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SPECIAL ARTICLE / *ARTIGO ESPECIAL*

Higher mortality during the COVID-19 pandemic in socially vulnerable areas in Belo Horizonte: implications for vaccine prioritization

Maior mortalidade durante a pandemia de COVID-19 em áreas socialmente vulneráveis em Belo Horizonte: implicações para a priorização da vacinação

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ABSTRACT: ***Objective*:** To assess mortality during the COVID-19 pandemic according to social vulnerability by areas of Belo Horizonte (BH), aiming at strategies for vaccination. ***Methods*:** Ecological study with mortality analysis according to census tracts classified by the Health Vulnerability Index, a composite indicator that includes socioeconomic and sanitation variables. Deaths by natural causes and by COVID-19 were obtained from the "Mortality Information System", between the 10th and 43rd epidemiological weeks (EW) of 2020. Excess mortality was calculated in a time series model, considering observed and expected deaths per EW, between 2015 and 2019, per census tracts. Mortality rates (MR) were calculated and age-standardized using population estimates from the 2010 census, by the Brazilian Institute of Geography and Statistics (IBGE). ***Results*:** Excess mortality in BH was 16.1% (n = 1,524): 11, 18.8 and 17.3% in low, intermediate and high vulnerability areas, respectively. The differences between observed and expected age-standardized MR by natural causes were equal to 59/100,000 inhabitants in BH, increasing from 31 to 77 and 95/100,000 inhabitants in the areas of low, intermediate and high vulnerability, respectively. There was an aging gradient in MR by COVID-19, ranging from 4 to 611/100,000 inhabitants among individuals aged 20–39 years and 75+ years. The COVID-19 MR per 100,000 older adults (60+ years) was 292 in BH, increasing from 179 to 354 and 476, in low, intermediate and high vulnerability areas, respectively. ***Conclusion*:** Inequalities in mortality, particularly among older adults, combined with the limited supply of doses, demonstrate the importance of prioritizing socially vulnerable areas during vaccination against COVID-19.

***Keywords*:** Mortality. Aged. Coronavirus infections. Social inequity. Vaccines.

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RESUMO: ***Objetivo*:** Avaliar a mortalidade por áreas de Belo Horizonte (BH) durante a pandemia de COVID-19 conforme a vulnerabilidade social, visando a uma estratégia de vacinação. ***Métodos*:** Estudo ecológico com análise de mortalidade, segundo setores censitários classificados pelo índice de vulnerabilidade da saúde, composto de indicadores de saneamento e socioeconômicos. Óbitos por causas naturais e COVID-19 foram obtidos do Sistema de Informação sobre Mortalidade, entre a 10ª e a 43ª semanas epidemiológicas (SE) de 2020. Calculou-se o excesso de mortalidade por modelo de série temporal, considerando-se as mortes observadas por SE entre 2015 e 2019, por setor censitário. Taxas de mortalidade (TM) foram calculadas e padronizadas por idade com base em estimativas populacionais do Instituto Brasileiro de Geografia e Estatística (IBGE). ***Resultados*:** Houve 16,1% (n = 1.524) de excesso de mortalidade em BH: 11, 18,8 e 17,3% nas áreas de baixa, média e elevada vulnerabilidade, respectivamente. As diferenças entre TM observadas e esperadas por causas naturais, padronizadas por idade, foi igual a 59/100 mil habitantes em BH, aumentando de 31 para 77 e 95/100 mil, nas áreas de baixa, média e elevada vulnerabilidade, respectivamente. Houve gradiente de aumento com a idade nas TM por COVID-19, variando de 4 a 611/100 mil habitantes entre as idades de 20–39 anos e 75+ anos. A TM por COVID-19 por 100 mil idosos (60+ anos) foi igual a 292, aumentando de 179 para 354 e 476 nos setores de baixa, média e elevada vulnerabilidade, respectivamente. ***Conclusão*:** Desigualdades na mortalidade, mesmo entre idosos, aliadas à baixa oferta de doses, demonstram a importância de priorizar áreas socialmente vulneráveis durante a vacinação contra COVID-19.

