



An estimate of the real number of COVID-19 deaths in Mexico

Gerardo M. Ortigoza Capetillo

gortigoza@uv.mx

Instituto de Ingeniería

Universidad Veracruzana

Av. Juan Pablo II S/N, Costa Verde,
94292 Boca del Río, Ver. Mexico

Roberto I. Ponce de la Cruz

rponcedelacruz@uv.mx

Instituto de Ingeniería

Universidad Veracruzana

Av. Juan Pablo II S/N, Costa Verde,
94292 Boca del Río, Ver. Mexico

Article History

Volume 6, Issue 12, 2024

Received: June 10, 2024

Accepted: July 5, 2024

doi:

10.48047/AFJBS.6.12.2024.4799-4804

ABSTRACT

Objective. *Rather than officially confirmed COVID-19 death counts, excess mortality is a more comprehensive measure of the full impact of the COVID-19 pandemic. This study determines an estimate to the real number of COVID-19 deaths in Mexico in the period from 2020 to 2023.*

Methods. *Using historical mortality data 2011 to 2019 provided by INEGI (National Institute of Statistics and Geography), we made a machine learning prediction for the number of deaths by any cause at years 2020 and 2021 in Mexico.*

Results. *The differences between INEGI officially reported numbers of total deaths by any cause for these years minus the machine learning predictions for deaths by any causes (trained data 2011-2019 before COVID-19) are compared to the officially reported COVID-19 deaths, thus scaling factors are obtained. The estimate for the real number of COVID-19 deaths in Mexico is accomplished by multiplying the scaling factor (mean of two values) times projected values for the number of officially reported COVID-19 deaths at the end of July 2023.*

Conclusions. *Machine learning algorithms have been employed to obtain first projections for the number of deaths in Mexico by any cause for years 2020 and 2021, and then a projection for the number of officially reported COVID-19 cases at the end of week 30 2023. Thus, we calculate an estimate of 760 398 for the real number of COVID-19 deaths in Mexico at the end of week 30 of 2023 (July 29th, 2023).*

Keywords Machine learning; COVID-19 deaths; estimate.

On February 28th, 2020, Mexico confirmed its first three COVID-19 infected cases and the first COVID-19 death occurred on March 18th, 2020. Three years and three months later, at the end of epidemiological week 22 of 2023 (June 3rd, 2023), the cumulative number of infected and dead officially reported reached 7 621 062 and 334 167 respectively. At this time, Mexico ranks fifth in total COVID-19 deaths around the world (1) and also is the second (4.5% observed case-fatality ratio) at the top of the list of countries that have the most death proportionally to their COVID-19 cases(2). Despite the fact that the WHO (World Health Organization) announced the end of the COVID-19 health emergency on May 5th, 2023, and one day later the Mexican government announced the end of the COVID-19 emergency in Mexico, not in large numbers but new cases (infected and deaths) were still reported in Mexico after this date. In fact, Mexican government stopped reporting COVID-19 cases and deaths on June 25th, 2023.

The great concern worldwide about COVID-19 was to reduce the number of infected and deaths, thus several measures were implemented in order to reduce COVID-19 infections such as mask wearing, social distance, vaccination, etc. Around the world several institutions have expressed disagree between the official data reported by governments and the actual number of COVID-19 deaths (2),(3), (4). The key point resides in observing the abrupt rise that the number of deaths from any cause had in 2020 and 2021 (years of the COVID-19 pandemic). Excess mortality captures not only the confirmed deaths, but also COVID-19 deaths that were not correctly diagnosed and reported as well as deaths from other causes that are attributable to the overall crisis conditions (5). The work is organized as follows: section 2 explains how data are used in order to make a machine learning prediction, how this prediction compares to the officially reported number of COVID-19 deaths and scaling factors are estimated, section 3 presents the main results and finally we close this work with some conclusions.

