

ORIGINAL ARTICLE

Lethality and mortality of COVID-19 in an important industrial center in Latin America, region of Grande ABC, São Paulo, Brazil

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Manuscript received: may 2021

Manuscript accepted: august 2021

Version of record online: november 2021

Abstract

Introduction: the new coronavirus (COVID-19) disease has been causing economic and health system impacts worldwide, triggering humanitarian crises in vulnerable regions, marked by high mortality rates of the disease. Brazil has been suffering an increase in the number of cases, characteristic of the formation of a second wave, with great epidemiological differences observed in the most diverse regions of the country. Many studies illustrate the behaviour of COVID-19 in the state of São Paulo, but there are gaps in the scientific literature on the epidemiology of COVID-19 in municipalities of the São Paulo metropolitan region that constitute an important industrial pole in Latin America, such as the region of Grande ABC.

Objective: to evaluate mortality and lethality trends of COVID-19 during the period March 2020 to July 2021, in municipalities on region of Grande ABC, metropolitan region of São Paulo, Brazil, divided into two periods (March to November 2020 and December to July 2021).

Methods: we conducted an ecological time series study with population data from the Brazilian Ministry of Health. We collected the number of cases and deaths confirmed for COVID-19 in the municipalities that make up the region of Grande ABC (Diadema, Mauá, Rio Grande da Serra, Ribeirão Pires, Santo André, São Bernardo do Campo, and São Caetano do Sul) from March 2020 to July 2021. Prais-Winsten linear regression was performed, and the percentage of daily change was calculated. Differences were considered significant when $p < 0.05$.

Results: in region of Grande ABC, in the period analysed, 217,264 cases and 10,004 deaths of COVID-19 were recorded. Although the mortality rate remained stationary during the first wave (March to November 2020) and the second wave (December 2020 to July 2021); lethality transitioned from decreasing during the first wave to increasing during the second wave, with rates varying according to municipality.

Conclusion: trend analyses in incidence, mortality, and lethality rates assist in understanding the behaviour of the COVID-19 Pandemic in the region known as Grande ABC. Efforts must be maintained throughout the region to control the Pandemic.

Keywords: COVID-19, lethality, mortality, trend.

Suggested citation: Martire Junior L, Morais TC, Eichemberg JO, Pereira JEG, Cavalcanti MPE, Pereira GAV, Silva HMR, Jacintho LC, Abreu LC. Lethality and mortality of COVID-19 in an important industrial center in Latin America, region of Grande ABC, São Paulow. *J Hum Growth Dev.* 2021; 31(3):436-446. DOI: 10.36311/jhgd.v31.12612

Authors summary

Why was this study done?

This study was carried out due to the need for epidemiological studies about the COVID-19 pandemic, especially in an important metropolitan region of São Paulo, the region of Grande ABC. Thus, it is extremely important to identify the epidemiological parameters of the first and second wave for better pandemic planning and reduced mortality.

What did the researchers do and find?

This study aimed to evaluate COVID-19 mortality and lethality trends during the period from March 2020 to July 2021, in municipalities in Grande ABC, metropolitan region of São Paulo, Brazil. As well as the objective of identifying and dividing into two periods (1st wave and 2nd wave). Thus, it was found that there was no decrease in COVID-19 mortality and lethality in the region of Grande ABC, even after one year of the Pandemic, observing a trend of stationary mortality in the first and second waves, while lethality was decreasing in the first and increasing during the second wave.

What do these findings mean?

From the analyzed data, the beginning of a second wave confronted by the inhabitants of the Greater ABC region stands out, elucidating the need for investments in the vaccine campaign as well as its distribution, as well as supplies for the health system itself, which is overloaded because of the pandemic. This study also highlights the need for analysis of epidemiological data with frequent updates and monitoring of COVID-19 throughout the country.

INTRODUCTION

The Coronavirus Disease (2019) (COVID-19) is an urgent Public Health Problem, which even after the World Health Organization declared on March 11, 2020, the disease as a Pandemic and instigated global efforts to contain the spread of the SARS-CoV-2¹ virus, its impacts are still directly affecting political, social, and economic structures of countries².

COVID-19 brought to light a scenario of a world that is beset by many crises and in need of effective changes. Its arrival in Latin America highlighted a region with weaknesses in public sectors (such as health, science, and education), in addition to scarce investments in public policies, significant fiscal austerity, fragile ties between official regional institutions, weaknesses in the instruments of national and regional government systems, which were already suffering the impact of weaknesses in global governance mechanisms³. In addition, political instability, corruption, social unrest, fragile health systems and socio-economic inequalities contributed to the fact that the Pandemic COVID-19, which began as a health crisis, is now, for Latin American countries, a humanitarian crisis, marked by one of the highest mortality rates in the world⁴.

Approximately 130 million cases of COVID-19 were registered in the world until the beginning of April 2021, with most cases concentrated in the Americas, with evidence for Latin American countries, especially Brazil, which leads the rank in number of cases in the region⁵. In that period, the Ministry of Health of the country recorded about 13 million cases of the disease; the southeast region, especially the state of São Paulo the most affected place⁶.

