International Clinical and Medical Case Reports Journal
Research Article

The Behavior of Covid-19 in Urban Health among The Capitals of Rio De Janeiro and Belo Horizonte Through The Dynamics of The Seir Model

E Souza[1*], O Brustolini[2], A Vasconcelos[2], S Cohen[1*]

[1]National School of Public Health Sérgio Arouca (Ensp) - Fiocruz, Street Leopoldo Bulhões, 1480, Manguinhos, State Rio de Janeiro, Brazil.

[2]Laboratory of Bioinformatics National Laboratory for Scientific Computing (LNCC) – Avenue Getulio Vargas, 333, Quitandinha, Petropólis, State Rio de Janeiro, Brazil

Citation: *E Souza, O Brustolini, A Vasconcelos, S Cohen. The Behavior of Covid-19 in Urban Health among The Capitals of Rio De Janeiro and Belo Horizonte Through The Dynamics of The Seir Model. Int Clinc Med Case Rep Jour. 2022;1(1):1-14.*

Received Date: 09 June, 2022; **Accepted Date:** 15 June, 2022; **Published Date:** 17 June, 2022

[*]**Corresponding author:** E Souza. National School of Public Health Sérgio Arouca (Ensp) - Fiocruz, Street Leopoldo Bulhões, 1480, Manguinhos, State Rio de Janeiro, Brazil.

ABSTRACT

Objective: To describe the dynamics of the Covid-19 pandemic associated with urban health in the capitals of Belo Horizonte and Rio de Janeiro using a mathematical model based on ordinary differential equations in the susceptible, exposed, infected, and removed SEIR dynamics model.

Study design: This is a search for data in the Department of Informatics of the Unified Health System (DATASUS) and data available and published online by the city hall and health secretariat of the capitals of Belo Horizonte (MG) and Rio de Janeiro (RJ).

Methods: A search was carried out between February 2019 and May 2020 between territorial area, mobility, sanitation, health information (TABNET), and information from the health secretariat of the capitals of Rio de Janeiro and Minas Gerais. It was used the SEIR differential equation model by the R program.

Result: The estimated population (2021) of Rio de Janeiro is 6,775,561 people, with a population density equal to 5,265.82 inhabitants per km^2. In Belo Horizonte, the population is 2,530,701 people, with a population density equal to 7,167.00 inhabitants per km^2. The number of COVID-19 cases in 2020 in Rio de Janeiro was 221,480, there were 18,962 deaths, and the case fatality rate was 8.7%. In Belo Horizonte, according to the epidemiological bulletin.

Conclusion: The SEIR model helped understand the urban health of Belo Horizonte and Rio de Janeiro about COVID-19. It demonstrated that the probability of transmission would be greater among the susceptible exposed to the infection, leading to the highest number of mortalities in an urban environment.

Keywords: COVID-19; Urban health; Dynamics of the model

INTRODUCTION

In December 2019, a group of people in Wuhan, China, were hospitalized and diagnosed with pneumonia of unknown etiology.[1,2] Sequencing lower respiratory tract samples revealed an outbreak of the SARS-COV-2 virus worldwide. The World Health Organization (WHO) classified February 11, 2020, as an outbreak of Covid-19, and on March 11, WHO declared Coronavirus disease (COVID-19) as a pandemic.[2,3]

The disease caused by the severe acute respiratory syndrome novel coronavirus (SARS-CoV-2) has infected 511,479,320 people worldwide.[3,4] According to the WHO, on May 2, 2022, the disease killed 6,238,832 people.[4,5] Despite efforts to stop the transmission of COVID-19, the infection has spread across mainland China, and in less than months, the infection has spread to at least 114 countries, causing over 4,000 deaths.[5,6]

The coronavirus is one of the primary pathogens that target the human respiratory system and could pose a more significant threat to those living in a dearth of infrastructure and housing.[5] Then, this outbreak causes a greater risk to the population residing in cities with inadequate conditions of housing, sanitation, transport, and precariousness in health services.[6,7]

During the period that COVID-19 lasted, there was an excess of scientific and non-scientific information.[8] The temporal evolution of the number of infected individuals is not linear, whereas epidemiological dynamics have the probability of a susceptible individual acquiring infection, depending on the number of infections.[7,8,9] Furthermore, the prediction of disease epidemics is essential for controlling and relating contagious diseases in urban areas.[10]

Previous studies have built mathematical models that describe the dynamics of infectious disease transmission, known as the Susceptible-Infectious-Remove (SIR) model, and fit the model to time-series data of the number of infected individuals.[11,12] Diseases such as COVID-19 demonstrate the need for predictive model applications to implement early and precisely tuned responses to their profound impact on society and the city.[13]

The city is a large human settlement defined as a permanent and densely established place by administrative boundaries. Cities generally have extensive housing, transportation, sanitation, utilities, land use, and communication systems.[14,15,16] However, the poor conditions of housing, sanitation, transport, and infrastructure in the urban environment of cities can generate several negative consequences for the health of the population.[15,16]

Urban health is the study of environmental, social, physical, and infrastructure characteristics of urban resources, in which city-specific factors are incidentally related to health, as shown in Figure 1. Such factors can influence the individual's health and disease in urban areas.[14,16]

