Social inequalities and the pandemic of COVID-19: the case of Rio de Janeiro

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ABSTRACT

Background The novel coronavirus (SARS-CoV-2) is a global pandemic. The lack of protective vaccine or treatment led most of the countries to follow the flattening of the infection curve with social isolation measures. There is evidence that socioeconomic inequalities have been shaping the COVID-19 burden among low and middle-income countries. This study described what sociodemographic and socioeconomic factors were associated with the greatest risk of COVID-19 infection and mortality and how did the importance of key neighbourhood-level socioeconomic factors change over time during the early stages of the pandemic in the Rio de Janeiro municipality, Brazil.

Methods We linked socioeconomic attributes to confirmed cases and deaths from COVID-19 and computed age-standardised incidence and mortality rates by domains such as age, gender, crowding, education, income and race/ethnicity.

Results The evidence suggests that although age-standardised incidence rates were higher in wealthy neighbourhoods, age-standardised mortality rates were higher in deprived areas during the first 2 months of the pandemic. The age-standardised mortality rates were also higher in males, and in areas with a predominance of people of colour, which are disproportionately represented in more vulnerable groups. The population also presented COVID-19 'rejuvenation', that is, people became risk group younger than in developed countries.

Conclusion We conclude that there is a strong health gradient for COVID-19 death risk during the early stages of the pandemic. COVID-19 cases continued to move towards the urban periphery and to more vulnerable communities, threatening the health system functioning and increasing the health gradient.

INTRODUCTION

The novel coronavirus (SARS-CoV-2) that causes the COVID-19 was identified in China in December 2019.[1] The virus had a high speed of transmission by human-to-human contact. In places with health services, the case fatality rate varied around 1%–3%.[2] The clinical evidence so far indicates that the evolution towards a severe or critical infection is more often in older adults and people with chronic comorbidities, such as hypertension, diabetes, cardiovascular-metabolic diseases and other respiratory diseases.[3] Globally, up to now, there were over 107.38 million cases and 2.38 million deaths from COVID-19.[4]

Socioeconomic inequalities can shape individuals' exposure and susceptibility to COVID-19. Without either a protective vaccine or effective treatment, the individual exposure risk is mediated solely by their ability to keep social distancing. This ability can be, in turn, affected by material conditions and infrastructure of their households and neighbourhoods, for example, overcrowded households and access to drinking water. Furthermore, the loss of income due to business closures may disproportionately affect individuals who have informal jobs. In their turn, COVID-19 susceptibility is influenced by chronic comorbidities that follow a pattern motivated by social disparities (eg, household income, occupation, education, wealth) that disproportionately affects some segments of society (eg, people of colour, immigrants).[5]

The COVID-19 epidemic is already showing an unequal burden distribution among populations. For instance, Chen *et al*[6] have evidenced a health gradient in the New York municipality. They have shown that people from areas with over 20% of households living in poverty conditions had a 44% more risk of being infected than people from areas where households' poverty conditions were less than 5%. Similar risk disparities occurred in areas with a majority of people of colour, a predominance of low-income households and miserable quality habitations (overcrowded households). In Scotland, people living in the most deprived areas were 2.3 times more likely to die by COVID-19 than those living in the least deprived ones.[7] In England, the mortality rate was 55 deaths for 100 000 people in the most deprived areas, compared with 25 in the wealthiest ones.[8] Besides, men of colour were four times more likely to die by COVID-19 than white men.[9]

Latin America is the most unequal region in the world, and Brazil is one of the more unequal countries in terms of *per capita* income.[10] During the first 2 months of the epidemic, Brazil had over 340 000 confirmed cases and 22 000 deaths from COVID-19, and Rio de Janeiro had over 20 161 confirmed cases and 2520 deaths.

This study's objective is to describe what sociodemographic and socioeconomic factors were associated with the greatest risk of COVID-19 infection and mortality and how did the importance of key neighbourhood-level socioeconomic factors change over time during the early stages of the pandemic in the Rio de Janeiro municipality, Brazil.

METHODS

Data

We obtained publicly available data of COVID-19 at the individual level from the Brazilian Center of Health Surveillance Strategic Information /Health

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Ministry. The database contained individual-level information about notification date and age (aggregated by 20-year windows, 0–19, 20–39, 40–59 and 60+), gender (women, men) and the neighbourhoods of only confirmed cases and deaths. Once the available data about positive tested people for COVID-19 routinely did not include individual-level socioeconomic information in health surveillance system data, we opted to link this information with socioeconomic census area in the most disaggregated geographic level (neighbourhood level). We used the geocoded health records to link them to socioeconomic attributes of Rio de Janeiro municipality imported from the Brazilian Demographic Census 2010 data. Four conceptual domains were considered relevant to characterising socioeconomic issues: crowding (average number of bathrooms by the permanent resident, measured as bathroom per person), education (% of illiteracy of neighbourhood residents from 10 to 14 years old), income (annual household *per capita* income as minimum wage fraction, 2010 R$510 current) and race/ethnicity (% of black or brown self-declared neighbourhood residents).