It is noteworthy that Brazil has been facing the biggest hospital and health crisis in its history, with accumulated death records of more than 300,000 victims of the disease and records of daily deaths that reflect the lack of control of the pandemic in the country. Among the 26 states and the Federal District, 20 regions are with high lethality and mortality rates, which make large percentages of global deaths by the disease⁷.

The region continues to break records for the wrong reasons, while it has experienced the deadliest episode faced since the beginning of the pandemic, due to the dissemination of new variants^{8,9}. These, resulting from genetic mutations, may be responsible for the increase in

the number of cases and the emergence of new waves of the disease¹⁰. This is a worrisome fact, since this second wave was even more lethal because the Brazilian population was already tired of the virus and lacked, for the most part, minimum educational and health measures⁷.

Despite the efforts and advances to minimize possible impacts of the pandemic, little is known about the spatial-temporal patterns of COVID-19, especially in urban spaces of highly affected regions, such as the metropolitan region of São Paulo¹¹.

It is noteworthy that many studies evaluate epidemiological patterns of the municipality of São Paulo, or the state. However, there are information gaps on the epidemiology of COVID-19 in important metropolitan regions, such as the region known as the Grande ABC.

The region of Grande ABC, located in the state of São Paulo, is a widely known region due to its socioeconomic importance. Its industrial park constitutes the largest industrial agglomeration in Latin America, with a focus on the automotive sector, in addition to petrochemical potential, with upstream (the Capuava Refinery) and downstream (the chemical, plastics segments and some others) ramifications¹².

Thus, there is an emerging need for regional studies to address the epidemiology of COVID-19 in the municipalities that make up the region of Grande ABC, highlighting the first and second waves of the Pandemic. Therefore, the objective of this study was to evaluate the mortality and lethality trends of COVID-19 during the period from March 2020 to July 2021, in municipalities of region of Grande ABC, metropolitan region of São Paulo, Brazil, dividing it into two periods (1st Wave and 2nd Wave).

METHODS

The protocol developed by Abreu, Elmusharaf and Siqueira (2021)¹³ was the base to conduct this ecological study of population-based time series of public access with information on cases of COVID-19 in the region of Grande ABC.

This region consists of the municipalities of Diadema (423,884 inhabitants), Mauá (472,912 inhabitants), Rio Grande da Serra (50,846 inhabitants), Ribeirão Pires (123,393 inhabitants), Santo André (718,773 inhabitants),

São Bernardo do Campo (838,936 inhabitants), and São Caetano do Sul (161,127 inhabitants), constituting a total population of 2,789,871 inhabitants. The population of each city was described based on data from the Ministry of Health, that considered the resident population used by the Federal Audit Court (TCU), according to estimates of 2019⁶.

The municipalities that make up the region of Grande ABC were characterized according to the analysis of the socioeconomic profile, using the Índice Paulista de Responsabilidade Social (Paulista Index of Social Responsibility/IPRS), which was thought to measure the degree of human development in the state of São Paulo. This index uses indicators of longevity, education, and wealth of a municipality, characterizing and allocating them into 5 distinct groups (Dynamic, Unequal, Equitable, In Transition, and Vulnerable)¹⁴.

The municipalities of region of Grande ABC presented a total of 217,264 cases and 10,004 deaths by COVID-19, notified during the period from March 2020 to July 2021. The new cases and new deaths were classified according to the location and date of disease notification.

The information was collected in August 2021. All notification of cases and deaths that referred to COVID-19 were included, using the International Classification of Diseases, 10th edition (ICD-10) of “U07.1 COVID-19, identified virus” or “U07.2 COVID-19, unidentified virus”, associated with the diagnosis of the disease, by laboratory and/or clinical-epidemiological confirmation¹⁵.

The data were extracted in a panel created by the Brazilian Ministry of Health, which was developed to be the official vehicle of communication on the epidemiological situation of COVID-19 in the country. This system uses the number of cases and deaths recorded by the Municipal and State Health Secretariats in that period and is updated daily⁶.

The collected data were distributed in Excel spreadsheet, illustrated in figures and tables.

Effective reproductive numbers (Rt) were calculated using the R studio software package EpiEstim version 2.2.4¹⁶, Effective reproductive number (Rt) were calculated using the R studio software package EpiEstim version¹⁷. A mean serial interval of 2.97 days with a mean standard deviation of 3.29 days was used, as described in previous studies^{18,19}, and in a window of 7 days.

Incidence rates were calculated (new cases/

population) expressed as new cases per 100,000 inhabitants; mortality (deaths/population) expressed as number of deaths per 100,000 inhabitants, and lethality (total deaths/total cases), expressed as a percentage.

For the trend analyses, the period was divided into first wave (March to November 2020) and second wave (December 2020 to July 2021); to define the period, the month with the lowest mortality rate was considered, which suggested the end of the first wave in the curve.

The incidence, mortality and lethality rate trend analyses were performed using the methods proposed by Antunes and Cardoso (2015)²⁰.

The Prais-Winsten regression model was used to calculate the time series construction rates. This method allows the first order autocorrelation corrections to be performed on the values, organized by time.