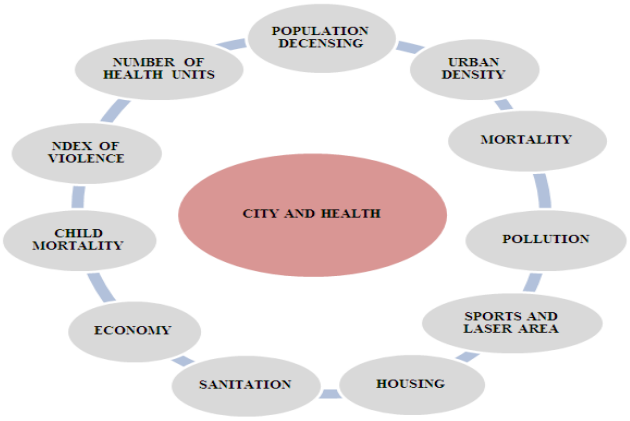


Figure 1: City-specific factors that can influence an individual's health.

Source: Adapted from the study Vlahov, David, et al. 2005

The mathematical models of population dynamics, such as the differential equation, help understand physical phenomena. These models often generate an equation containing some derivatives of an unknown function.[17]

Moreover, the Infection Dynamics and Health Remodelling Model, i.e., the SEIR in COVID-19 with peak infectivity before and at the onset of symptoms, explains the hidden accumulation of exposed individuals that challenges containment strategies due to delayed epidemic responses to non-pharmaceutical interventions. For this study, the objective is to use a mathematical model based on ordinary differential equations (SEIR), which models the dynamics of susceptible, exposed, infected, and removed between urban regions between Belo Horizonte and Rio de Janeiro.

MATERIALS AND METHODS

Study area

The southeastern region of Brazil consists of the states of Espírito Santo, Minas Gerais, Rio de Janeiro, and São Paulo. This region has an area of 924,511.3 km^2 and a density of 96/km^2. For this study, we will use data from the state capitals of Minas Gerais and Rio de Janeiro. Belo Horizonte is the capital of Minas Gerais, located in the central portion of the territory of Minas Gerais, in an area of rugged relief and typical tropical climate.

The city of Belo Horizonte was planned and built according to urban precepts to be the political and administrative capital of the state of Minas Gerais. It has a diversified geographical area, with hills and lowlands and an area of approximately 331km^2. The Serra surrounds the city do Curral, which serves as a natural frame and historical reference.

The capital of the state of Rio de Janeiro has the same name and is classified as the second-largest metropolis in the country. The city of Rio de Janeiro has a modern structure. However, the state's successive financial and political crises have made it difficult to attract investments.

The municipality belongs to the intermediate and immediate geographic regions of Rio de Janeiro, the city was developed on narrow alluvial plains compressed between mountains and hills and is located between Pedra Branca, Gericinó and Tijuca, with tourist spots such as Bico do Papagaio, Andaraí, Pedra da Gávea, Corcovado, Dois Irmãos and Pão de Açúcar.

The coastal region is 197 kilometers long and includes more than one hundred islands that occupy 37 km^2; and is divided into three parts, facing Sepetiba Bay, the Atlantic Ocean, and Guanabara Bay. Due to the high concentration of industries in the metropolitan region, the city has faced severe environmental pollution problems. Guanabara Bay has lost mangrove areas and suffers from residues from domestic sewage, oils, and heavy and industrial metals.

Data source

Data collection took place in the database available online by the Department of Informatics of the Unified Health System (DATASUS) and the Brazilian Institute of Geography and Statistics, Health Surveillance Department (SVS), and State Health Departments (SES). To understand the rate of violence in Belo Horizonte and Rio de Janeiro, we have analyzed the Mortality Information System (SIM), including deaths from 2012 to 2020, infant mortality rate, and Covid-19.

Analysis

The SEIR compartment model of Infectious, Exposed, and Exposed Susceptible is a behavioral model that demonstrates the evolution of susceptible over time. An easy visualization through graphs of an epidemic's maximum, intermediate, and minimum points was made in R software using the package ODE.

The SEIR compartment model of Infectious, Exposed and Exposed Susceptible is a behavioural model that demonstrates the evolution of susceptible over time. This allows an easy visualization through graphs of the maximum, intermediate and minimum points of an epidemic.

The population is divided in four classes, depending on their current status with respect to the disease. The compartments consist of the susceptible individuals S (those able to contract the disease), the exposed individuals E (those who have been infected but are not yet infectious and may not have symptoms), the infective individuals I (those capable of transmitting the disease), and the recovered individuals R (those who have recovered and become immune). The disease transmission flow is represented in (Figure 2).