***Palavras-chave*:** Mortalidade. Idosos. Infecções por coronavírus. Iniquidade social. Vacinas.

INTRODUCTION

Brazil is one of the countries with the highest number of COVID-19 cases and deaths in the world, even though COVID-19 mortality is underreported by at least 20%[1]. Belo Horizonte, the sixth largest capital city in the country, with 2,423,737 million inhabitants, had 63,387 cases and 1,877 deaths from COVID-19 reported by December 2020[2]. Through continuous monitoring of the disease, the municipality was a pioneer in establishing restrictive measures to contain the pandemic in Brazil and promptly started the vaccination process[3].

Having determined the efficacy and safety of the different vaccines available for emergency use, mass vaccination of the population is the next strategy for coping with COVID-19, in order to reduce mortality and morbidity due to the disease[4,5]. However, until the production of vaccines reaches the levels required to meet all demand, it is recommended the implementation of staggered vaccination, with criteria for prioritizing groups in each country[6]. The Brazilian government has proposed that the allocation of vaccines against COVID-19 be aimed to preserving the functioning of health services, protecting individuals at greater risk of severe forms and death, followed by preserving the functioning of essential services and the protection of individuals with a higher risk of infection[7].

The Ministry of Health's National Immunization Program (PNI, in the Brazilian acronym) is based on allocating vaccines to target populations[8]. However, the distribution of doses occurs as they are made available. In this moment of dose restriction for COVID-19,

one must discuss the criteria for prioritizing vaccination in the groups considered priority and beyond, in order to organize the logistics of vaccination for the Brazilian population, optimizing existing resources.

Studies in Brazil and across the world have shown that the COVID-19 pandemic hit people unevenly, with a greater number of cases, hospitalizations and deaths in greater social vulnerability groups[9-11]. Since 1998, after recognizing that the risk of health loss is associated with worse environmental and social conditions, the Municipal Health Secretariat of Belo Horizonte (SMS-BH) has worked with a composite indicator, called the health vulnerability index (HVI), to adopt public policies and allocate resources to the most vulnerable territories of the city[12,13].

Aiming to contribute with the discussion about the next stages of vaccination in the city of Belo Horizonte, this article tested the hypothesis that the population residing in areas of greater social vulnerability may have experienced higher mortality in the COVID-19 pandemic.

METHODS

This is an ecological study comparing the profile of mortality by natural causes and by COVID-19 between March and October 2020—from the 10th to the 43rd epidemiological week (EW)—by group of census tracts in Belo Horizonte, classified and grouped according to the HVI.

All deaths by natural causes of residents in the municipality notified to the Mortality Information System (SIM) of the Ministry of Health were selected and qualified[14]. Code B34.2, coronavirus infection of unspecified site, from the Tenth Revision of the International Classification of Diseases (ICD-10), was temporarily defined as the underlying cause of death by COVID-19, until the SIM was changed to incorporate the new code for COVID-19 recommended by the World Health Organization (WHO)[15,16]. Population estimates by census tract were obtained from the Brazilian Institute of Geography and Statistics (IBGE)[17].

The HVI in Belo Horizonte, updated in 2012 based on data from each census tract in the 2010 Demographic Census, is composed of five indicators: percentage of basic sanitation, garbage collection and water supply, literacy level, and skin color[13]. In 2010, Belo Horizonte had 2.4 million residents in 3,830 census tracts grouped, according to the HVI, into four health risk categories: low (1330 tracts), medium (1,460 tracts), high (737 tracts) and very high risk (303 tracts)[13]. As tracts of very high risk represent a small portion of the population, this analysis was carried out by groups of low, medium and high vulnerability, the latter resulting from the sum of tracts of high and very high vulnerability.

To obtain the denominator of mortality rates, the population of Belo Horizonte in 2020 was estimated for the three health vulnerability groups, based on 2010 Census estimates. The differences in age structure by HVI observed after the construction of age pyramids with data from the 2010 census were taken into account (Figure 1). First, the specific population growth rate by age and sex for the entire municipality was calculated,

based on a population projection previously published[18]. These growth rates were then applied to the same age and sex strata for each of the three groups of HVI (low, medium and high), leading to the population estimate in 2020. Differentiation by sex was considered only for the population estimate, as the mortality analyses were performed for both sexes.