Statistical methodology

We computed crude and standardised incidence and mortality rates (per 100 000 people), calculated as the number of cases/deaths from COVID-19 by the total population exposed to the risk, respectively. Rates were standardised by age using the age distribution of Rio de Janeiro municipality as reference. We used the generalised linear Poisson model with the total population (log10 transformed) as an offset to estimate relative ratios and CIs. We also estimated the case fatality rate, calculated as the number of confirmed deaths divided by the number of confirmed cases. All analyses were performed in the R software V.3.6.3 (http://www.r-project.org).

FINDINGS

Our completed sample contained information from 27 February to 23 May, with 17 423 cases and 2463 deaths. The first section describes how COVID-19 risks are distributed in terms of socioeconomic attributes during the entire period. The second one, by their turn, displays the COVID-19 epidemic trends among socioeconomic attributes over time.

The COVID-19 epidemic in early stages

Table 1 shows a descriptive epidemiological analysis of COVID-19 risks in Rio de Janeiro municipality. Demographic attributes were available either at the individual level (ie, age and gender) or at the neighbourhood level (ie, crowding, education, income and race/ethnicity). For analysis purposes, continuous variables available at the neighbourhood level were categorised using quartile cut-points based on the distribution of neighbourhood attributes in the Rio de Janeiro municipality.

Since socioeconomic status is highly correlated with life expectancy and age distribution, and COVID-19 risks are higher in older people, the analysis focused on age-standardised rates. As can be seen, crude and age-standardised rates are quite different in some situations showing that age is an essential confounder.

Among the demographic attributes, the difference in age-standardised incidence and mortality rate by gender was statistically significant. On average, women were nearly 0.73 times more likely to be infected or die with COVID-19 than men. However, the probability of dying when infected was higher for women, 18%. Additionally, all the risks associated with a COVID-19 event increased as long as people were getting older. For instance, people aged over 80 years had a mortality risk 12 times higher, and the case fatality rate almost five times higher than individuals aged 40–59 years.

All socioeconomic factors (crowding, education, income and race/ethnicity) were correlated with a higher age-standardised mortality rate, although the age-standardised incidence rate showed the opposing or mixed trend depending on which socioeconomic factors were considered. Although cases were proportionately concentrated in wealthy neighbourhoods, the deaths were frequently more observed in deprived areas. In more detail, people living in high-income neighbourhoods (highest quartile) had 37% more risk to be infected than low-income ones (lowest quartile), even though in low-income areas, they had 56% more risk to die (36.4 vs 57 per 100 000 persons). In neighbourhoods with the predominance of people of colour (highest quartile), there was 54% more risk to die (50.66 vs 32.92 per 100 000 persons) than in neighbourhoods with the predominance of white people (lowest quartile). This behaviour is similar if we consider the neighbourhoods with the worst habitation quality (overcrowded households) or lower educational levels of their residents.

Overall, considering death as the most undesirable health outcome, we found a strong gradient using COVID-19 death risk measures. These associations were not always monotonic in statistical terms. All socioeconomic attributes presented some monotonicity, although it was more robust for income and crowding. If otherwise, we consider the probability of dying when infected, the health gradient is also consistent, and monotonicity is even stronger than in the age-standardised mortality rate case.

COVID-19 epidemic trends over time

Figure 1 presents the trend of COVID-19 cases distribution by socioeconomic attributes. Results come from ecological analyses at the neighbourhood level.

The first epidemic weeks were concentrated in wealthy areas, but COVID-19 cases progressively tended to move towards the urban periphery and more vulnerable communities. Overall, graphs A–D display a tendency of decreasing in average income, education and the household quality of infected people. The health gradient tends to get stronger as the pandemic continues.

DISCUSSION

The complex social and economic structure that produces social inequalities might be associated with an unequal distribution of COVID-19 disease burden in the Rio de Janeiro municipality experience. This study assessed demographic and socioeconomic factors associated with risk exposure/susceptibility to infection/death from SARS-CoV-2 in the first 2 months of the pandemic.

