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Original Article

Association between cumulative incidence rates, mortality, and lethality from COVID-19 among the elderly and socioeconomic indicators

Associação entre taxas de incidência acumulada, mortalidade e letalidade por COVID-19 entre idosos e indicadores socioeconômicos

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Tatiane Vitória Souza dos Reis[1]
Priscila Poli[1]
Sílvia Carla da Silva André Uehara[1]

[1]Universidade Federal de São Carlos.
São Carlos, SP, Brazil.

Corresponding author:
Tatiane Vitória Souza dos Reis
Rodovia Washington Luis s/n, km 235
Caixa Postal 676. CEP: 13565-905.
São Carlos, SP, Brazil.
E-mail: treis@estudante.ufscar.br

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ABSTRACT

Objective: to analyze the association between the cumulative incidence, mortality, and lethality rates of COVID-19 in the older and socioeconomic indicators. **Methods:** this is an ecological time-trend study that considered all COVID-19 cases and deaths reported by the elderly people in all municipalities in the state of São Paulo. **Results:** weak positive correlations were found between the cumulative incidence rate of COVID-19 and factors such as the illiteracy rate in people aged 60 and over and elderly people with an income of up to one minimum wage. In addition, there were weak positive correlations between mortality and lethality rates and the municipal Human Development Index. There was a moderate correlation between the mortality rate and the rate of elderly people with no income. **Conclusion:** there is an association between income, schooling, and the municipal Human Development Index with the cumulative incidence, mortality, and lethality rates of COVID-19 in older people. **Contributions to practice:** the need for individualized and integrated approaches in health services is strengthened to minimize the effects of the social determinants of health on elderly people, especially in health emergencies.

Descriptors: COVID-19; Health of the Elderly; Incidence; Mortality; Social Determinants of Health.

RESUMO

Objetivo: analisar a associação entre as taxas de incidência acumulada, mortalidade e letalidade por COVID-19 em pessoas idosas e os indicadores socioeconômicos. **Métodos:** trata-se de um estudo ecológico de tendência temporal, que considerou todos os casos e óbitos por COVID-19 notificados em pessoas idosas em todos os municípios do estado de São Paulo. **Resultados:** foram encontradas correlações positivas fracas entre a taxa de incidência acumulada da COVID-19 e fatores como a taxa de analfabetismo em pessoas com 60 anos ou mais e pessoas idosas com renda de até um salário mínimo. Além disso, houve correlações positivas fracas entre as taxas de mortalidade e letalidade com o índice de desenvolvimento humano municipal. Observou-se correlação moderada entre a taxa de letalidade e a taxa de pessoas idosas sem rendimento. **Conclusão:** há associação entre renda, escolaridade e índice de desenvolvimento humano municipal com as taxas de incidência acumulada, mortalidade e letalidade por COVID-19 em pessoas idosas. **Contribuições para a prática:** fortalece-se a necessidade de abordagens individualizadas e integradas nos serviços de saúde, a fim de minimizar os efeitos dos determinantes sociais da saúde na população idosa, especialmente em situações de emergência sanitária.

Descritores: COVID-19; Saúde do Idoso; Incidência; Mortalidade; Determinantes Sociais da Saúde.

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Introduction

The COVID-19 pandemic has revealed significant disparities in public health, highlighting the influence of social, economic, and political inequalities on the severity of the disease. The high incidence and mortality resulting from infection with Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), observed in more vulnerable communities, exposed the unequal pattern of deaths and infections between regions of the same country, especially those with high social inequality[1].

In Latin America, the high incidence of cases and deaths has been strongly associated with socioeconomic inequalities and low investment in public health. A positive correlation has been identified between gross domestic product, the countries' Human Development Index (HDI), and the incidence of the disease, as well as a direct relationship with the availability of testing, vaccination coverage, and the proportion of elderly people[2].

In Brazil, COVID-19 initially spread to regions with better socioeconomic conditions due to the greater flow of people and the presence of air transportation routes. Subsequently, the spread reached more vulnerable areas, where the population faced inadequate housing conditions and low educational levels. Income inequality, as measured by the Gini Index, was associated with a higher incidence of the disease in these regions, and the difficulty of adhering to restrictive measures contributed to the transmission of the virus[3].

The older population stood out as a group at risk of complications and death from COVID-19. The impact of the disease among the elderly population has not been limited to immunosenescence and comorbidities; socioeconomic factors have played a vital role in the progression of the disease[4-6]. In Brazil, vulnerable individuals aged over 50 had a 32% higher risk of death compared to non-vulnerable individuals, with higher mortality in the North and Northeast regions, where the pandemic started late and severely[7-8].