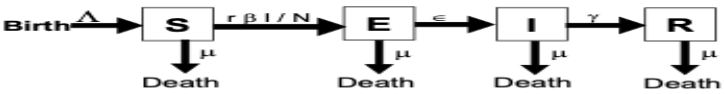


Figure 2: The disease transmission flow is depicted

RESULTS AND DISCUSSION

The first case record of a patient with Covid-19 in Rio de Janeiro was on March 5, 2020, while in Belo Horizonte the first confirmed case of the disease was only on March 16, 2020. Data on confirmed cases and of deaths by Covid-19 between the two capitals is shown in Tables 1, 2 and 3, in which the city of Rio de Janeiro shows a higher incidence of cases and deaths from Covid-19 than the city of Belo Horizonte. The estimated population (2021) of Rio de Janeiro is 6,775,561 people, and according to the Census (2010), it was 6,320,446 people, and the population density is 5,265.82 inhabitants per km^2. In Belo Horizonte, the estimated population (2021) is 2,530,701 people, and according to the Census (2010), it was 2,375,151 people, with a population density of 7,167.00 inhabitants per km^2.

Table 1: Epidemiological profile of the city of Rio de Janeiro

Rio de Janeiro	Confirmed Cases	Incidence Rate (per 100,000 people)	Deaths	Fatality Rate (%)
2020	221.48	3,271.90	18.962	8.7
2021	306.807	4,319.90	16.207	5.6
2022	451.695	6,780.80	1.732	0.4

Source: Rio COVID-19 Panel

Table 2: Epidemiological profile of the city of Belo Horizonte

Belo Horizonte	Notified	Confirmed	Deaths
2020	534.357	112.789	2.573
2021	847.802	199.726	4.673
2022	407.682	79.803	567

Source: e-SUS VE e SIVEP Gripe/CIEVS/GVIGE/DPSV/SMSA/PBH

The estimated population (2021) of Rio de Janeiro is 6,775,561 people, and according to the Census (2010), it was 6,320,446 people, and the population density is 5,265.82 inhabitants per km2. In Belo Horizonte, the estimated population (2021) is 2,530,701 people, and according to the Census (2010), it was 2,375,151 people, with a population density of 7,167.00 inhabitants per km^2.

According to Census data (2010) from the Brazilian Institute of Geography and Statistics, the sanitation in Rio de Janeiro is 94.4%, and in Belo Horizonte, it is 96.2%. The hydrography of Belo Horizonte shows no great river just small streams as Ribeirão Arrudas and Ribeirão das Onças.

The climate is tropical with hot, rainy summers and dry, mild winters. The average temperature during the year varies between 19 and 25 °C. The mild climate of Belo Horizonte is made up of mountains and hills, with an altitude that varies along its regions from 700 to 1500 meters. The city's highest point is located in Serra do Curral, at 1,538 meters. Moreover, the vegetation is 1,316 hectares of forest. The municipality's original biome is the Atlantic Forest, and the forest covers 3.9%.

The hydrography of Rio de Janeiro is made up of 200 watercourses (Rivers, Streams, and Streams). The most important are Guanabara Bay, Rodrigo de Freitas Lagoon, the Atlantic Ocean, and Sepetiba Bay between the lowlands of Guaratiba and Santa Cruz. The climate of the city of Rio de Janeiro is tropical Atlantic, semi-humid with an average annual temperature of around 24°C with abundant rainfall in summer and dry winters. The rainfall exceeds 1,500 mm per year. In the Table 3 describes some characteristics of the city of Belo Horizonte and Rio de Janeiro and (Figure 3) shows the map of the regions of Belo Horizonte and Rio de Janeiro.

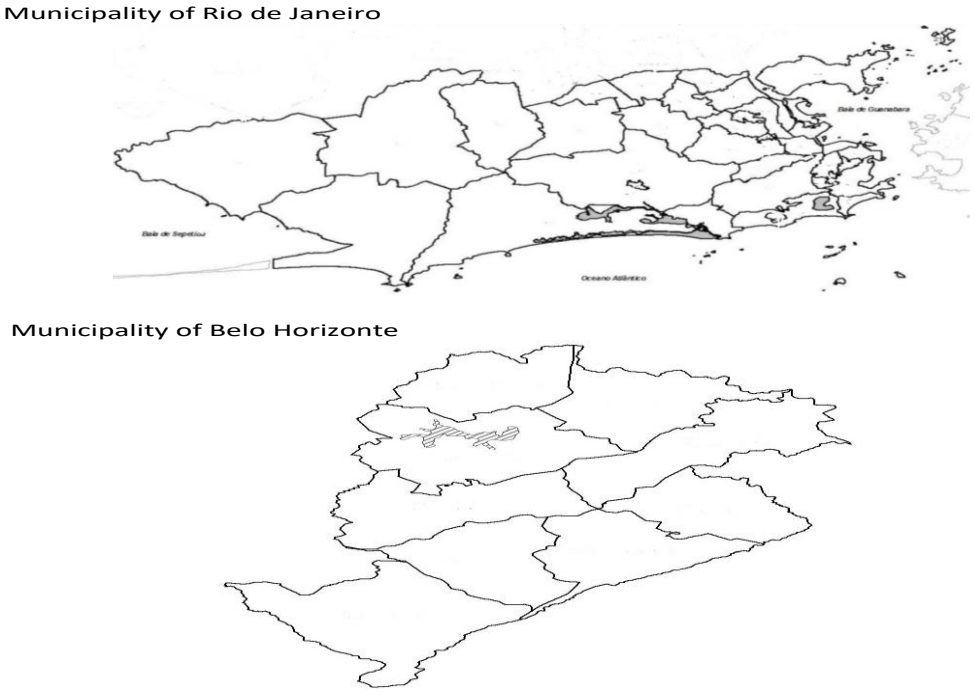


Figure 3: Map of the municipality of Rio de Janeiro and the municipality of Belo Horizonte
Source: Adapted from Instituto Pereira Passos and City Hall of Belo Horizonte - bhgeo