MATERIAL AND METHODS

First, we considered historical data for deaths in Mexico (any cause) in the period 2011-2019 (6). Thus, machine learning predictions for years 2020 and 2021 were obtained and compared to the officially reported deaths for 2020 and 2021, the differences give us numbers that reflect the effect of COVID-19 in the number of deaths in the years 2020 and 2021 in Mexico. Next, we obtained scaling factors by comparing these differences with the official numbers of confirmed COVID-19 deaths during 2020 and 2021. Finally, by applying machine learning algorithms to officially reported COVID-19 data, we obtained a prediction for the cumulative number of deaths at the end of July 2023 and then we used our scaling factors to produce our estimates for the real number of COVID-19 deaths at the end of weeks 22 and 30, 2023 in Mexico. This approach differs from those previously used to estimate excess deaths(7), (8), (9), (10), as it relays on machine learning projections. Machine learning has shown to be an effective technique to produce valuable predictions that help governments and health agencies to make decisions in order to reduce the spread of COVID in the world (11),(12),(13), (14),(15). As described by Palacio et al. (16), the leading causes of excess mortality in Mexico during the COVID-19 pandemic 2020-2021; the largest increases in cause-specific mortality, occurred in diabetes (36.8% over expected), respiratory infections (33. 3%), ischaemic heart diseases (32. 5%) and hypertensive diseases (25 %). As reported at (17), Dahal et al. findings indicate that Mexico has been disproportionately affected by the COVID-19 pandemic.

RESULTS

Table 1 shows yearly deaths in Mexico by any cause. The values at 2020 and 2021 were obtained with the Predict function (18), which employs machine learning algorithms in Wolfram Mathematica 13.1. Predicted values correspond to the neural network algorithm with R-Squared = 0.998927. INEGI reports a total of 1 086 743 deaths for 2020 and 1 122 249 for 2021. Thus, we have excess in deaths of 316 162 for 2020 and 328 240 for 2021 with respect to the predicted values.

TABLE 1. Yearly deaths in Mexico 2011-2019.

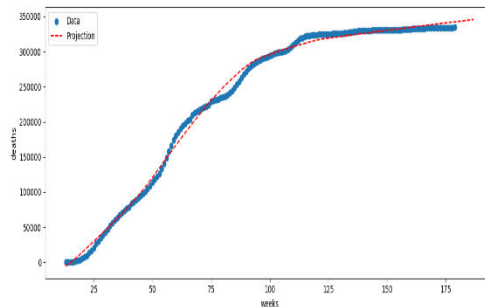
Year	Deaths
2011	590
2012	602
2013	623
2014	633
2015	655
2016	685
2017	703
2018	722
2019	747
2020	770
2020	581
2021	794
2021	009

Source: self made

By the end of 2020, the Mexican Health Secretary reported a total of 125 807 confirmed COVID-19 deaths (19), while the total of officially reported COVID deaths for 2021 was 173 621. Therefore, scaling factors of 2.513 and 1.89 are obtained that relate the real numbers of COVID-19 deaths to the numbers of officially reported COVID-19 deaths.

At the end of epidemiological week 22 of 2023, the total of COVID-19 deaths reported in Mexico is 334 167. By using the scaling factor, we can provide the estimate of 735 669 COVID-19 deaths at this date. Despite we were descending from the sixth COVID-19 wave, new cases of infection and deaths were still reported, thus we make predictions of the cumulative number of reported deaths eight weeks ahead in the future until the end of week 30 of 2023 (July 29th, 2023). We consider cumulative weekly data of COVID-19 deaths from weeks 13th, 2020 until week 22nd, 2023 (a total of 114 data points). Figure 1 shows the projected values for the weekly cumulative numbers of COVID-19 deaths in Mexico. They were obtained by a 4-layers artificial neural network model (sklearn python, nodes=[15,15,15,1], with activation functions relu and tanh), 80% trained data, 20% test data.

FIGURE1. Neural network prediction cumulative number of COVID-19 deaths in Mexico.



Source: self made.

Table 2 displays MAE and RMSE errors for the neural network model where also the coefficients of determinations (R-squared) are included for train and test data.

TABLE 2.MAE, RMSE, and R-squared for the4-layers artificial neural network model

data	MAE	RMSE	R-squared
train	0.048552	0.060550	0.996259
test	0.049066	0.059510	0.996658

Source: self made.

The neural model predicts 345 400 confirmed deaths (up to July 29th, 2023). Hence, our estimate for the real number of COVID-19 deaths in Mexico is 760 398 at the end of week 30, 2023 (July 29th, 2023). It is worth to mention that the Institute for Health Metrics and Evaluation (20) with historical data up to December 16th, 2022, produced an estimate of 770 824 for the real number of COVID-19 deaths in Mexico dated April 1st, 2023.