Despite evidence of the influence of social and economic factors on COVID-19 incidence and mortality among the older population, especially in the early years of the pandemic, few studies have explored this relationship in depth[6-8]. Thus, there is still a gap in knowledge regarding the association between HDI, schooling, and income with the cumulative incidence, mortality, and lethality rates of COVID-19 among the elderly.

Given the above, this study aimed to analyze the association between the cumulative incidence, mortality, and lethality rates of COVID-19 in the older and socioeconomic indicators.

Methods

This is an ecological time trend study. All COVID-19 cases and deaths reported in elderly people in all municipalities in São Paulo between February 25, 2020, and February 25, 2023, were considered.

The state has an estimated elderly population of 7,650,568 inhabitants, with a Gross Domestic Product per capita of R$ 60,583.00, an average income of R$ 3,840.00, a HDI of 0.783 and an illiteracy rate of 5.6% for people over the age of 15, organized into 16 administrative regions[9].

The inclusion criteria were COVID-19 cases and deaths in people aged 60 or over, while the exclusion criteria were records with incomplete data.

The dependent variables were cumulative incidence per 100,000 elderly people (number of new cumulative cases/number of elderly people in the state x 100,000), mortality per 100,000 elderly people (number of deaths/number of elderly people in the state x 100,000), and lethality per 100 cases (number of deaths from COVID-19/total number of COVID-19 cases x 100). The independent variables included the municipal HDI, the illiteracy rate of people aged 60 and over, and the proportion of elderly people with no income or an income of up to one minimum wage. To calculate the cumulative incidence rate, the population estimate from the State Data Analysis System Foundation was considered, and data on COVID-19 cases and

deaths from the state of São Paulo was collected[9]. The independent variables were obtained from the Brazilian Institute of Geography and Statistics, with the data collected referring to the 2010 census, available at the time of data collection and analysis[10]. They were then included in Microsoft Excel spreadsheets, and descriptive analyses were carried out. The Bivariate Global Moran's Index was calculated to assess the spatial autocorrelation of the variables of interest.

Regarding the Bivariate Global Moran's index description, positive values (between 0 and +1) indicate positive autocorrelation, while negative values (between 0 and -1) indicate negative autocorrelation and provide statistical significance. Positive values suggest direct proportionality between the variables, indicating that places with high values of one variable tend to have high values of the other. On the other hand, negative values indicate inverse proportionality, where areas with high values of one variable tend to have low values of the other. Furthermore, the closer the correlation is to the extreme values (-1 or 1), the stronger it is, while values close to zero indicate no correlation between the variables. This index and the p-value for the hypothesis test H0: index = 0 *vs.* H1: index ≠ 0 were estimated using GeoDa software version 1.20.0.10.

Changes in monthly rates between 2020 and 2023 were analyzed using a join point regression model. Based on a Poisson regression, the positions of the change points and regression coefficients were estimated. At the same time, the optimum number of join points was selected using a Monte Carlo permutation test, considering a maximum of 6 points. The monthly percentage changes for each line segment and the 95% confidence interval were estimated to facilitate interpretation. The data was analyzed using Join Point Regression version 4.9.1.0[11]. A significant level of 5% was adopted for all analyses.

This study did not require approval from the Research Ethics Committee as it used publicly accessible data following Resolution 466/12 of the National Health Council.

Results

The administrative regions of São José do Rio Preto and Araçatuba had the highest cumulative incidence rates of COVID-19 in the elderly, while São Paulo and Franca had the lowest. It should be noted that the highest mortality rates were found in São José do Rio Preto and Santos and the lowest in the Central and Bauru regions; and the highest lethality rates were found in São Paulo and Santos and the lowest in the Central and Bauru administrative regions (Table 1).

Table 1 – Cumulative incidence, mortality, and lethality rates of COVID-19 among the elderly by administrative region of São Paulo. São Carlos, SP, Brazil, 2024