Thus, the values of the angular coefficient (β) and respective probability (p) were estimated, considering the significance level of 95% confidence interval (CI 95%). The data modeling process included the transformation rates (dependent variable = Y value) in a logarithmic function of base 10. The independent variable (X value) was the months of the historical series.

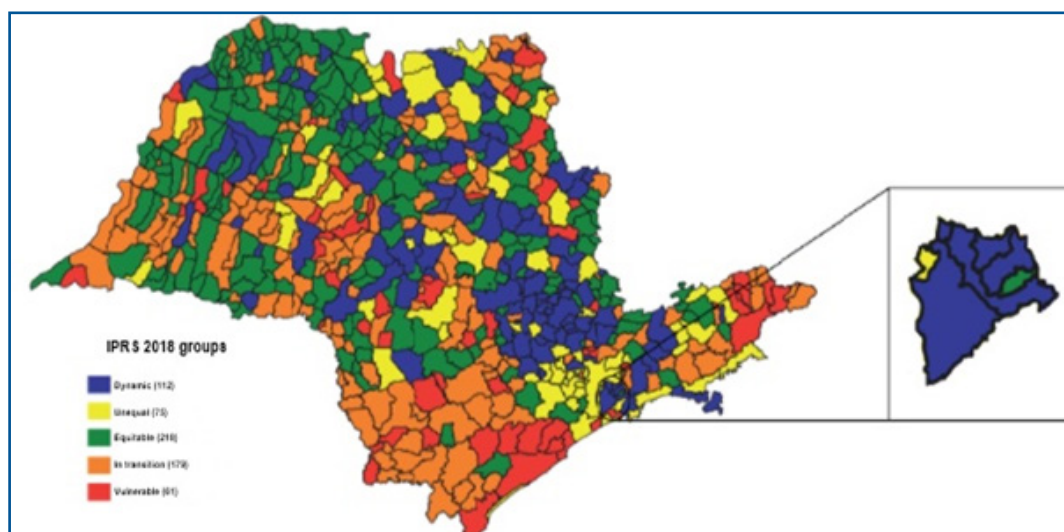
The results of the log rates (β) of the Prais-Winsten regression allowed us to estimate the Daily Percent Change (DPC) in each region, with the respective confidence intervals (95% CI).

This procedure made it possible to determine the rates as increasing, decreasing, or stationary and to quantify the percentage variation in daily incidence, mortality, and lethality rates. The trend was considered stationary when the coefficient was not significantly different from zero ($p > 0.05$).

Statistical analyzes were performed using the STATA 14.0 software (College Station, TX, U.S. 2013).

RESULTS

The socio-demographic analysis of the component municipalities of the Grande ABC region, via IPRS, illustrated that the municipalities of Mauá, São Bernardo do Campo, São Caetano do Sul and Santo André presented the highest level of IPRS (Dynamic level), while, Diadema is at the Unequal level and Rio Grande da Serra presented the lowest index (equitable level) among the municipalities (figure 1).



Local	Wealth	Longevity	Schooling	IPRS
Diadema	42	66	56	Unequal
Mauá	40	74	57	Dynamic
Ribeirão Pires	41	77	66	Dynamic
Rio Grande da Serra	37	74	58	Equitable
São Bernardo do Campo	47	76	60	Dynamic
São Caetano do Sul	53	77	82	Dynamic
Santo André	45	75	58	Dynamic

Figure 1: Municipalities in the State of São Paulo, according to groups in the São Paulo Social Responsibility Index (IPRS), with emphasis on the region of Grande ABC

Source: Fundação Seade. Paulista Social Responsibility Index - IPRS, 2019 (adapted)¹³.

RPS - Paulista Index of Social Responsibility, Wealth - 15 to 62, Longevity - 43 to 94, Schooling - 30 to 94. Dynamic - High Wealth, Longevity and Medium or High Schooling. Equitable – Low Wealth, Longevity and Medium or High Schooling. Unequal - High wealth, low longevity and medium or high schooling or medium or high longevity and low schooling.

There were 217,264 cases (100.00%) by COVID-19 in the region of Grande ABC in the period from March 2020 to July 2021, and 10,004 cases evolved to death. Among the cities that constitute the region it was São Bernardo do Campo that presented the highest number of cases (32.90%) and deaths (31.06%), followed by the city of Santo André with 61,568 cases (28.34%) and 2,905 (29.04%) deaths; the city of Rio Grande da Serra constituted only 0.96% of the cases of COVID-19 in the region and 0.81% of the deaths.

The reproductive number effect (R_t) during the analysis period (March 28, 2020, to July 31, 2021) in the region of Grande ABC of São Paulo started at values close to 1.6 in early April and remained similar until July 2020 with a predominance of R_t greater than 1, followed by a reduction in transmissibility in August 2020. However, in early November 2020, there was a high peak in transmissibility, reaching values of R_t of approximately 2.8 (the highest value observed in the analyzed period). After this period, R_t values were maintained below 1.4 until July 2021.