Brazil's first COVID-19 case arrived by plane from a trip to Italy and circulated among the country's middle and upper classes, from 26 February (date of the first case) to early April, when it began to spread to the most economically deprived segments in Rio. Consequently, the early epidemic stages exhibit this unexpected reality where incidence risk for COVID-19 was greater in relatively wealthier areas, with relatively comfortable houses and well-educated neighbours.

Despite higher COVID-19 age-standardised incidence rate in wealthy areas, both age-standardised mortality rate and case fatality rate behaviour indicated a health gradient. In other words, as higher the levels of household *per capita* income and education, and the lower the poverty, the lower is the risk of dying of COVID-19. People living in deprived areas have a narrow range of options to protect their health. It is a reflection of an unequal

Table 1 COVID-19 risks by demographic and socioeconomic characteristics. Rio de Janeiro municipality, 27 February to 23 May 2020

Variables	Categ/Qi CP	Cases	Death	IR	MR	CFR	RIR (95% CI)	RMR (95% CI)	(Std)IR	(Std)MR	(Std)RIR (95% CI)	(Std)RMR (95% CI)
Gender	Men	9104	1046	307.59	35.34	0.11	1	1	370.11	418.69	1	1
	Women	8323	1417	247.66	42.16	0.17	0.81 (0.78 to 0.83)	1.19 (1.1 to 1.29)	265.17	307.2	0.72 (0.7 to 0.73)	0.73 (0.72 to 0.75)
Age	0–19	267	14	15.79	0.83	0.05	0.02 (0.01 to 0.02)	0 (0 to 0)	–	–	–	–
	20–39	5472	127	266.56	6.19	0.02	0.28 (0.27 to 0.3)	0.01 (0.01 to 0.02)	–	–	–	–
	40–59	6648	571	406.28	34.90	0.09	0.43 (0.41 to 0.46)	0.08 (0.08 to 0.09)	–	–	–	–
	60–79	3582	1107	455.95	140.91	0.31	0.49 (0.46 to 0.52)	0.34 (0.31 to 0.37)	–	–	–	–
	80+	1455	644	937.24	414.83	0.44	1	1	–	–	–	–
Crowding	Q1 <1.235	3162	571	178.75	32.28	0.18	1	1	294.81	54.79	1	1
	Q2 (1.235–1.357)	4136	672	237.20	38.54	0.16	1.33 (1.27 to 1.39)	1.19 (1.07 to 1.34)	317.33	52.32	1.08 (1.05 to 1.1)	0.95 (0.91 to 1.01)
	Q3 (1.357–1.577)	3433	491	258.53	36.98	0.14	1.45 (1.38 to 1.52)	1.15 (1.02 to 1.29)	262.92	39.65	0.89 (0.87 to 0.91)	0.72 (0.68 to 0.76)
	Q4 >1.577	6654	729	460.17	50.42	0.11	2.57 (2.47 to 2.69)	1.56 (1.4 to 1.74)	378.16	36.38	1.28 (1.26 to 1.31)	0.66 (0.63 to 0.7)
Education	Q1 <1.015	4456	488	407.53	44.63	0.11	1	1	298.26	30.4	1	1
	Q2 (1.015–1.547)	5837	763	340.63	44.53	0.13	0.84 (0.8 to 0.87)	1 (0.89 to 1.12)	404.3	50.25	1.36 (1.33 to 1.38)	1.65 (1.56 to 1.76)
	Q3 (1.547–2.364)	3876	619	241.29	38.53	0.16	0.59 (0.57 to 0.62)	0.86 (0.77 to 0.97)	293.94	48.86	0.99 (0.96 to 1.01)	1.61 (1.51 to 1.71)
	Q4 >2.364	3216	593	171.69	31.66	0.18	0.42 (0.4 to 0.44)	0.71 (0.63 to 0.8)	276.37	52.86	0.93 (0.91 to 0.95)	1.74 (1.64 to 1.85)
Income	Q1 <1.196	3516	691	173.12	34.02	0.20	1	1	280.29	57	1	1
	Q2 (1.196–1.595)	3801	587	229.57	35.45	0.15	1.33 (1.27 to 1.39)	1.04 (0.93 to 1.16)	315.53	52.47	1.13 (1.1 to 1.15)	0.92 (0.87 to 0.97)
	Q3 (1.595–2.624)	3090	433	291.10	40.79	0.14	1.68 (1.6 to 1.76)	1.2 (1.06 to 1.35)	266.25	36.83	0.95 (0.93 to 0.97)	0.65 (0.61 to 0.68)
	Q4 >1.571	4142	777	189.46	35.54	0.19	0.44 (0.42 to 0.46)	0.73 (0.66 to 0.81)	384.75	36.4	1.37 (1.34 to 1.4)	0.64 (0.6 to 0.68)
Race/ethnicity	Q1 <36.465	6408	677	469.90	49.64	0.11	1	1	362.25	32.92	1	1
	Q2 (36.465–49.458)	3710	516	296.45	41.23	0.14	0.63 (0.61 to 0.66)	0.83 (0.74 to 0.93)	320.94	44.36	0.89 (0.87 to 0.9)	1.35 (1.27 to 1.43)
	Q3 (49.458–57.55)	3911	613	229.46	35.97	0.16	0.49 (0.47 to 0.51)	0.72 (0.65 to 0.81)	336.22	57.76	0.93 (0.91 to 0.95)	1.75 (1.66 to 1.86)
	Q4 >57.55	3356	657	170.62	33.40	0.20	0.36 (0.35 to 0.38)	0.67 (0.6 to 0.75)	250.41	50.66	0.69 (0.68 to 0.71)	1.54 (1.45 to 1.63)