Administrative region	Incidence		Mortality		Lethality	
	Rate	*CI 95%	Rate	95% CI	Rate	95% CI
Araçatuba	70.1	69.3–70.9	16.2	15.5–16.8	7.7	7.4–8.0
Barretos	64.3	63.3–65.3	17.6	16.7–18.6	9.1	8.7–9.6
Bauru	60.9	60.3–61.6	13.6	13.1–14.1	7.4	7.2–7.7
Campinas	53.6	53.3–53.8	15.8	15.6–16.0	9.8	9.7–10.0
Central	59.2	58.5–59.8	11.6	11.1-12.1	6.5	6.3–6.8
Franca	38.0	37.4–38.6	13.8	13.2–14.5	12.1	11.6–12.7
Itapeva	66.6	65.6–67.6	17.2	16.3–18.1	8.6	8.2–9.0
Marília	56.6	56.0–57.2	15.6	15.1–16.2	9.2	8.9–9.5
Presidente Prudente	59.6	58.9–60.3	15.0	14.4–15.6	8.4	8.1–8.7
Registro	69.9	68.5–71.3	16.5	15.3–17.7	7.9	7.3–8.4
Ribeirão Preto	47.1	46.6–47.7	18.8	18.3–19.4	13.3	12.9–13.7
Santos	45.1	44.7–45.5	19.0	18.6–19.5	14.1	13.7–14.4
Sorocaba	51.6	51.2–52.0	15.0	14.6–15.4	9.7	9.4–9.9
São José do Rio Preto	88.4	87.8–89.0	20.7	20.2–21.2	7.8	7.6–8.0
São José dos Campos	46.7	46.3–47.0	13.8	13.4–14.2	9.9	9.6–10.1
São Paulo	33.5	33.4–33.6	16.9	16.8–17.0	16.8	16.7–17.0
São Paulo State	45.9	45.8–46.0	16.4	16.3–16.5	11.9	11.8–12.0

*Confidence interval; Note: Cumulative incidence and mortality rates per 100,000 elderly people/year, case fatality rate per 100 COVID-19 cases

There was a positive spatial correlation (Moran's Index: 0.136; p<0.010) between regions with a higher illiteracy rate among the elderly and a higher incidence of COVID-19 in this population. There was also a negative spatial correlation (Moran's Index: -0.242; p<0.010) between regions with a higher

proportion of elderly people with no income and a lower incidence of COVID-19. In addition, there was a positive spatial correlation (Moran's Index: 0.188; p<0.010) between regions with a higher proportion of elderly people with an income of up to one minimum wage and a higher incidence of COVID-19 (Table 2).

The results indicated a positive spatial correlation (Moran's Index: 0.040; p 0.015) between regions with a higher HDI and higher COVID-19 mortality among the elderly. There was a positive spatial correlation (Moran's Index: 0.052; p<0.010) between higher HDI and higher lethality and a negative spatial correlation (Moran's Index: -0.109; p<0.010) between regions with a higher illiteracy rate among the elderly and lower lethality. There was also a positive spatial correlation (Moran's Index: 0.200; p<0.010) between regions with a higher proportion of elderly people with no income and higher COVID-19 lethality and a negative spatial correlation (Moran's Index: -0.134; p<0.010) between the proportion of elderly people with an income of up to one minimum wage and lower lethality (Table 2).

The administrative regions of Araçatuba, Barretos, Bauru, Campinas, Registro, Santos, São José do Rio Preto, São José dos Campos, São Paulo, and the state of São Paulo showed no change in trend in the cumulative incidence rates of COVID-19 in elderly people; In contrast, the regions of Itapeva, Marília, Central, Presidente Prudente, Ribeirão Preto, and Sorocaba showed three points of change in trend (Table 3).

Table 2 – Bivariate Global Moran's Index between cumulative incidence, mortality, and lethality rates for COVID-19 and socioeconomic indicators. São Carlos, SP, Brazil, 2024

Socio-economic indicator	Incidence		Mortality		Lethality	
	Moran's Index	p-value*	Moran's Index	p-value	Moran's Index	p-value
Human development index for municipalities	-0.018	0.180	0.040	0.015	0.052	<0.010
The illiteracy rate among the elderly	0.136	<0.010	0.020	0.443	-0.109	<0.010
The proportion of elderly people with no income	-0.242	<0.010	0.011	0.278	0.200	<0.010
The proportion of elderly people with an income of up to one minimum wage	0.188	<0.010	0.014	0.216	-0.134	<0.010

*Pseudo-significance test; Note: Cumulative incidence and mortality rates per 100,000 elderly people/year, lethality rate per 100 COVID-19 cases

Table 3 – Trend analysis of the cumulative incidence rate of COVID-19 per 100,000 elderly people per year in the administrative regions of the state of São Paulo. São Carlos, SP, Brazil, 2024