Table 1: Number of cases, recovered cases, and deaths by COVID-19, in metropolitan region of the State of São Paulo, Grande ABC, in the period March 2020 to July 2021.

Grande ABC Region	Cases		Deaths	
	N	%	N	%
Santo André	61,568	28.34	2,905	29.04
São Caetano do Sul	18,405	8.47	862	8.62
São Bernardo do Campo	71,481	32.90	3,107	31.06
Diadema	25,139	11.57	1,256	12.55
Mauá	30,198	13.9	1,459	14.58
Ribeirão Pires	8,377	3.86	334	3.34
Rio Grande da Serra	2,096	0.96	81	0.81
Total	217,264	100.00	10,004	100.00

Source: Cases and deaths extracted from the Ministry of Health

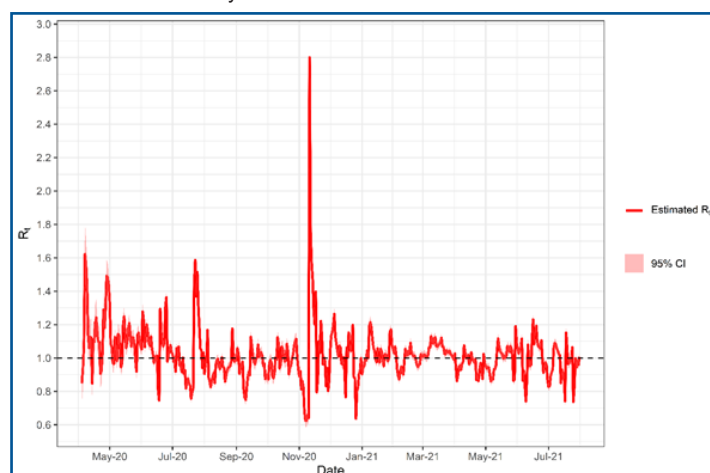


Figure 2: estimated R_t during the period March 28, 2020 to July 31, 2021
CI = Confidence Interval.

The temporal distribution of the incidence rate of COVID-19 in the analyzed period was illustrated in figure 3.

It was observed that the municipality of São Caetano do Sul presented the highest incidence rates of the disease, except in June and July, with a maximum peak registered in March 2021, with a rate of 1,387.72 cases per 100 thousand inhabitants.

At the end of the period analyzed (July 2021), the lowest incidence rates were presented by the municipalities of Rio Grande da Serra (171.09 cases per 100,000 inhabitants) and Diadema (270.18 cases per 100,000 inhabitants) (figure 3).

The analyses of the trends of the incidence of COVID-19 in the region of Grande ABC were evidenced in table 2.

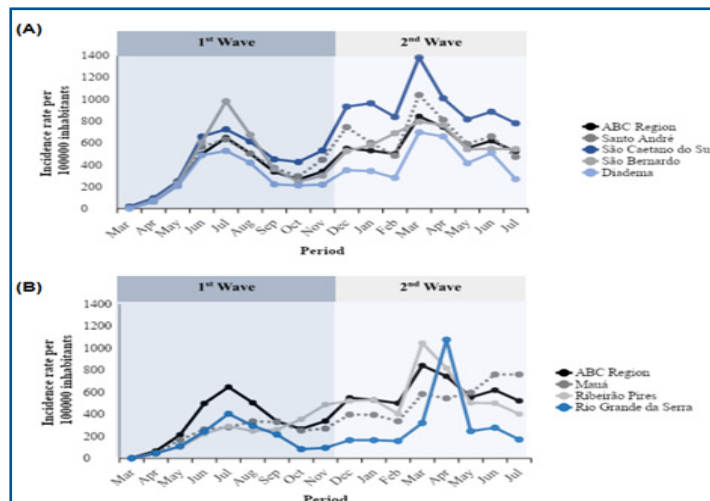


Figure 3: Incidence rate per 100 thousand inhabitants of COVID-19, in the period from March 2020 to July 2021, in cities of the metropolitan region of São Paulo (ABC Region) and the contribution of each component municipality (A) Santo André, São Bernardo, São Caetano do Sul, Diadema, (B) Mauá, Ribeirão Pires, Rio Grande da Serra in their outcomes.

It was found that the incidence of the disease in the region of Grande ABC showed increasing trends in the period from March 2020 to November 2020 (First Wave), $p < 0.05$, and stationary trends during the second wave, considering the period from December to July 2021 ($p > 0.05$). The municipalities of Mauá, Ribeirão Pires, São Bernardo do Campo, São Caetano do Sul, and Santo André

also presented increasing trend of incidence rate at the end of the first wave ($p < 0.05$). While, during a possible second wave, in the period from December to July 2021, only Mauá presented incidence rate with increasing trend, with daily increase of 0.23%, $p < 0.05$ (table 2).

The mortality rates of the region of Grande ABC and its component municipalities were described in figure 4.