Table 3: Capitals of the Southeast Region of Brazil

Characteristics	Rio de Janeiro	Belo Horizonte
Population Estimate (2021)	6.775.561	2.530.701
Mortalidade Infantil (2020)	12,1	9,28
GDP (2019)	R$ 52.833,25	R$ 38.695,31
HDI (2010)	0,799	0.81
Territorial area (2021)	1200,329 km^2	331.354 km^2
Demographic density	5.265,82 hab./km^2	7.167,00 hab./km^2
Afforestation	70,5%	82,7%
Urbanization of Public Roads	78,4%	44,2%

Source: Brazilian Institute of Geography and Statistics

The health services in Belo Horizonte are composed of 152 health centers, 589 Family Health Strategy teams, the Odilon Behrens Metropolitan Hospital. The capital has eight mental health reference centers (CERSAM) for mental health. In specialized care, the capital of Belo Horizonte, the city has 5 Secondary Reference Units (URS), 9 Medical Specialty Centers (CEM), 4 Dental Specialty Centers (CEO) and Rehabilitation (CREAB), a Municipal Center for Diagnostic Imaging (CMDI) and an Ophthalmology Center.

The Urgency and Emergency services in Belo Horizonte are composed of 9 Emergency Care Units (UPA), a Night Psychiatric Emergency Service (SUP), and the SAMU. The diagnostic support network has five district laboratories, a central laboratory, a Sexually Transmitted Diseases laboratory, and nine UPA laboratories. Moreover, there are 78 Academies in the city with more than 19 thousand students in health promotion.

In Rio de Janeiro, health services are composed of more than 100 Family Clinics with various health actions such as food and nutrition, vaccination coverage, mental health, smoking, school health, and tuberculosis. The capital comprises gym programs, stork, and home care programs for the elderly. There are ten secondary care polyclinics. The city's urgency and the emergency network comprises three different types of units: 2 UPA (Emergency Care Unit), 7 CER (Regional Emergency Coordination), and eight emergency hospitals in the central planning areas of the city.

According to the municipality, deaths from external causes are the outbreaks of violence between the period 2012 to 2020, with ICD 10: X85-Y09. The data showed that in 2012 the proportion of violence in Belo Horizonte was higher than in Rio de Janeiro as shown in the (Figure 4). However, there was a decline in the proportion of violence in Belo Horizonte, and in the city of Rio de Janeiro, it assumes a higher proportion between 2017-2020.

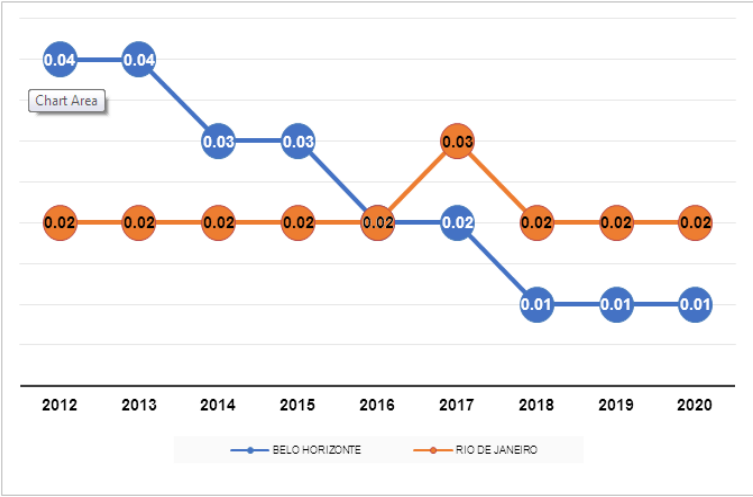


Figure 4: Proportion of deaths due to violence and aggression in the CID 10: X85-Y09.

Source: Mortality Information System (SIM)

The infant mortality rate is based on every 1,000 live births. Infant mortality rate in the city of Rio de Janeiro is higher than the city of Belo Horizonte as shown in Figure 5(A) of the city of Belo Horizonte and in Figure 5(B) of the city of Rio de Janeiro. These data are essential in assessing the city's quality of life. It is possible to obtain information on the effectiveness of public services and the city's infrastructure, such as basic sanitation, health system, availability of medicines and vaccines, medical monitoring, education, maternity, food, and several other factors that contribute to the quality of an urban environment. In (Figure 6), the graph demonstrates the population of children between the city of Rio de Janeiro and Belo Horizonte among the age groups younger than 1 year and among the age groups from 1 year to 5 years old. The city of Rio de Janeiro has a larger population of children than the city of Belo Horizonte.