Administrative region /Period	Incidence rate	
	MPC (CI 95%)	MAPC (95% CI)
São Paulo State		
Mar/20 to Fev/23	-0.40 (-0.31 ; 2.40)	-0.40 (-0.31 ; 2.40)
Araçatuba		
Mar/20 to Feb/23	1.90 (-1.30; 5.20)	1.90 (-1.30; 5.20)
Barretos		
Mar/20 to Feb/23	0.90 (-1.70; 3.70)	0.90 (-1.70; 3.70)
Bauru		
Mar/20 to Feb/23	2.00 (-0.90; 4.90)	2.00 (-0.90; 4.90)
Campinas		
Mar/20 to Feb/23	-0.30 (-2.50; 3.20)	-0.30 (-2.50; 3.20)
Registro		
Mar/20 to Feb/23	2.10 (-0.90; 5.20)	2.10 (-0.90; 5.20)
Santos		
Mar/20 to Feb/23	-0.80 (-3.60; 2.00)	-0.80 (-3.60; 2.00)
São José do Rio Preto		
Mar/20 to Feb/23	2.00 (-1.00; 5.10)	2.00 (-1.00; 5.10)
São José dos Campos		
Mar/20 to Feb/23	-0.40 (-3.40; 2.80)	-0.40 (-3.40; 2.80)
São Paulo, Brazil		
Mar/20 to Feb/23	-2.80 (-5.50 ; -0.10) §*	-2.80 (-5.50 ; -0.10)*

(the Table 3 continue in the next page...)

Franca		
Mar/20 to Apr/21	11.30 (1.40 ; 22.20)*	-3.30 (-7.50 ; 1.10)
Apr/21 to Feb/23	-11.00 (15.20 ; 6.50)*	
Central		
Mar/20 to Jun/21	15.50 (5.40 ; 26.70)*	3.00 (-35.60 ; 64.90)
Jun/21 to Oct/21	-65.10 (-92.90 ; 71.50)	
Oct/21 to Jan/22	347.6 (-97.80 ; 92235.40)	
Jan/22 to Feb/23	-10.30 (-17.60 ; -2.40)*	
Itapeva		
Mar/20 to May/21	27.50 (14.00 ; 42.60)*	5.30 (-29.70 ; 57.70)
May/21 to Oct/21	-53.20 (-79.00 ; 4.50)	
Oct/21 to Jan/22	235.90 (-97.00 ;37771.40)	
Jan/22 to Feb/23	-10.40 (-17.40 ; -2.90)*	
Marília		
Mar/20 to May/21	24.70 (14.40 ; 35.90)*	3.50 (-23.50 ; 40.00)
May/21 to Oct/21	-45.80 (-66.10 ; -13.40)*	
Oct/21 to Jan/22	162.00 (-92.70 ;9347.90)	
Jan/22 to Feb/23	-12.40 (-18.80 ; -5.40)*	
Presidente Prudente		
Mar/20 to May/21	19.90 (8.10 ; 33.10)*	4.30 (-29.00 ; 53.20)
May/21 to Oct/21	-41.20 (-68.20 ; 8.80)	
Oct/21 to Jan/22	147.80 (-97.40 ; 23660.70)	
Jan/22 to Feb/23	-8.40 (-15.10 ; -1.20)*	
Ribeirão Preto		
Mar/20 to May/21	8.40 (1.60 ; 15.60)*	-4.00 (-31.10 ; 33.80)
May/21 to Oct/21	-39.80 (-64.20 ; 1.20)	
Oct/21 to Jan/22	97.50 (-96.10 ; 9939.30)	
Jan/22 to Feb/23	-14.60 (-24.60 ; -3.30)*	
Sorocaba		
Mar/20 to Jun/21	14.70 (6.80 ; 23.20)*	1.00 (-33.50 ; 53.30)
Jun/21 to Oct/21	-62.90 (-88.60 ; 21.10)	
Oct/21 to Jan/22	260.20 (-97.10 ; 45342.70)	
Jan/22 to Feb/23	-11.50 (-19.30 ; -3.00)*	

*Statistically significant changes; MPC: Monthly percentages of variation; MAPC: Mean annual percentage change; CI: Confidence Interval

It was not possible to analyze the trend in the COVID-19 mortality rate in the elderly in the administrative regions of Araçatuba, Barretos, Bauru, Franca, Itapeva, and Registro, as there were no deaths from the disease in any period, making the analysis of the joinpoint model ineffective. On the other hand, the Central, Marília, and São José dos Campos regions showed three points of change in mortality rate trends; the administrative areas in Presidente Prudente and São Paulo showed four points of change in trend, while the regions of Campinas, Ribeirão Preto, Santos, São José do Rio Preto, Sorocaba and the state of São Paulo showed five points of change in trends (Table 4).