Table 2: Prais-Winsten regression estimates and Daily Percent Change (DPC) of incidence rates per 100,000,000 inhabitants of COVID-19 in São Paulo Metropolitan Region (region of Grande ABC) in the period March 2020 to July 2021

Local	DPC (95% CI) Incidence	p	Incidence Trend	Period
ABC Region	0.59 (0.21 : 0.97)	0.002	Crescent	1st Wave
Santo André	0.68 (0.34 : 1.02)	<0.001	Crescent	
São Bernardo do Campo	0.46 (0.04 : 0.89)	0.034	Crescent	
São Caetano do Sul	0.47 (0.14 : 0.80)	0.005	Crescent	
Diadema	0.22 (-0.14 : 0.57)	0.227	Stationary	
Mauá	0.65 (0.36 : 0.95)	<0.001	Crescent	
Ribeirão Pires	0.59 (0.32 : 0.85)	<0.001	Crescent	
Rio Grande da Serra	-0.07 (-0.33 : 0.19)	0.593	Stationary	
ABC Region	0.04 (-0.14 : 0.22)	0.671	Stationary	2nd Wave
Santo André	-0.10 (-0.28 : 0.08)	0.272	Stationary	
São Bernardo do Campo	0.04 (-0.15 : 0.23)	0.680	Stationary	
São Caetano do Sul	0.04 (-0.23 : 0.31)	0.772	Stationary	
Diadema	0.13 (-0.12 : 0.38)	0.306	Stationary	
Mauá	0.23 (0.03 : 0.42)	0.021	Crescent	
Ribeirão Pires	-0.08 (-0.32 : 0.17)	0.545	Stationary	
Rio Grande da Serra	0.19 (-0.08 : 0.46)	0.165	Stationary	

DPC – Daily Percent Change (%); CI 95% – Confidence Interval 95%; p – p value: probability of statistical significance, * Means statistical difference - Prais-Winsten regression test, $p < 0.05$. Source: Cases, deaths extracted from the Ministry of Health.

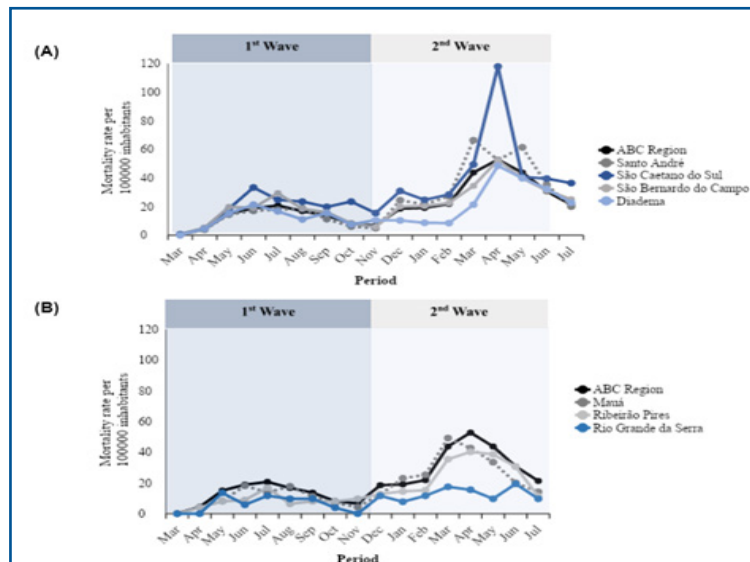


Figure 4: Comparison of mortality rate (per 100 thousand inhabitants) of COVID- 19, in the period March 2020 to July 2021, among cities of the Metropolitan Region of São Paulo (Region of Grande ABC) and the contribution of each component municipality (A) Santo André, São Bernardo, São Caetano do Sul, Diadema, (B) Mauá, Ribeirão Pires, Rio Grande da Serra in their outcomes.

The highest mortality rate for the region of Grande ABC was verified in April 2021, with records of 52.78 deaths per 100,000 inhabitants; it should be noted that in this same period, the municipalities of São Caetano do Sul, followed by Santo André and São Bernardo do Campo presented mortality rates higher than those presented by the region of Grande ABC, with the respective values: 117.93, 52.54 and 52.46 deaths per 100,000 inhabitants (figure 4).

The Prais-Winsten Regression estimates of the mortality rate were illustrated in table 3.

It was verified that there were stationary trends for mortality rates for the region of Grande ABC and its municipalities during the first wave (March to October 2020) ($p > 0.05$). But, during a possible second wave, it was highlighted that the Municipality of Diadema showed an increasing trend in mortality ($p < 0.05$) and daily growth rate of 0.45% (table 3).

The lethality rate of COVID-19 in the region of Grande ABC and constituent municipalities were described in figure 5.

Table 3: Prais-Winsten regression estimates and Daily Percent Change (DPC) of mortality rates (per 100 thousand inhabitants) of COVID-19 in São Paulo Metropolitan Region (Region of Grande ABC) in the period March 2020 to July 2021.