We have used machine learning in two instances: the first to estimate the total numbers of deaths from any cause in Mexico for the years 2020 and 2021, and the second to predict the number of officially reported COVID-19 deaths at the end of week 30 of 2023. At figure 1, the projection curve for the cumulative number of deaths shows just a slight increase for the end of week 30 2023. Here we are taking a conservative approach by assuming no new COVID-19 waves will appear on the second half of year 2023. In this work, machine learning methods were used to obtain an estimate of the real number of COVID-19 deaths in Mexico but is also worth to mention some other applications of machine learning methods related to COVID-19 mortality. Machine learning methods were employed by Banoei et al. (21) to predict mortality and identify patients at low and high risk of dying, Zarei et al. (22) predict in-hospital death among COVID-19 patients while Kuno et al.(23) predict in-hospital mortality for COVID-19 patients treated with steroid and remdesivir. Kogan et al.(24) developed a prognostic model for alerting to imminent deterioration of hospitalized COVID-19 patients while Jamshidi et al. (25) predicted COVID-19 mortality based on typical laboratory results and clinical data on the day of the ICU.

DISCUSSION

As COVID-19 has spread around the world, people have become familiar with the official weekly number of deaths reported by their governments. Regrettably, the total number of deaths caused by the pandemic could be higher, for a number of reasons. First, in many countries official statistics omit victims who did not test positive for coronavirus before they died, which can be the vast majority in places with low testing capacity. Second, due to COVID-19 lockdowns, hospitals and civil registries

may not process death certificates for several days, or weeks, leading to data delays. And finally, the pandemic has discouraged people from going to the hospital and made it harder for doctors to treat other conditions, which may have indirectly caused an increase in deaths from diseases other than COVID-19 (for example people who interrupted their treatment or could not have surgery). Having an estimate of the real number of COVID-19 deaths, allows us to carry out an analysis about what was not done, what was done wrong and to be able to correct it in future health emergencies.

Some powerful machine algorithms could help us to develop better diagnostic methods not only to detect COVID-19 but also other new diseases. Additionally, it makes it possible to model and forecast how new medicines will work, as well as customize care based on a patient's comorbidities and medical records.

CONCLUSIONS

Machine learning algorithms have been employed to obtain first projections for the number of deaths in Mexico by any cause for years 2020 and 2021, and then a projection for the number of officially reported COVID-19 cases at the end of week 30 2023. Thus, we calculate an estimate of 760 398 for the real number of COVID-19 deaths in Mexico at the end of week 30 of 2023 (July 29th, 2023). All the calculations made here can be replicated with data from other countries to obtain similar estimates of excess deaths from COVID-19.

REFERENCES

1. Worldmeters. Covid-19 coronavirus pandemic. [Online].; 2023 [cited 2023 noviembre 2. Available from: <https://www.worldmeters.info/coronavirus/>.
2. Medicine JHUa. Coronavirus Resource Center, Mortality Analysis. [Online]. [cited 2023 noviembre 2. Available from: <https://coronavirus.jhu.edu/data/mortality>.
3. Giattino C, Ritchie H, Ortiz-Ospina E, Hasell J, Rodés-Guirao L, Roser M. Our World in Data. [Online]. [cited 2024 abril 18. Available from: <https://ourworldindata.org/excess-mortality-covid>.
4. Worldometer. Worldometer. [Online]. [cited 2024 abril 18. Available from: <https://www.worldometers.info/coronavirus/coronavirus-death-rate/>.
5. Karlinsky A, Kobak D. Tracking excess mortality across countries during the COVID-19 pandemic with the World Mortality dataset. *eLife*. 2021 June 30; 10(e69336).
6. INEGI. Estadística de defunciones registradas de enero a junio de 2021. Comunicado de prensa. INEGI; 2022.
7. Castro Añorve AF. El exceso de mortalidad por Covid en México: breve descripción de tres metodologías. *Boletín sobre Covid-19*. 2021 agosto 3; 2(19-20).
8. Shang W, Wang Y, Yuan J, Guo Z, Liu J, Liu M. Global excess mortality during COVID-19 Pandemic: A systematic review and meta-analysis. *Vaccines*. 2022 octubre; 10(1702): p. 1-17.
9. Kepp KP, Kontis V, Parks RM, Beak K, Baek KT, Emilsson L, et al. Estimates of excess mortality for the five Nordic countries during the COVID-19 pandemic 2020-2021. 2022 december 13; 51(6): p. 1722-1732.
10. Stang A, Standl F, Kowall B, Brune B, Böttcher J, Brinkmann M, et al. Excess mortality due to COVID-19 in Germany. *Journal of Infection*. 2020; 81(5): p. 797-801.
11. Ghafouri-Fard S, Mohammad-Rahimi H, Motie P, Minabi MAS, Taheri M, Nateghinia S. Application of machine learning in the prediction of COVID-19 daily new. *Heliyon*. 2021; 7(10).
12. Lalmuanawma S, Hussain J, Chhakchhuak L. Applications of machine learning and artificial intelligence for Covid-19 (SARS-CoV2) pandemic: A review. 2020; 139: p. 110059.
13. Ortigoza G., Lorandi A., Proyecciones matemáticas para los casos de COVID-19 en México. *Revista Mexicana de medicina forense y ciencias de la salud*. 2021; 6(2).
14. Ortigoza G, Hermida G, Hernández M. Simulations of seasonal covid spread models: case study Mexico. *Revista Mexicana de Medicina Forense y Ciencias de la Salud*. 2022; 7(2): p. 147-161.