The administrative regions of Ribeirão Preto, Santos, and São José do Rio Preto showed two points of change in the trend of COVID-19 fatalities among elderly people, Marília (3), São José dos Campos (4), Campinas, Central, Presidente Prudente and Sorocaba (5), São Paulo and the state of São Paulo (6). It was not possible to analyze COVID-19 lethality in elderly people in Araçatuba, Barretos, Bauru, Franca, Itapeva and Registro, as there were no deaths from the disease in any period (Table 4).

Table 4 – Trend analysis of the COVID-19 mortality and lethality rate per 100,000 elderly people in the administrative regions. São Carlos, SP, Brazil, 2024

Administrative regions/Period	Mortality rate		Lethality rate	
	MPC (95% CI)	MAPC (95% CI)	MPC (95% CI)	MAPC (95% CI)
Central				
Mar/20 to Apr/21	24.9 (17.1 ; 33.3)*	–2.4 (–22.8 ; 23.3)	–	–6.1 (–11.8 ; –0.1)*
Apr/21 to Oct/21	-42.0 (-55.8 ; -24.0)*		–	
Oct/21 to Jan/22	99.9 (-87.3 ; 3045.8)		–	
Jan/22 to Feb/23	-17.9 (-27.0 ; -7.6)*		–	
Mar/20 to Dec/20	–	–	-4.4 (-11 ; 2.8)	
Dec/20 to Mar/21	–	–	24 (-2.1 ; 57.2)	
Mar/21 to Jun/21	–	–	-27.4 (-43.4 ; -7)*	
Jun/21 to Sep/21	–	–	37.6 (-15.2; 123.3)	
Sep/21 to Mar/22	–	–	-31.5 (-43 ; -17.5)*	
Mar/22 to Feb/23	–	–	-1.7 (-7.9; 4.9)	
Marilia				
Mar/20 to Apr/21	34.6 (25.5 ; 44.5)*	0.3 (–23.6 ; 31.7)	–	–4.3 (–8.3 ; 0)*
Apr/21 to Oct/21	-39.3 (-51.5 ; -24.0)*		–	
Oct/21 to Jan/22	79.6 (-93.2; 4618.4)		–	
Jan/22 to Feb/23	-17.6 (-25.2 ; -9.3)*		–	
Mar/20 to Dec/20	–	–	-4.5 (-13.1; 5)	
Dec/20 to Mar/21	–	–	22.5 (-14.0; 74.5)	
Mar/21 to Jan/22	–	–	-11.4 (-16.5 ; -6.0)*	
Jan/22 to Feb/23	–	–	-3.9 (-8.1; 0.5)	
São José dos Campos				
Mar/20 to Apr/21	15.5 (8.0 ; 23.6)*	–4.9 (–29.3 ; 28.0)	–	–5.4 (–18 ; 9.2)
Apr/21 to Oct/21	-36.8 (-53.5 ; -14.1)*		–	
Oct/21 to Jan/22	101.4 (-94.0; 6714.0)		–	
Jan/22 to Feb/23	-20.5 (-31.1 ; -8.2)*		–	
Mar/20 to Dec/20	–	–	-12.6 (-17.6 ; -7.3)*	
Dec/20 to Mar/21	–	–	23.7 (-5.9; 62.4)	
Mar/21 to Feb/22	–	–	-5.7 (-7.9 ; -3.6)*	
Feb/22 to May/22	–	–	-30.6 (-87.6; 289.1)	
May/22 to Feb/23	–	–	4.4 (-3.1; 12.5)	
Presidente Prudente				
Mar/20 to Dec/20	11.0 (–7.8 ; 33.6)	–3.1 –24.4 24.2	–	–7.6 (–15.3 ; 0.8)
Dec/20 to Mar/21	68.4 (–24.7 ; 276.5)		–	
Mar/21 to Oct/21	–31.5 (–42.8 ; –18.1)*		–	
Oct/21 to Jan/22	57.1 (–90.8 ; 2572.8)		–	
Jan/22 to Feb/23	–16.2 (–24.6 ; –6.9)*		–	
Mar/20 to Dec/20	–	–	–10.0 (–15.4 ; –4.2)*	
Dec/20 to Mar/21	–	–	31.6 (0.4 ; 72.4)*	
Mar/21 to Jun/21	–	–	–25.5 (–40.9 ; –6)*	
Jun/21 to Oct/21	–	–	20.9 (–3.2 ; 51.1)	
Oct/21 to Jan/22	–	–	–36.6 (–75.6 ; 64.3)	
Jan/22 to Feb/23	–	–	–8.5 (–11.7 ; –5.2)*	
São Paulo				
Mar/20 to May/20	79.2 (–49.7 ; 538.3)	–4.7 (–16.6 ; 8.8)	–	–5.1 (–9.6 ; –0.5)*
May/20 to Oct/20	–27.4 (–51.0 ; 7.6)		–	
Oct/20 to Mar/21	49.5 (7.0 ; 109.0)*		–	
Mar/21 to Jun/21	–39.7 (–77.2 ; 59.3)		–	
Jun/21 to Feb/23	–8.4 (–15.4 ; –0.9)*		–	
Mar/20 to Jul/20	–	–	–21.6 (–27.3 ; –15.4)*	
Jul/20 to Dec/20	–	–	–3.2 (–11 ; 5.4)	
Dec/20 to Mar/21	–	–	18 (–3.5 ; 44.3)	
Mar/21 to Jul/21	–	–	–12.9 (–22.1 ; –2.6)*	
Jul/21 to Oct/21	–	–	18 (–19.3 ; 72.5)	
Oct/21 to Jun/22	–	–	–14.8 (–22.9 ; –5.9)*	
Jun/22 to Feb/23	–	–	1.8 (–7 ; 11.4)	