The expected number of deaths by natural causes for each HVI category was estimated by applying the autoregressive integrated moving average (ARIMA) model[19] to the observed number of deaths from each EW in 2015 to the 9th EW of 2020, only then

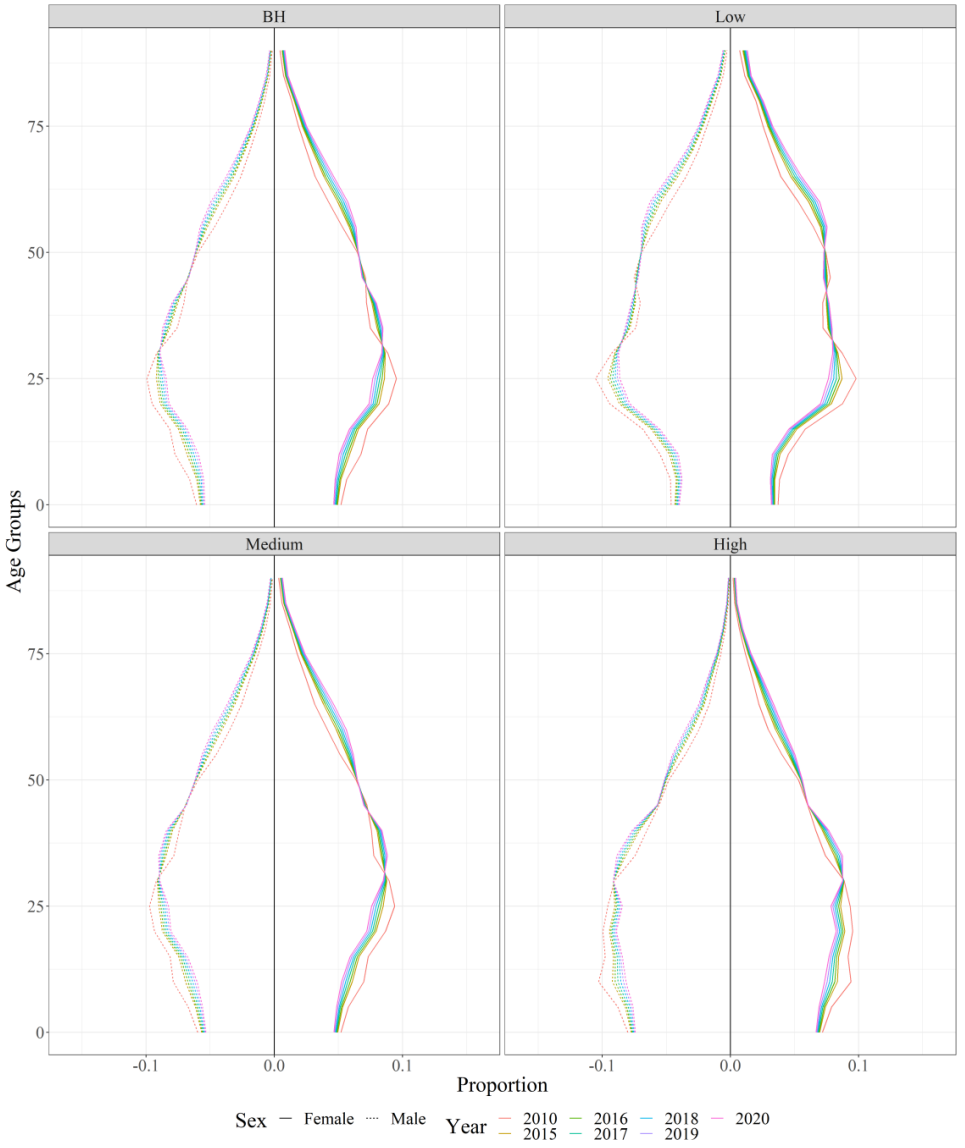

Figure 1. Age pyramids in the city of Belo Horizonte and in areas classified by health vulnerability, from 2010 to 2020.

projecting the number of deaths between the 10th and the 43rd EWs of 2020. Excess deaths, by EW and HVI, was calculated as the difference between the moving average of the last three weeks of observed and expected number of deaths in each EW. The estimate of expected mortality rates by natural causes and by COVID-19 assumed that the projected (expected) number of deaths in 2020, between the 10th and the 43rd EWs, had the same distribution by age recorded in 2019.