Categ/Qi CP, categories or quartile cut-points; CFR, case fatality rate; (Std)IR, age-standardised incidence rate; (Std)MR, age-standardised mortality rate; (Std)RIR, age-standardised relative incidence rate; (Std)RMR, age-standardised relative mortality rate.

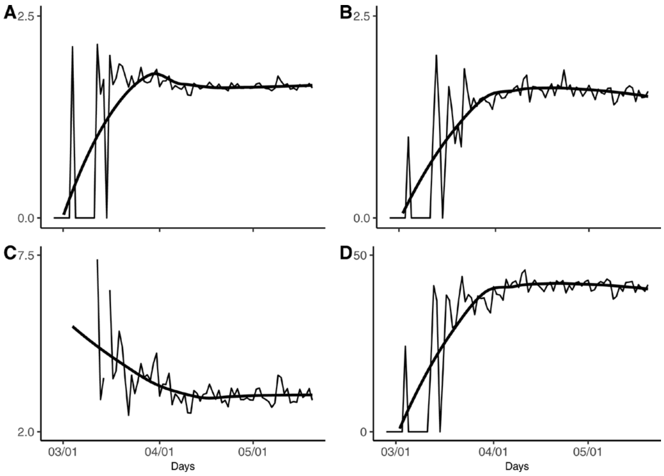

Figure 1 Mean value of (A) crowding, (B) education, (C) income, and (D) race/ethnicity computed at COVID-19 case individual over time. Rio de Janeiro municipality, 27 February to 23 May 2020. Black solid lines indicate locally estimated scatterplot smoothing (Loess) smoothed trend lines.

distribution of opportunities to improve socioeconomic status and contributes to the development of chronic diseases, such as hypertension, diabetes, cardiovascular-metabolic diseases and other respiratory diseases. These pre-existing conditions are risk factors to COVID-19 and therefore increase their susceptibility, which is confirmed by the higher risks of death in these deprived areas. What about the association between the age-standardised mortality rate and the areas with a predominance of people of colour? The health gradient may act against people of colour due to pre-existing medical conditions. That is, perhaps, because they are disproportionately represented in more vulnerable groups, for example, less educated, informal workers, people living in marginalised urban areas.

The evidence shows statistically significant differences in risks by age groups. As expected, people over 80 years old were more likely to become infected and die than any other age group. The novelty in the perspective of international comparison is the so-called COVID-19 'rejuvenation'. The age group of 60–79 years old had a percentage of fatality cases only compared with people more than 80 years old in Spain, Italy, China and South Korea.[4] It stresses the relatively poor pre-existing health condition (and then higher COVID-19 susceptibility) of people from Rio compared with those countries (it can also reflect differences in the scale of testing among countries). Rio de Janeiro also presented statistically significant differences in age-standardised mortality rates unfavourable to males. This is consistent with a recent study that supported that men with COVID-19 are more at risk for worse outcomes and death than women, independent of age.[11]

Our data exhibited a changing pattern in the burden of SARS-CoV-2 from infecting higher to lower socioeconomic status individuals over time. This spread of SARS-CoV-2 in the early stages of the pandemic suggested that the mortality rate would increase significantly shortly, which happened. The poor pre-existing health conditions among low socioeconomic status individuals were an important mechanism to reinforce the health gradient.

There are significant limitations to this study. Part of them attributed the geolocation and the most important of them due to COVID-19 epidemic data bias.