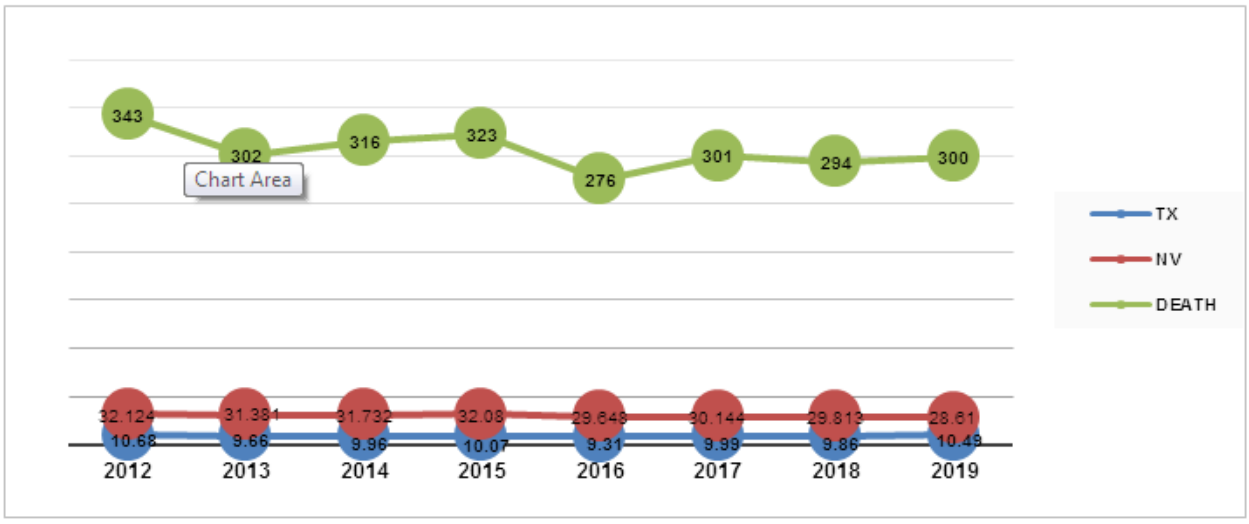


Figure 5(A): The infant mortality in Belo Horizonte. (Tx) means mortality rate, (NV) means live births

Source: Ms/SVS/CGIAE – SIM

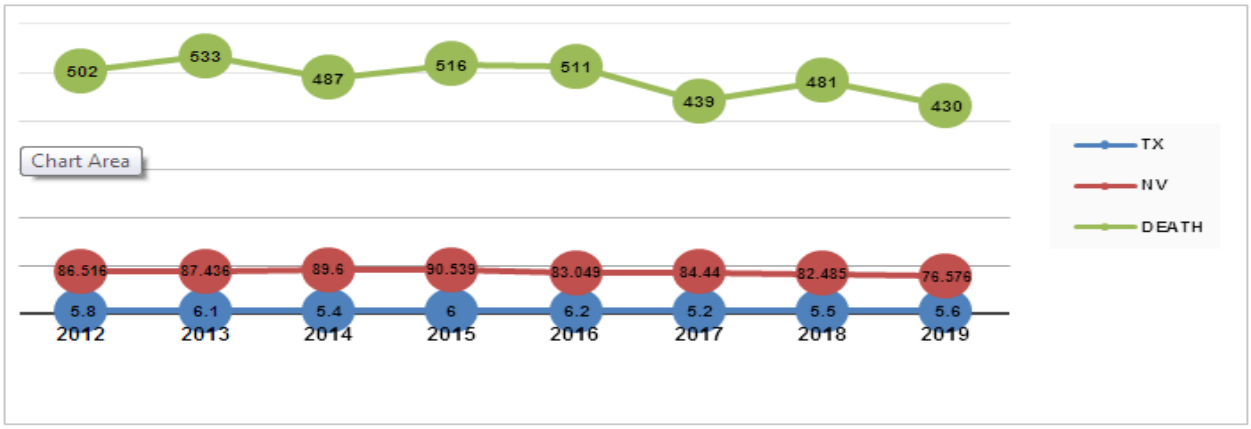


Figure 5 (B): The infant mortality in Rio de Janeiro. (Tx) means mortality rate, (NV) means live births

Source: Ms/SVS/CGIAE – SIM

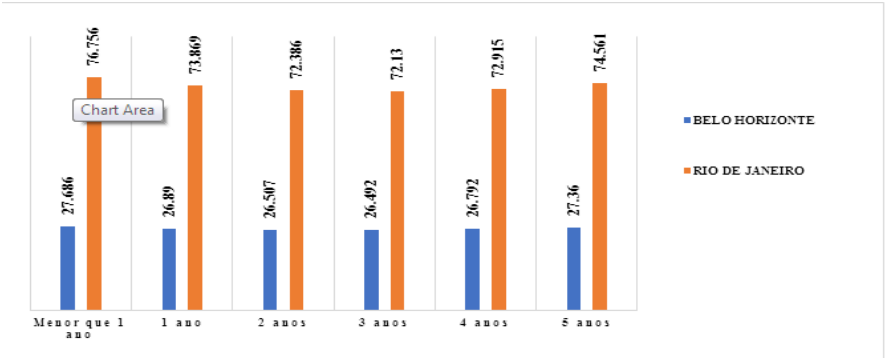


Figure 6: The graph demonstrates the population between the capitals of Rio de Janeiro and Belo Horizonte between the age groups below one year to the age group of 5 years old.