(the Table 4 continue in the next page...)

State of São Paulo				
Mar/20 to May/20	121.9 (-15.9 ; 485.3)		–	–
May/20 to Oct/20	-21.1 (-36.4 ; -2.2)*		–	–
Oct/20 to Mar/21	46.3 (20.4 ; 77.8)*	–5.1 (–20.0 ; 12.7)	–	–
Mar/21 to Oct/21	-32.9 (-40.7 ; -24.1)*		–	–
Oct/21 to Jan/22	69.3 (-75.2 ; 1057.6)		–	–
Jan/22 to Feb/23	-20.0 (-26.7 ; -12.7)*		–	–
Mar/20 to Jul/20	–	–	–22.9 (–30.5 ; –14.5)*	
Jul/20 to Dec/20	–	–	–5.1 (–13.7 ; 4.3)	
Dec/20 to Mar/21	–	–	21.5 (–2.2 ; 51)	
Mar/21 to Jun/21	–	–	–17 (–32.1 ; 1.5)	–6.9 (–11.2 ; –2.4)*
Jun/21 to Oct/21	–	–	7.6 (–11 ; 30.2)	
Oct/21 to May/22	–	–	–20.5 (–31.6 ; –7.6)*	
May/22 to Feb/23	–	–	1 (–5 ; 7.5)	
Campinas				
Mar/20 to Jun/20	200.9 (22.2 ; 641.0)*		–	–
Jun/20 to Oct/20	–34.3 (–56.4 ; –0.9)*		–	–
Oct/20 to Mar/21	56.4 (20.3 ; 103.3)*	0.1 (–19.1 ; 23.9)	–	–
Mar/21 to Oct/21	–30.7 (–40.3 ; –19.5)*		–	–
Oct/21 to Jan/22	63.5 (–84.2 ; 1594.4)		–	–
Jan/22 to Feb/23	–19.0 (–26.5 ; –10.8)*		–	–
Mar/20 to Nov/20	–	–	–15.1 (–20.2 ; –9.7)*	
Nov/20 to Mar/21	–	–	23.8 (7.7 ; 42.2)*	
Mar/21 to Jun/21	–	–	–15.1 (–33.1 ; 7.8)	–6.2 (–10.8 ; –1.3)*
Jun/21 to Sep/21	–	–	6.7 (–26.4 ; 54.8)	
Sep/21 to May/22	–	–	–18.3 (–27.7 ; –7.8)*	
May/22 to Feb/23	–	–	1.5 (–4.7 ; 8.1)	
Ribeirão Preto				
Mar/20 to Jul/20	121.2 (24.1 ; 294.5)*		–	–
Jul/20 to Nov/20	-35.7 (-58.8 0.4)		–	–
Nov/20 to Mar/21	67.3 (13.6 ; 146.2)*	–0.1 (–23.1 ; 29.7)	–	–
Mar/21 to Oct/21	-30.6 (-40.0 ; -19.7)*		–	–
Oct/21 to Jan/22	59.3 (-92.2; 3142.5		–	–
Jan/22 to Feb/23	-16.6 (-24.2 ; -8.1)*		–	–
Mar/20 to Dec/20	–	–	–9.3 (–14.3 ; –4)*	
