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Prognostic equations on COVID-19 in the province of Cienfuegos, Cuba

Abstract

Cuba and all its provinces have been affected by Covid-19 disease. The government and the health system carry out measures to avoid contagion. To take these measures it is important to have estimates of the rate of infection. To this aim the authors' research evaluate the effectiveness of three important stochastic mathematic models (Weibull, Gompiertz and Log-logarithm models) on the prognostic equations of COVID-19 in the 8 Municipalities of the Province of Cienfuegos. The obtained results allows to confirm the good quality of the three predictive models.

Objective: The objective of this work is to analyze effectiveness of the application of these models in order to predict the behavior of pandemics in the case of the city Cienfuegos, results that can be of great help to the authorities that must deals with such situations.

Keywords: Covid-19, predictive equations, Gompiertz, log-logaritms, weibull

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Main text

Many natural phenomena put the development of the human species at risk. In 2007, a warning was issued in the manuscript "unprepared for a pandemic" Osterholm[1], in which the author warned of the economic and social consequences of a new pandemic for which the current generation was not fully prepared. Just in 2020 a new pandemic was unleashed of which its precise place of origin is not known.

Although it is difficult to predict a global catastrophe of any kind, the actions that are generally taken during health emergencies are clearly based on foresight and scenario analysis to make decisions in advance while retaining a certain percentage of the collateral damage caused by this type of virulent phenomena. The outcome of the Sars-Cov2 virus has surprised the world community in different ecological, social, and economic dimensions, even though the world's governments have some experience in the fight against other recent epidemics such as H1N1 in 2009, cholera in Haiti in 2010 or the Ebola outbreak that hit Africa hard in 2014.

Mathematical models for the study and prediction of the behavior of infectious diseases are a primary objective in the search for solutions to help reduce the consequences of these diseases. The main task of a mathematical model in this context is to improve the understanding of a system for the prevention of future diseases, the determination of the prevalence and incidence of a disease and the support in decision making for the control and eradication of these diseases.[2]

There are two essential types of mathematical models: deterministic and stochastic. For the deterministic model, a set of inputs produces the same number of invariable outputs and neither the existence of chance nor the principle of certainty is considered. In a stochastic model, chance is considered so that a set of inputs can produce several outputs in an unpredictable way and therefore, the possible outcomes will be generated with a probability function.[3]

Most of the studies on predictive equations for Covid-19 are based on the stochastic models known as logistic differential equations.[4]

$$\frac{dP(t)}{dt} = r.P(t).\left(1-\frac{P(t)}{K}\right)$$ Logistic differential equation and

$$\frac{dP(t)}{dt} = r.P(t).1n\left(\frac{K}{P(t)}\right)$$ Gompertz differential equation

Both equations describe the growth of population $P(t)$ at a given time (t), where r represents the instantaneous rate of increase and K corresponds to the carrying capacity of the environment or the maximum number of individuals that the population can sustain. K and r are positive real numbers and the function $P(t)$ is positive, monotonically increasing and suitable for representing epidemiological models, because it presents a rapid initial growth that is approximately exponential and as the number of infections increases, the number of non-infected individuals in the population decreases.[5]

The objective of this work is to analyze effectiveness of the application of these models in order to predict the behavior of pandemics in the case of the city Cienfuegos, results that can be of great help to the authorities that must deals with such situations.

To this aim an experimental analysis was designed consisted of a cross-sectional case study, and the statistical analysis of the confirmed cases of COVID -19 in the 8 municipalities of the province of Cienfuegos, from March 2020 to August 2021.

The analysis allows to studies the behavior of number of confirmed cases in the time and the relationships of this magnitude with other variables, like, age, place, time and the dates on which the confirmed cases are presented.