15. Yu CS, Chang SS, Chang TH, Wu JL, Lin YJ, Chien HF, et al. A COVID-19 pandemic artificial intelligence–based system with deep learning forecasting and automatic statistical data acquisition: development and implementation study. *Journal of medical Internet research.* ; 23(5): p. e27806.
16. Palacio-Mejía LS, Hernández-Ávila JE, Dyer-Leal D, Barranco A, Quezada-Sánchez AD, Alvarez-Aceves M, et al. Leading causes of excess mortality in Mexico during the COVID-19 pandemic 2020-2021: A death certificates study in a middle-income country. *The Lancet Regional Health - Americas.* 2022; 13: p. 1-15.
17. Dahal S, Banda JM, Bento AI, Mizumoto K, Chowell G. Characterizing all-cause excess mortality patterns during COVID-19 pandemic in Mexico. *BMC Infectious.* 2021; 21(1): p. 432.
18. Predict function Wolfram Mathematica. [Online]. [cited 2023 noviembre 2. Available from: <https://reference.wolfram.com/language/ref/Predict.html>.
19. Informe Técnico Diario COVID-19 México. Técnico. Secretaria de Salud, Subsecretaria de Prevención y Promoción de la Salud; 2021.
20. IHME. [Online]. [cited 2 noviembre 2023. Available from: <https://covid19.healthdata.org/mexico?view=cumulative-deaths&tab=trend>.
21. Banoei MM, Dinparastisaleh R, Zadeh AV, Mirsaeidi M. Machine-learning-based COVID-19 mortality prediction model and identification of patients at low and high risk of dying. *Critical Care.* 2021; 5: p. 328.
22. Zarei J, Jamshidnezhad A, Shoushtari MH, Hadianfard AM, Cheraghi M, Sheikhtaheri A. Machine Learning Models to Predict In-Hospital Mortality among Inpatients with COVID-19: Underestimation and Overestimation Bias Analysis in Subgroup Populations. *Journal of Healthcare Engineering.* 2022; 13.
23. Kuno T, Sahashi Y, Kawahito S, Takahashi M, Iwagami M, Egorova NN. Prediction of in-hospital mortality with machine learning for COVID-19 patients treated with steroid and remdesivir. *Journal of medical virology.* 2021; 94(3): p. 958-964.
24. Kogan Y, Robinson A, Itelman E, Bar-Nur Y, Jakobson DJ, Segal G, et al. Developing and validating a machine learning prognostic model for alerting to imminent deterioration of hospitalized patients with COVID-19. *Scientific Reports.* 2022; 12(1): p. 19220.
25. Jamshidi E, Asgary A, Tavakoli N, Zali A, Setareh S, Esmaily H, et al. Using machine learning to predict mortality for COVID-19 patients on day 0 in the ICU. *Frontiers in digital health.* 2022; 3: p. 681608.