Dec/20 to Mar/21	–	–	14.3 (–14.3 ; 52.5)	3.4 (–6.2 ; –0.6)*
Mar/21 to Feb/23	–	–	–3.2 (–4.4 ; –2)*	
Santos				
Mar/20 to May/20	185.9 (-4.4; 755.0)		–	–
May/20 to Sep/20	-31.4 (-50.6 ; -4.8)*		–	–
Sep/20 to Mar/21	35.7 (16.8 ; 57.6)*	–5.4 (–18.7 ; 10.2)	–	–
Mar/21 to Oct/21	-36.2 (-45.0 ; -25.9)*		–	–
Oct/21 to Jan/22	102.5 (-57.5; 865.0		–	–
Jan/22 to Feb/23	-22.6 (-30.4 ; -13.9)*		–	–
Mar/20 to Jul/20	–	–	–24.7 (–36.8 ; –10.3)*	
Jul/20 to Apr/21	–	–	7.0 (2.3 ; 12)*	–7.6 (–10 ; –5.2)*
Apr/21 to Feb/23	–	–	–9.7 (–11.8 ; –7.6)*	
São José do Rio Preto				
Mar/20 to Jul/20	150.3 (12.9 ; 455.1)*		–	–
Jul/20 to Nov/20	-26.6 (-54.1; 17.2)		–	–
Nov/20 to Mar/21	58.4 (3.2 ; 143.0)*	1.8 (–23.2 ; 35.0)	–	–
Mar/21 to Oct/21	-30.0 (-41.6 ; -16.2)*		–	–
Oct/21 to Jan/22	60.3 (-93.4; 3769.8)		–	–
Jan/22 to Feb/23	-17.8 (-26.0 ; -8.7)*		–	–
Mar/20 to Dec/20	–	–	–5.9 (–13 ; 1.9)	
Dec/20 to Mar/21	–	–	17.2 (–24.5 ; 82)	–8.1 (–11.9 ; –4.1)*
Mar/21 to Feb/23	–	–	–11.8 (–13.3 ; –10.2)*	
Sorocaba				
Mar/20 to Jun/20	125.9 (-13.8 ; 491.6)		–	–
Jun/20 to Oct/20	-24.7 (-54.8 ; 25.6)		–	–
Oct/20 to Mar/21	63.2 (25.8 ; 111.7)*	–1.3 (–21.8 ; 24.4)	–	–
Mar/21 to Oct/21	-32.8 (-42.4 ; -21.8)*		–	–
Oct/21 to Jan/22	62.8 (-87.2 ; 1976.5)		–	–
Jan/22 to Feb/23	-20.1 (-27.5 ; -11.8)*		–	–
Mar/20 to Dec/20	–	–	–10.8 (–16.5 ; –4.8)*	
Dec/20 to Mar/21	–	–	29.8 (–9.3 ; 85.7)	
Mar/21 to Jun/21	–	–	–17.4 (–37.7 ; 9.7)	–6.2 (–12.4 ; 0.6)
Jun/21 to Oct/21	–	–	11.3 (–19.8 ; 54.2)	
Oct/21 to May/22	–	–	–23.5 (–37.5 ; –6.4)*	
May/22 to Feb/23	–	–	0.5 (–8.8 ; 10.8)	