Local	DPC (95% CI) Mortality	p	Mortality Trends	Period
ABC Region	0.22 (-0.10 : 0.54)	0.178	Stationary	1st Wave
Santo André	0.04 (-0.24 : 0.33)	0.759	Stationary	
São Bernardo do Campo	0.08 (-0.18 : 0.34)	0.555	Stationary	
São Caetano do Sul	0.10 (-0.16 : 0.36)	0.452	Stationary	
Diadema	-0.05 (-0.31 : 0.20)	0.675	Stationary	
Mauá	-0.08 (-0.33 : 0.18)	0.543	Stationary	
Ribeirão Pires	-0.05 (-0.26 : 0.15)	0.602	Stationary	
Rio Grande da Serra	0.00 (-0.13 : 0.13)	0.988	Stationary	
ABC Region	0.24 (-0.07 : 0.55)	0.134	Stationary	2nd Wave
Santo André	0.23 (-0.11 : 0.56)	0.184	Stationary	
São Bernardo do Campo	0.10 (-0.16 : 0.36)	0.452	Stationary	
São Caetano do Sul	0.04 (-0.24 : 0.33)	0.759	Stationary	
Diadema	0.45 (0.18 : 0.71)	0.001	Crescent	
Mauá	0.04 (-0.24 : 0.32)	0.771	Stationary	
Ribeirão Pires	0.27 (-0.01 : 0.55)	0.057	Stationary	
Rio Grande da Serra	0.06 (-0.15 : 0.28)	0.564	Stationary	

DPC – Daily Percent Change (%); CI 95% 95% Confidence Interval; p - p value: probability of statistical significance, * Means statistical difference - Prais-Winsten regression test, $p < 0.05$. Cases, deaths and population extracted from the Ministry of Health.

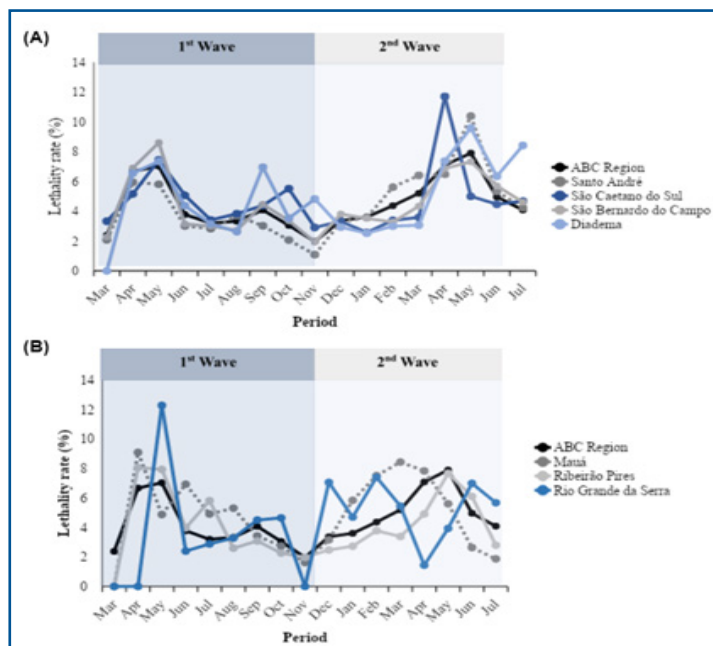


Figure 5: Comparison of the lethality rate (%) of COVID-19, in the period from March 2020 to July 2021, among cities of the metropolitan region of São Paulo (ABC region) and the contribution of each component municipality (A) Santo André, São Caetano do Sul, São Bernardo do Campo, Diadema, (B) Mauá, Ribeirão Pires, Rio Grande da Serra, in their outcomes.

It was observed that the highest lethality percentage for the region of Grande ABC was in May 2021 (7.90%). In this same period, the city of Santo André had the highest lethality (10.39%) by COVID-19 among all analyzed regions. The end of the 1st wave (month of November 2020) illustrated lower lethality percentages for the region of Grande ABC and most of the studied municipalities, being respectively: ABC - 1.97%, Santo André - 1.09%, São Bernardo do Campo - 1.93%, Mauá - 1.63%, Ribeirão Pires - 1.98 and Rio Grande da Serra - 0.00% (figure 5), trends in lethality rates are illustrated in table 4.

The first wave of COVID-19 (March 2020 to November 2020) was marked by decreasing trend of the lethality percentage, and a negative daily variation percentage for the region of Grande ABC and its component municipalities ($p < 0.05$), except for Diadema and Rio Grande da Serra, that presented stationary trend ($p < 0.05$). During the second wave, Santo André and Diadema showed an increasing trend of lethality of COVID-19 ($p < 0.05$), while the other municipalities studied showed lethality with stationary trends during the second wave ($p > 0.05$) (table 4).

Table 4: Prais-Winsten regression estimates and the Daily Percent Change (DPC) of lethality (%) of COVID-19, in São Paulo Metropolitan Region (ABC Region) in the period March 2020 to July 2021.