The age-standardized mortality rates, as well as observed and expected, considered cases registered by the HVI for five age groups: all ages; 20–39, 40–59, 60–74 and 75 and over. The direct method for age standardization used the population of Belo Horizonte in 2020 as a reference. The standardized mortality ratio (SMR, observed mortality divided by expected mortality) and the differential mortality (observed mortality minus expected mortality) were also calculated.

The research was evaluated and approved by the Research Ethics Committee of Universidade Federal de Minas Gerais (UFMG) and by the SMS-BH, per the Certificate of Presentation for Ethical Appreciation (CAAE) nº 39778720.4.3001.5140.

RESULTS

The population of Belo Horizonte was estimated by the 2010 Census at 2,370,609 inhabitants and projected to reach 2,423,737 inhabitants in 2020, with a similar percentage distribution by sex and HVI, and with a slightly higher mean age, as expected for the period. In 2020, most of the population (39.8%) lived in the tracts of medium vulnerability, while 34.8 and 25.4% lived in the tracts of low and high health vulnerability, respectively. Women were the majority, 53% in the municipality, with proportions varying from 52, 53 and 55% between the tracts of high, medium and low vulnerability. As expected, age in the most vulnerable areas was lower. In the whole municipality, the average age in 2020 was 39 years (standard deviation – SD = 21), ranging from 43 ± 22 years, 38 ± 21 years and 33 ± 21 years, in low, medium and high vulnerability tracts, respectively.

In 2020, the number of deaths by natural causes reported in the municipality was 16.1% higher than expected, varying from 11% in the low vulnerability tracts to 18.8 and 17.3% in the medium and high vulnerability tracts, respectively. The standardized mortality ratio showed an increase of 16.1% in deaths by natural causes in Belo Horizonte, with increases of 11.1, 18.8 and 19.4% in the low, medium and high vulnerability tracts. While the crude mortality rates did not vary greatly according to the HVI and were lower in the tracts with high HVI (424, 455 and 387 per 100,000 inhabitants in the tracts with low, medium and high HVI, respectively – data not shown), the age-standardized mortality rates by natural causes showed an increasing risk of death as social vulnerability increases (Table 1). This occurs for both the expected and observed values, revealing the highest mortality in tracts of high vulnerability, but always higher for observed numbers because of the impact of the pandemic.

This trend was also seen in the differences between expected and observed mortality rates, suggesting that disparities in mortality between the HVI groups were exacerbated by the pandemic. During the study period, for every 100,000 inhabitants, there was an excess of 59 deaths in the municipality, varying from 31 to 95 between the low and high vulnerability tracts (Table 1). Also during this period, there were 1,524 deaths by COVID-19 in Belo Horizonte. The age-standardized mortality rate by COVID-19 was 63 per 100,000 inhabitants, varying from 35 to 78 and 105 per 100,000 inhabitants as health vulnerability increases (Table 1).

Figure 2 shown the overlap between the moving averages of excess deaths by natural causes and deaths by COVID-19 in the period, both for the whole municipality and for the population living in census tracts classified by each group of HVI. The beginning of the pandemic is seen in the 10th EW, with a peak between the 25th and 35th EWs. The biggest difference between the lines of mortality by natural causes and by COVID-19 at the peak of the pandemic (EW 30) stands out in the group of higher vulnerability.

The analysis by age groups shows a consistent increase in the observed mortality rate compared to expected numbers, with greater differences for deaths over 60 years of age and in the most vulnerable tracts (Figure 3).