In this case were used five-parameter models obtained from the Gompertz, Weibull and Log-Logistic models, which have been used successfully in the Covid-19 epidemic for the cases of China, Italy, South Korea, Costa Rica and various countries.[6–11]

The application of the Weibull, Gompiertz and Log-logarithm models on the giving data can be summarized in the following best predictive fit equations for the municipalities of Cienfuegos (Table 1).

$$f(t) = c + (d-c).\left(1-e^{-e^{b.(1nt-1na)}}\right)$$ 5-parameter Weibull model

$$f(t) = c + (d-c).e^{-e^{b.(t-a)}}$$ Gompertz model

$$f(t) = C + \frac{d-c}{1-e^{e^{b.(1nt-1na)^h}}}$$ 5-parameter Log-Logaritsm

Table 1 Results of predictive equations

Modelo	Rodas	Aguada	Cumanayagua	Abreus	Cruces	Palmira	Cienfuegos	Lajas
Weibull			b= 40.50 c= 366.03 d= 4415.47 e= 525.11 RCAdj= 0.995	b=51.18 c=110.41 d=3008.3 e=524.78 RCAdj= 0..997		b= 50.76 c=281.78 d=4005.08 e=524.48 RCAdj= 0.997	b=39.87 c=1212.31 d=29772.14 e=523.15 RCAdj= 0.999	
Gompertz		b=-0.04 c=500.59 d=4839.37 e=519.29 RCAdj= 0.993						
Log Logarítm	b=-54.21 c=347.64 d=3546.44 e=508.73 f=1.66 RCAdj= 0.99				b=-01.88 c=57.52 d=3461.66 e=529.70 f=0.29 RCAdj= 0.997			b=-00.34 c=492.01 d=3411.02 e=555.04 f=0.14 RCAdj= 0.996

Results of predictive equations in the Province of Cienfuegos. Cuban [9]

The calculated parameters shows values of RCAdj (Adjusted Regression Coefficient) close to 1, which implies a good regression quality for all the three models.

Daily data were downloaded as .csv files, decoded using Maxima 5.41.0 symbolic software programs and R 3.6.1 programming language.[12]

From the predictive models found for each municipality, the value and date of the peak of the pandemic were calculated. The forecast peak date in the municipalities of Abreus, Cumanayagua, Palmira and Cienfuegos totally coincided with the actual date; in the rest of the municipalities the forecast was a few days apart from reality.[11,13–15] Figure 1 shows the peak curve for the municipality Cienfuegos.

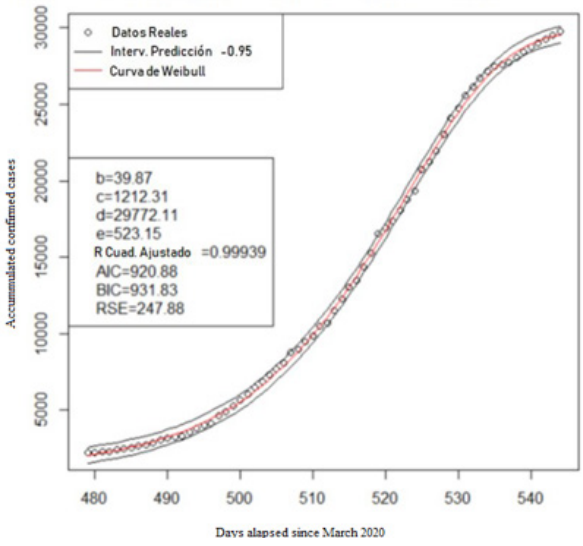

Figure 1 Peak curve for municipality Cienfuegos by the data from March 2020 to August 2021.

The obtained results were wery usefull for health authorities in order to make decisions in advance regarding the pandemic diseases.

Conclusion

Predictive models were obtained using the Gompiertz, Weibull and Log-logarithm equations for the forecast equations of COVID-19 in the 8 Municipalities of the Province of Cienfuegos with satisfactory results.

The investigation consisted of a cross-sectional case study, making a statistical analysis of confirmed cases of COVID -19, from March 2020 to August 2021.

The best Weibull, Gompiertz and Log - logarithm models were selected for the data of each of the 8 municipalities of the province of Cienfuegos, Cuba.

The application of the predictive models of the populations studied for the forecasts of the COVID-19 pandemic in the province of Cienfuegos, Cuba constitute reliable models for use by Health representatives in the Province.

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Conflicts of interest

None.

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