Source: IBGE

Cities play an important role in monitoring the impact of diseases in urban areas. Moreover, the measures implemented are essential to the city's entire population, especially regarding social inequalities. Figure 7A and 7B show the modeled value of the city of Belo Horizonte in the time from 150 to 180 days. With the significant number of infected people, the infection curve is prolongated in urban areas. The modeling results are shown in Figure 7 and Figure 8.

The period of infection has a more extended time. The lower the exposure of susceptible individuals, as shown in Figure C, the number of infected and the permanence of the disease will represent a decline and stability within 360 days. Furthermore, Figure 8 shows the modeled value of Rio de Janeiro from 150 to 180 days with a greater flow of people, and agglomerations were higher rates of people affected.

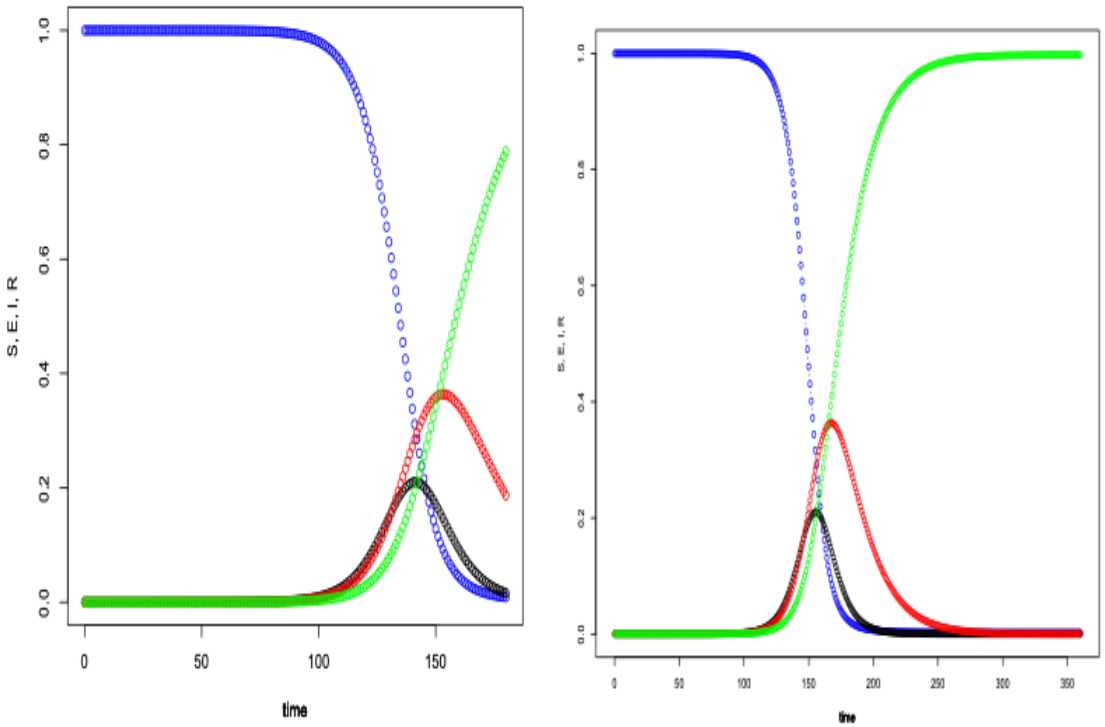
This disease behavior reaffirms the importance of this dynamic model shown in Figure 7 of the Belo Horizonte and Figure 8 of Rio de Janeiro. What will differentiate in this dynamics model is the TIME relationship.

Therefore, the higher the contact rate and the probability of transmission, in this case, Covid-19, which has a high rate of transmissibility - the greater the number of people exposed and infected. Furthermore, thinking about the city of Rio de Janeiro, where public transport has been facing severe problems with broken transport and mobility that is super crowded with people, consequently worsening the rapidity of the spread of the disease among people, shown in Figures 7 and 8.

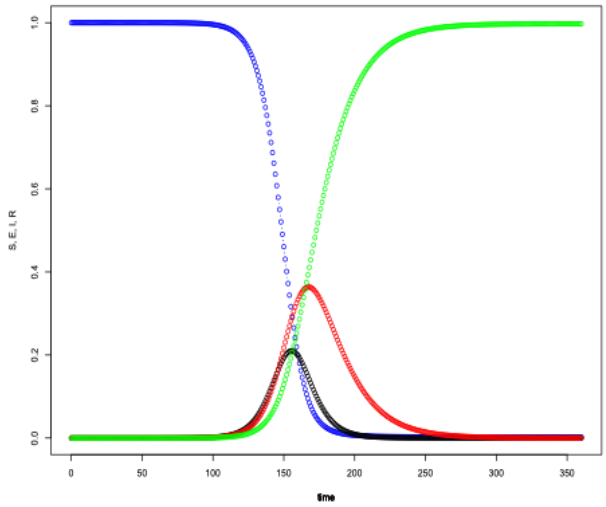
SEIR Input Parameters

* Contact_rate = 15 ± 5
* Transmission_probability = 0.06 ± 0.03
**Infectious_period=2
*** Latent_period = 8
* Urban factors that are associated with SEIR parameters.
** Parameter that may be associated with sanitation and substandard housing.
*** Latency period is normally associated with pathogen biology