The mortality rate by COVID-19 per 100,000 older adults (60+ years) was 292, increasing from 179 to 354 and 476 in the low, medium and high vulnerability tracts, respectively. Table 2 details the aspects presented in Figure 3. In Belo Horizonte, the values of the SMR (standardized mortality ratio) show little or no impact of the pandemic on mortality among the youngest (99.9%), with an increase of 16.4, 23.1 and 15.5% in individuals aged 40–59 years, 60–74 and 75+ years old. If the results are observed by groups of

Table 1. Distribution of mortality by natural causes and COVID-19 in Belo Horizonte, per groups of health vulnerability, between the 10th and the 43rd epidemiological weeks of 2020.

Mortality indicator	Belo Horizonte	HVI		
		Low	Medium	High
Expected deaths (N)	8,916	3,218	3,697	2,039
Observed deaths (N)	10,356	3,573	4,391	2,392
Excess deaths (%)	16.1	11	18.8	17.3
Expected mortality rate*	368	281	411	491
Observed mortality rate*	427	312	489	587
Differential mortality (observed – expected)	59	31	77	95
Standardized mortality *ratio* (observed/expected)	116.1	111	118.8	119.3
Deaths by COVID-19 (N)	1,524	408	699	417
Mortality rate* by COVID-19	63	35	78	105

*age-standardized rates, per 100,000 inhabitants; HVI: health vulnerability index.

HVI, among the youngest (20–39 years) the observed mortality was higher than expected only in the tracts of low vulnerability, with an inversion of this pattern as age increases. However, when comparing SMR of the low HVI to the SMR of medium and high HVI in all other age groups, the impact of the pandemic is clearly greater in the medium and high vulnerability tracts, when compared to low vulnerability tracts. For older adults aged