The geolocation methodology works better when the population is reasonably homogeneous over geographic areas regarding socioeconomic composition. It is not the case in Rio de Janeiro. The best option would be to link socioeconomic data for census sector levels, but this possibility was not available. Another limitation is the availability of only outdated socioeconomic information, belonging to the last Brazilian census, in 2010. Besides, due to municipal health surveillance authorities' failures, there have been notification mistakes to compute the address information, vital to the geolocation and linking of socioeconomic attributes.

The number of confirmed cases is not the total number of people who have been infected; the latter is supposedly much higher. Due to the low capacity for testing people during the early stages of the pandemic, the Brazilian Ministry of Health has prioritised testing on high-risk groups, such as hospitalised patients with symptoms of COVID-19 and health workforce members. The impressive quantity of COVID-19 cases under-reported made the official numbers numerically not representative of the total cases in Brazil. Nevertheless, since these tests were made available in the first 2 months of the pandemic exclusively in the public health system, we do not believe that the reported cases had a significant socioeconomic bias.

What is already known on this subject

- Socioeconomic inequalities can shape individuals' exposure and susceptibility to COVID-19. Without either a protective vaccine or effective treatment, the individual exposure risk is mediated solely by their ability to keep social distancing. This ability can be, in turn, affected by material conditions and infrastructure of their households and neighbourhoods. Furthermore, the loss of income due to business closures may disproportionately affect individuals who have informal jobs. In their turn, COVID-19 susceptibility is influenced by chronic comorbidities that follow a pattern motivated by social disparities (eg, household income, occupation, education, wealth) that disproportionately affects some segments of society (eg, people of colour, immigrants).

What this study adds

- This study described what sociodemographic and socioeconomic factors were associated with the greatest risk of COVID-19 infection and mortality and how did the importance of key neighbourhood-level socioeconomic factors change over time during the early stages of the pandemic in the Rio de Janeiro municipality, Brazil. The evidence suggests that although age-standardised incidence rates were higher in wealthy neighbourhoods, age-standardised mortality rates, (Std)MR, were higher in deprived areas during the first 2 months of the pandemic. The (Std)MR were also higher in males, and in areas with a predominance of people of colour, which are disproportionately represented in more vulnerable groups. The population also presented COVID-19 'rejuvenation', that is, people became risk group younger than in developed countries. We conclude that there is a strong health gradient for COVID-19 death risk during the early stages of the pandemic. COVID-19 cases continued to move towards the urban periphery and to more vulnerable communities, threatening the health system functioning and increasing the health gradient.

CONCLUSION

This article shows that social inequalities are associated with COVID-19 burden distribution in Rio. There was a dangerous trend of cases moving towards the urban periphery and more vulnerable communities. The unfavourable pre-existing health risk condition (comorbidities) in these areas pointed out the necessity of fast interventions to protect people by reducing COVID-19 risk exposure.

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REFERENCES

1 Oliveira WKde, Duarte E, França GVAde, *et al*. How Brazil can hold back COVID-19. *Epidemiol Serv Saude* 2020;29:e2020044.
2 WHO. *Coronavirus disease 2019 (covid-19): situation report (NO. 45*. World Health Organization, 2020.
3 Yang J, Zheng Y, Gou X. Prevalence of comorbidities in the novel Wuhan coronavirus (covid-19) infection: a systematic review and meta-analysis. *International Journal of Infectious Diseases* 2020.
4 Max Roser EO-O, Ritchie H, Hasell J. Coronavirus pandemic (covid-19). *Our World in Data* 2020.
5 Berkman LF, Kawachi I, Glymour MM. *Social epidemiology*. Oxford University Press, 2014.
6 Chen JT, Waterman PD, Krieger N] . *"COVID-19 and the unequal surge in mortality rates in Massachusetts, by city/town and ZIP Code measures of poverty, household crowding, race/ethnicity, and racialized economic segregation." Harvard Center for Population and Development Studies*. Harvard Center for Population and Development Studies, 2020and.
7 NRS. *Deaths involving coronavirus (covid-19) in Scotland (NO. week 16*. National Record of Scotland, 2020.
8 ONS, 2020a. *Deaths involving covid-19 by local area and socioeconomic deprivation: deaths occurring between 1 March and 17 April*. England: Office for National Statistics, 2020.
9 ONS, 2020b. *Coronavirus (covid-19) related deaths by ethnic group, England and Wales: 2 March 2020 to 10 April*. England: Office for National Statistics, 2020.
10 UN. *Human development report 2019. beyond income, beyond averages, beyond today: inequalities in human development in the 21st century (United nations development programme No. 1*. United Nations, 2019.
11 Jin J-M, Bai P, He W, *et al*. Gender differences in patients with covid-19: focus on severity and mortality. *Front Public Health* 2020;8:152.