in compliance with the journal guidelines.

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Supplementary material

Supplementary material is available upon request from authors.

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النموذج التجريبي لحالات COVID- 19 المسجلة و الوفيات الناتجة عنها في مصر أثناء الانتشار المتسارع والتنبؤ بالمرحلة الاخيرة

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لقد قمنا في هذه الدراسة بتطوير نموذج رياضي يمكن استخدامه لتحليل انتقال وانتشار فيروس كوفيد-١٩ المستجد خلال الموجة الأولى من الوباء في مصر. هذا النموذج الرياضي يمكننا من معرفة ديناميكيات الانتشار المبكر للعدوى وتقييم كفاءة التدابيرالازمة للسيطرة علي الازمة الوبائية وكذلك تقييم مدي احتمالية حدوث انتقال مستمر خلال الموجات القادمة. ومن خلال هذه الدراسة قد تأكدنا من اهمية تأثير إجراءات الكشف والمكافحة في كبح انتشار العدوي . يعتمد نموذجنا التجريبي المقترح لمرحلة الانتشار المتسارع على تقنية الانحدار غير الخطي ، والاستيفاء ، وطرق الظلال ، وطرق التربيع الصغرى ، والتحسين لتحديد المراحل المختلفة للوباء والتنبؤ بالمرحلة المتأخرة. لقد أثبتنا أن

نموذجنا متسق رياضيًا ويقدم نتائج محاكاة مختلفة باستخدام قيمة المعلمة الأفضل تقديرًا. يمكن تحـــديث النموذج بسهولة عند تغيير القيود والمشكلات الأخرى. نأمل أن توجه نتائج المحاكاة السلطات المحليـــة لاتخاذ القرارات الصحيحة في الوقت المناسب لنتجنب الانتشار المتزايد للعدوي.