Local	DPC (95% CI) Lethality	p	Lethality Trend	Period
ABC Region	-0.50 (-0.69 : -0.30)	<0.001	Descending	1st Wave
Santo André	-0.78 (-1.07 : -0.49)	<0.001	Descending	
São Bernardo do Campo	-0.60 (-0.93 : -0.27)	<0.001	Descending	
São Caetano do Sul	-0.52 (-0.93 : -0.11)	0.013	Descending	
Diadema	-0.21 (-0.57 : 0.15)	0.253	Stationary	
Mauá	-0.49 (-0.80 : -0.19)	0.002	Descending	
Ribeirão Pires	-0.64 (-1.04 : -0.24)	0.002	Descending	
Rio Grande da Serra	-0.57 (-1.47 : 0.34)	0.207	Stationary	
ABC Region	0.22 (0.00 : 0.44)	0.046	Crescent	2nd Wave
Santo André	0.35 (0.03 : 0.67)	0.034	Crescent	
São Bernardo do Campo	0.25 (-0.01 : 0.52)	0.064	Stationary	
São Caetano do Sul	0.18 (-0.18 : 0.54)	0.318	Stationary	
Diadema	0.42 (0.17 : 0.67)	0.001	Crescent	
Mauá	-0.23 (-0.52 : 0.06)	0.115	Stationary	
Ribeirão Pires	0.32 (-0.05 : 0.70)	0.091	Stationary	
Rio Grande da Serra	-0.19 (-0.79 : 0.41)	0.527	Stationary	

DPC – Daily Percent Change (%); CI 95% – Confidence Interval 95%; p - p value: probability of statistical significance, *Means statistical difference - Prais-Winsten regression test, $p < 0.05$. Source: Cases, Deaths and Population extracted from the Ministry of Health.

DISCUSSION

The trend analyses of incidence, mortality and lethality rates in the studied municipalities help in understanding the behavior of the COVID-19 pandemic in the region of Grande ABC. Although the incidence rate in this region went from increasing (1st wave - March to November 2020) to stationary (2nd wave - December 2020 to July 2021), the mortality rate remained stationary, while the lethality rate went from decreasing in the first wave to increasing in the second wave, with rates varying according to the period and municipality.

It is noteworthy that the incidence rate is a fundamental concept in the epidemiology of infectious diseases, since it describes the frequency of new cases of the disease in each period. However, this index suffers direct limitations due to the number of tests for infection detection²¹. Thus, it is possible that the stationary trends of new cases of COVID-19 observed for Diadema and Rio Grande da Serra, during the first wave, and for the region of Grande ABC and its component municipalities (except Mauá) during the second wave, are a reflection that the percentage of testing of cases did not follow the actual increase in the incidence of the disease.

It is noteworthy that, during the period studied, the state of São Paulo was enacting the emergency phase of the pandemic, with the adoption of harsh restrictive measures to curb the increase in the number of new cases, hospitalizations, and deaths by COVID-19 and to contain the overload of hospital beds observed throughout the state²².

Although efforts are being made to contain the spread of SARS-CoV-2 infections in São Paulo, differences in mortality rates from the disease among regions are observed. Therefore, it is essential that geographic triages are performed in different locations, so that this information can guide intervention strategies aimed to promote the reduction of the pandemic in the metropolitan region of São Paulo⁸.

In this study, it was observed that the municipalities of the metropolitan region of São Paulo, which constitute Grande ABC, presented stationary mortality during the first and second waves, except for the municipality of Diadema, which presented an increasing trend in the mortality rate by COVID-19. However, it was highlighted that the lethality of the disease suffered significant variations in the periods evaluated according to the period and municipality.

It was found that the municipalities of Ribeirão Pires, São Bernardo do Campo, São Caetano do Sul and Mauá went from a lethality rate that presented decreasing trends in the first wave (March to November 2020), to stationary in the second wave (December 2020 to July 2021); while the municipality Rio Grande da Serra remained with the lethality with stationary trend in both periods. Moreover, the municipalities of Santo André and Diadema were the only places where the lethality rate of COVID-19 presented increasing trends at the end of the second wave, illustrating a more alarming scenario.

In this context presented, there is a need for future monitoring throughout the ABC region, especially in the municipalities of Santo André and Diadema, which showed lethality rates indicating daily increase even after

the pandemic year. It is possible that during the second wave, the viral action has triggered in these places a more lethal scenario of the disease. Moreover, in regions where the lethality rate remained stationary at the end of the period studied, efforts should also be intensified to reduce the dissemination and aggravations of the disease caused by the new coronavirus.

It is noteworthy that the evolution of the pandemic can trigger greater impacts in places of São Paulo with worse socioeconomic conditions⁸, that is, with higher rates of social vulnerability, corroborating the results of the current study. It was found that the two municipalities of the ABC Region that presented different IRPS indices, which were the municipalities of Diadema and Rio Grande da Serra, which had indices classified as unequal (high wealth, low longevity and medium/high education or low education and medium/high longevity) and equitable (Unequal - Low Wealth, Longevity and Medium or High Education), were the only municipalities that, during the first wave, the trends of incidence and lethality remained stationary. It is possible that the socioeconomic conditions of these cities reflected in some deficit in the number of testings for the disease and even in the quality of care provided by the Health services.

Studies still show the need for control of the pandemic of COVID-19 in regions of the state of São Paulo^{22,23}. Similarly, in the region of Grande ABC, even after more than a year of the pandemic, there were periods when the Rt indices showed high transmissibility, suggesting that the pandemic was out of control. These results corroborate the Rt values verified for the state of São Paulo, it is known that at the beginning of April 2021, this state had the Rt for the disease equal to 1.1 (CI: 0.93 - 1.2), with expected changes in daily cases probably increasing²⁴.