1. number of contacts per day
2. transmission probabilitty
3. Infection period

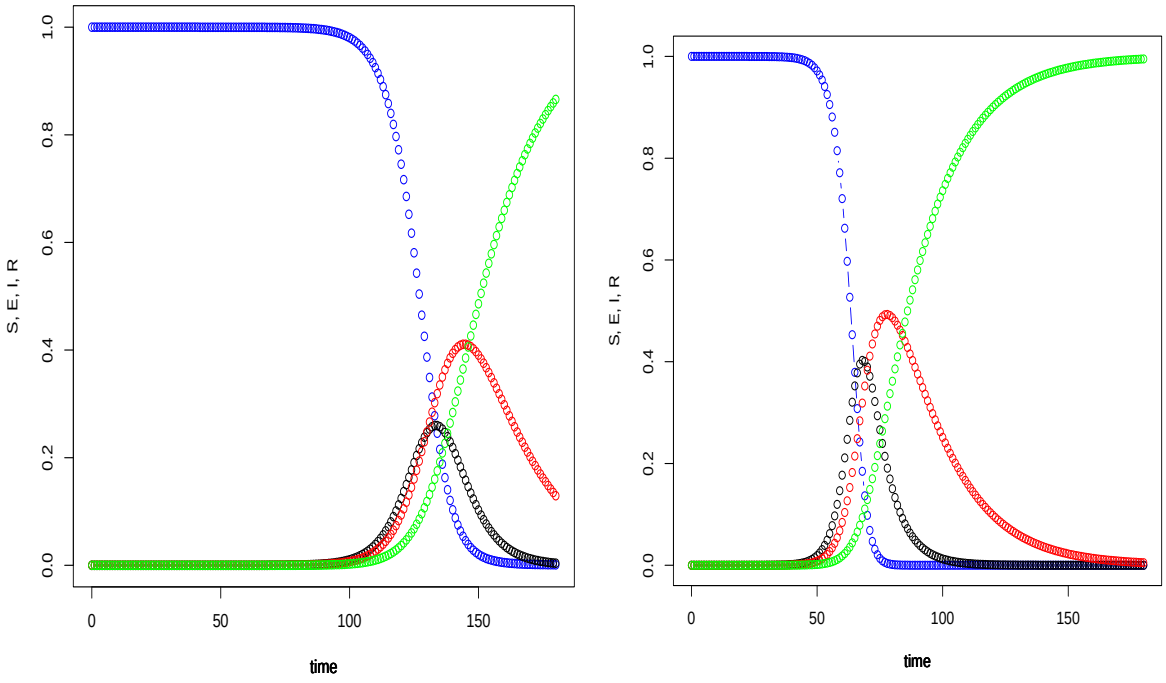


A **B**

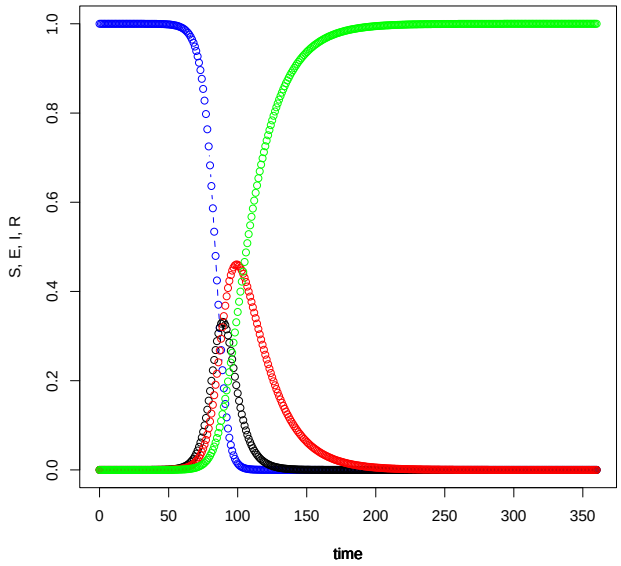


C

Figure 7: SEIR Epidemic in Belo Horizonte. Graphics A and B show a lower contact rate and lower probability index within 150 and 180 days. Graphics C have the highest Contact Rate: (1 to 30) and the highest contact probability rate (360 days). Between colours and their relationships where the colour is:1. Blue means Susceptible - They will drop as the infection rises; 2. Black means Exposed - It keeps and goes up according to the reaction of the susceptible; 3. Red means Infected - Increases as susceptibles are exposed; 4. Green means It increases from the responses that the susceptible are exposed to the virus.