*Statistically significant changes; MPC: Monthly percentages of variation; MAPC: Mean annual percentage change; CI: Confidence Interval

Discussion

The analysis of the administrative regions of São Paulo reveals an association between socioeconomic factors, such as income, schooling, and municipal HDI, and the cumulative incidence, mortality, and lethality rates of COVID-19. In areas with a higher HDI, the spread of the disease was more intense, possibly due to greater testing capacity and population mobility, increasing the notification of cases[12-13].

However, the high mortality among the elderly can be attributed to immunosenescence, which compromises the immune system with advancing age, as well as to the high prevalence of chronic comorbidities, which aggravate the clinical picture during viral infections. Factors such as limited access to health care and inadequate living conditions also contribute to the greater vulnerability of this population[4-5,14].

Analysis of socioeconomic inequalities highlights the crucial role of HDI in COVID-19 incidence and mortality rates. Cities with higher GDP per capita tend to be more mobile, resulting in a greater spread of disease[12]. On the other hand, municipalities with a lower HDI have higher mortality rates associated with a lack of access to quality health services and greater exposure to vulnerable groups[15]. Regions with higher population density and HDI also showed higher numbers of cases and deaths, especially among elderly men over 80[16].

The different phases of the pandemic in the regions of São Paulo have directly influenced trends in cumulative incidence, mortality, and lethality rates, being affected by socioeconomic and health indicators and new variants of the virus. The politicization of pandemic management in Brazil, especially the lack of adherence by some municipal managers to state technical standards, also impacted these results[17].

In Brazil, three significant pandemic waves have affected incidence, mortality, and lethality rates in São Paulo's elderly population. The increase in these indicators in the first wave, from February to July 2020, resulted from the emergence of COVID-19, the absence of effective treatments and vaccines, and the limited reorganization of health services. The second wave, driven by the Gamma variant, which occurred from November 2020 to April 2021, caused a significant increase in cases and deaths in the state and country. The third wave, associated with the Omicron variant and predominant from December 2021 to May 2022, increased the incidence of the disease. Still, due to widespread vaccination, mortality rates did not rise to the same extent[18].

Vaccination, which began in São Paulo in January 2021, was the primary strategy to control the critical phase of the pandemic. Based on the regional distribution of immunizers and the population's adherence to the vaccine, a significant reduction in mortality from the disease was observed among people over 80 years of age, one of the first groups to be vaccinated, as of the sixth epidemiological week of 2021[19].

In this context, there has been a relationship between the socioeconomic vulnerability of the elderly and COVID-19 lethality. An analysis of social indicators and policies for dealing with the pandemic in countries in America, Europe, Asia, and Oceania showed that the proportion of the elderly population aged over 70 had the highest mortality and lethality rates. They also indicated that countries that have strengthened public policies on physical distancing have had a lower incidence of the disease[20].

Latin America and the Caribbean stand out as regions with high levels of social inequality, where the population lacks essential goods and services, such as adequate access to health, food and housing, facing financial insecurity and discrimination. These conditions have directly influenced the outcome of COVID-19, especially among the most vulnerable populations[21].

In the critical phase of the pandemic, individuals in socio-economic vulnerability were forced to continue their work activities to ensure their livelihoods due to the absence of timely financial aid from the federal government. Informal and essential services workers, who could not opt for home office, were more exposed to the virus. In addition, the restrictive measures have increased unemployment, leading

many families to rely on the pensions of their elderly members[22]. The inability to carry out activities remotely has meant that many older people are exposed to the virus as they commute to work daily using public transport and are susceptible to contamination due to the nature of their jobs[23-24].

In this scenario, individuals in socioeconomic vulnerability faced difficulties in maintaining physical distancing during the critical phase of the pandemic due to housing characteristics such as overcrowding. These difficulties included underemployment and unequal access to health services, both in terms of diagnosis and treatment of the disease[23].

In 2021, Brazil ranked second worldwide in COVID-19 deaths, with a strong correlation with socioeconomic factors. Mortality rates were associated with social vulnerability, with income having a more significant impact than comorbidities such as immunodeficiency. Mortality was higher among the elderly, especially in the North, where access to education and income is limited. Individuals with low levels of schooling, mainly illiterate people, had a high risk of death due to the difficulty in understanding health information[25].

Regarding income, it was observed that in Brazil, the higher the relative income, the lower the chance of death from COVID-19[22]. Similarly, in the United States, mortality associated with the disease was higher in the low-income population, especially among black residents and people over 65[26].

In addition to the typical characteristics of this age group and the intrinsic factors of each individual, the socio-economic indicators mentioned (HDI, schooling, and income) can contribute to the increase in the incidence, mortality, and lethality of COVID-19 in the elderly population in different locations, presenting different intensities, as with other infectious diseases.

Study limitations

The study has limitations, such as potential inconsistencies in the information collected from publicly accessible electronic databases due to underreporting of the disease. In addition, the use of the 2010 census may have influenced the results. However, these limitations did not compromise the reliability of the results, which showed an association between schooling, income, and HDI and the incidence, mortality, and lethality of COVID-19 in the elderly population.

Contributions to practice

Identifying the association between socioeconomic indicators and COVID-19 outcomes in the elderly population highlights the need for individualized and integrated approaches in developing health promotion and disease prevention actions. In this way, the creation of programs aimed at health education and facilitated access to health services can mitigate the effects of social determinants on the health of this population group, especially in the face of a health emergency.

Conclusion

An association was found between income, schooling, and the municipal human development index and the cumulative incidence, mortality, and lethality rates for COVID-19 in the elderly population of São Paulo — Brazil, showing the influence of socioeconomic indicators on the health of the elderly.

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Authors´ contribution

Conception and design or analysis and interpretation of data; drafting of the manuscript or relevant critical revision of the intellectual content; final approval of the version to be published; agreement to be responsible for all aspects of the manuscript being

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