It is emphasized that measures adopted in metropolitan regions of that state, such as social distancing and improvement of testing protocols, use of masks and standard health safety, can decrease the effective reproduction rate of COVID-19. However, this scenario suffers variations throughout regions and period and may not be enough to contain the epidemic²³.

Given the oscillation in health indicators, mainly due to the growing tendencies in the lethality of the COVID-19 verified during the second wave for the ABC region, with daily growth rates of 0.22%, it is emphasized the importance of the precepts of health promotion in search of the reorientation of hygiene practices, after all, the current situation experienced by the population demands an agile and preventive posture²⁵. Moreover, it is necessary that investments be directed to the development of vaccines and, especially, to the weak health systems that suffer the impacts of the onus arising from the pandemic. After all, this health crisis cannot be defeated without robust national health systems; however, these are the places that have received the least political attention or funding^{13,26}.

Although our spatial analysis is subject to methodological limitations arising from ecological studies and secondary database analysis, such as delays in notifications or underreporting of cases of the disease,

the results contribute to a better understanding of the evolution of the disease in the metropolitan region of São Paulo, a region that has been facing numerous challenges in the face of a disease that undergoes daily changes in its health indicators. The analyses illustrate the beginning of a second wave faced by the population of the region, so it is essential to remember that the Pandemic is not over, thus, it is necessary the constant analysis of epidemiological data to update and monitor the COVID-19 in all regions of Brazil.

■ CONCLUSION

The trend analysis of important health indicators that are associated with disease severity revealed that there was no decrease in mortality and lethality of COVID-19 in the region of Grande ABC, even after one year of the pandemic. Mortality maintained a stationary trend in the first and second wave of the pandemic in this region, while the lethality changed from decreasing trends in the initial period to increasing in the second wave.

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It was highlighted that during the second wave of COVID-19 only the municipality of Diadema presented increasing tendencies in mortality, evidencing a daily increase rate of 0.45%. Diadema also presented increasing tendencies in lethality during the second wave, as well as the municipality of Santo André.

These results together are important indicators for monitoring the behavior of the Pandemic in the ABC Region and its component municipalities, although this scenario is constantly changing. Thus, it is emphasized that efforts remain necessary to contain the spread of the disease in all municipalities analyzed until the disease does not represent a threat to Public Health, for which the data presented in this paper can be useful.

Acknowledgments

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001. The financial viability of the article is due to the Acre - Health Project in the Western Amazon (multi-institutional agreement process no. 007/2015 SESACRE-UFAC-FMABC).

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Resumo

Introdução: a doença do novo coronavírus (COVID-19) vem ocasionando impactos econômicos e nos sistemas de saúde mundiais, desencadeando crises humanitárias em regiões vulneráveis, marcadas por elevadas taxas de mortalidade da doença. O Brasil vem sofrendo por um aumento no número de casos, característicos da formação de uma segunda onda, com grandes diferenças epidemiológicas observadas nas mais diversas regiões do país. Muitos estudos ilustram o comportamento da COVID-19 no estado de São Paulo, mas há lacunas na literatura científica sobre a epidemiologia da COVID-19 em municípios da região metropolitana de São Paulo que constituem importante polo industrial da América latina, como por exemplo a região do Grande ABC.

Objetivo: avaliar as tendências de mortalidade e letalidade da COVID-19 durante o período de março de 2020 a julho de 2021, em municípios do Grande ABC, região metropolitana de São Paulo, Brasil, dividindo em dois períodos (março a novembro de 2020 a dezembro a julho de 2021).

Método: foi realizado um estudo ecológico de series temporais com dados populacionais oriundo do Ministério da Saúde do Brasil. Foram coletados o número de casos e óbitos confirmados para COVID-19 nos municípios que compõe a região do Grande ABC (Diadema, Mauá, Rio Grande da Serra, Ribeirão Pires, Santo André, São Bernardo do Campo e São Caetano do Sul) no período de março de 2020 a julho de 2021. Foi realizado a regressão linear de Prais-Winsten, e calculado o percentual de mudança diária. Foram consideradas diferenças significativas, quando $p < 0,05$.

Resultados: na região do Grande ABC, no período analisado, foram registrados 217.264 casos e 10.004 óbitos de COVID-19. Apesar da taxa de mortalidade ter se mantido estacionária durante a primeira onda (março a novembro de 2020) e a segunda onda (dezembro de 2020 a julho de 2021); a letalidade transitou de decrescente durante a primeira onda para crescente durante a segunda onda, com índices variando segundo o município.

Conclusão: as análises de tendência nas taxas de incidência, mortalidade e letalidade auxiliam na compreensão do comportamento da Pandemia da COVID-19 na região conhecida como Grande ABC. Esforços devem ser mantidos em toda à região para o controle da Pandemia.

Palavras-chave: COVID-19; letalidade; mortalidade; tendência.

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