A B



C

Figure 8: SEIR Epidemic in the city of Rio de Janeiro. Graphics A and B show the Lowest Contact Rate: (1 to 10) and the lowest contact probability rate (180 days). It shows that before 100 days, the infected curve begins with a Higher Contact Rate (1 to 20) and high transmission probability. It shows that before 50 days, the curve of the infected begins (150 days). Graphics C have the highest contact rate: (1 to 30) and the highest contact probability rate. In a time of 360 days. Between colours and their relationships where the colour is:1. Blue means Susceptible - They will drop as the infection rises; 2. Black means Exposed - It keeps and goes up according to the reaction of the susceptible; 3. Red means Infected - Increases as susceptibles are exposed; 4. Green means It increases from the responses that the susceptible are exposed to the virus.

CONCLUSION

The SEIR model compartmentalized the urban health of Rio de Janeiro and Belo Horizonte about Covid-19. It demonstrated that the increase in the contact rate and the probability of transmission will be more significant among the susceptible exposed infected and may lead to more infections. Therefore, city infrastructure or organization can directly affect the contact rate and the probability of transmission over time.

ACRONYMS

ENSP- National School of Public Health Sérgio Arouca

LNCC- Laboratory of Bioinformatics National Laboratory for Scientific Computing

SIM- Mortality Information System

CGIAE- General Coordination of Epidemiological Information and Analysis

SVS- Health Surveillance Department

SES- State Health Departments

IBGE- Brazilian Institute of Geography and Statistics

SIR- Susceptible-Infectious-Remove

SEIR- Susceptible-Exposed-Infected Individuals-Removed Recovered

DATASUS- Department of Informatics of the Unified Health System

HDI- Human Development Index

WHO- World Health Organization

COVID-19- Coronavirus disease 2019

ODE- Ordinary Differential Equation

SMSA-BH- Health Department of the City of Belo Horizonte

REFERENCES

1. Allam, Zaheer, David S. Jones. On The Coronavirus (COVID-19) Outbreak and The Smart City Network: Universal Data Sharing Standards Coupled with Artificial Intelligence (AI) to Benefit Urban Health Monitoring and Management. Healthcare (Basel). 2020;8(1):46.
2. Park, Su Eun. Epidemiology, Virology, and Clinical Features of Severe Acute Respiratory Syndrome-Coronavirus-2 (SARS-CoV-2; Coronavirus Disease-19). Clin Exp Pediatr. 2020;63(4):119-124.
3. World Health Organization (WHO). Coronavírus Disease (COVID-2019). Available in: Access 03 may. 2022.
4. World Health Organization (WHO). Regional Office for Europe. Available in: Access 03 may. 2022.
5. World Health Organization (WHO). Emergency Dashboard. Available in: Access 03 may. 2022.
6. Gralinski, Lisa E, Vineet D Menachery. Return of the Coronavirus: 2019-nCoV. Viruses. 2020;12(2):135.
7. Jin Yong Kim, Pyoeng Gyun Choe, Yoonju Oh, Kyung Joong Oh, Jinsil Kim, So Jeong Park, et al. The First Case of 2019 Novel Coronavirus Pneumonia Imported into Korea from Wuhan, China: Implication for Infection Prevention and Control Measures. J Korean Med Sci . 2020;35(5):e61.
8. Ashish Girdhar, Himani Kapur, Vijay Kumar, Manjit Kaur, Dilbag Singh, Robertas Damasevicius. Effect of COVID-19 Outbreak on Urban Health and Environment. Air Qual Atmos Health. 2021;14(3):389-397.
9. Edouard Mathieu, Hannah Ritchie, Esteban Ortiz-Ospina, Max Roser, Joe Hasell, Cameron Appel, et al. A Global Database of COVID-19 Vaccinations. Nat Hum Behav. 2021;5(7):947-953.
10. Cesari, Matteo, Marco Proietti. COVID-19 in Italy: Ageism and Decision Making in A Pandemic. J Am Med Dir Assoc. 2020;21(5):576-577.
11. Singh, Ram Babu, Bathula Srinagesh, Subhash Anand. Urban Health Risk and Resilience in Asian Cities. Berlin: Springer, 2020.
12. Kermack William Ogilvy, Anderson G McKendrick. A Contribution to The Mathematical Theory of Epidemics. Proceedings of The Royal Society Of London. Series A, Containing Papers of a Mathematical and Physical Character. 1927;115;772.

13. Calafiore, Giuseppe C, Carlo Novara, Corrado Possieri. A Modified SIR Model for the COVID-19 Contagion in Italy. 59th IEEE Conference on Decision and Control (CDC). IEEE, 2020.
14. Sun Peiliang, Kang Li. An SEIR Model for Assessment of Current COVID-19 Pandemic Situation in the UK. *medRxiv*. 2020.
15. David Vlahov. Sandro Galea, Emily Gibble, Nicholas Freudenberg. Perspectives on Urban Conditions and Population Health. Cadernos de Saúde Pública. 2005;21:949-957.
16. James, Paul. Urban Sustainability in Theory and Practice: Circles of Sustainability. Routledge, 2015.