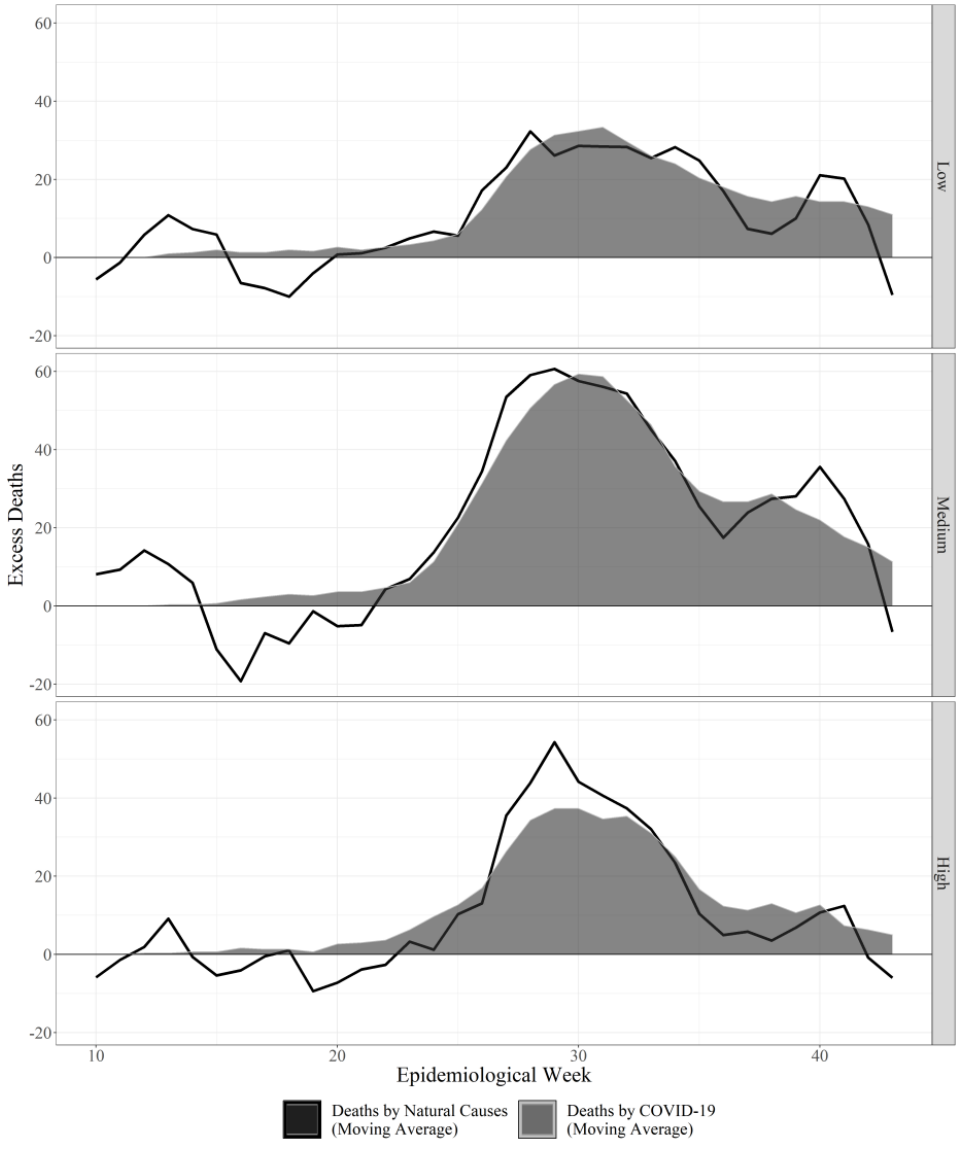

Figure 2. Representation of the moving average of excess deaths by natural causes and by COVID-19, in Belo Horizonte, between the 10th and 43rd epidemiological weeks of 2020.

60–74 years, for example, the SMR varied 116, 122 and 131.7% in areas of low, medium and high HVI, respectively.

The disparities in mortality by age group and by HVI are even more evident when analyzing the difference in the observed versus expected rate. It was null only for individuals aged 20–39 years (-0.02), increasing to 35, 184 and 562 per 100,000 inhabitants among the aged 40 and 59, 60 and 74 and 75+, respectively. For the latter, in general, the differences between the HVI groups are more accentuated when the tracts with low HVI are compared to tracts with medium or high HVI. For example, among middle-aged adults (40–59 years), the increase in observed mortality rate compared to the expected rate is equal to 35 per 100,000 inhabitants in Belo Horizonte, and 13, 45 and 45 per 100,000 inhabitants in the respective tracts of low, medium and high vulnerability. Among the older adults, the gradient of increase between the HVI is clearer: among

Table 2. Distribution of mortality by natural causes and COVID-19 among adults and older adults in Belo Horizonte, per level of health vulnerability, between the 10th and 43rd epidemiological weeks of 2020.

Mortality indicator	Belo Horizonte	HVI		
		Low	Medium	High
20–39 years				
Expected MR*: observed MR	36: 36	18: 22	37: 36	59: 53
Observed MR – expected MR**	-0.02	4.16	-0.7	-5.5
Expected/observed MR***	99.9	123.1	98.1	90.6
MR by COVID-19	4	2	5	6
40–59 years				
expected MR: observed MR	211: 246	116: 129	241: 286	337: 382
Observed MR – expected MR	35	13	45	45
expected/observed MR	116.4	110.9	118.8	113.4
MR by COVID-19	33	12	42	56
60–74 years				
expected MR: observed MR	794: 978	570: 662	912: 1113	1101:1450
observed MR – expected MR	184	91	200	349
expected/observed MR	123.1	116	122	131.7
MR by COVID-19	164	79	182	331
75 years and more				
expected MR: observed MR	3.620: 4.182	3148: 3.435	4.016: 4.839	4.393: 5.242
observed MR – expected MR	562	287	823	850
expected/observed MR	115.5	109.1	120.5	119.3
MR by COVID-19	611	409	800	874

*MR: Age-standardized mortality rates, per 100,000 inhabitants; **Differential mortality, **Standardized mortality ratio; HVI: health vulnerability index.

those aged 60–74 years, the difference in observed and expected rate is equal to 184 per 100,000 inhabitants in Belo Horizonte, ranging from 91 to 200 and 349 per 100,000 inhabitants in terms of vulnerability tracts.

Regarding mortality rate by COVID-19, there was a clear trend of increase with age, which varied from 4, 33, 164 to 611 per 100,000 inhabitants between age groups 20–39, 40–59, 60–74 and 75+, respectively. The mortality differential between the HVI was greater with increasing age, and mortality among older adults (75+ years) were 408, 800 and

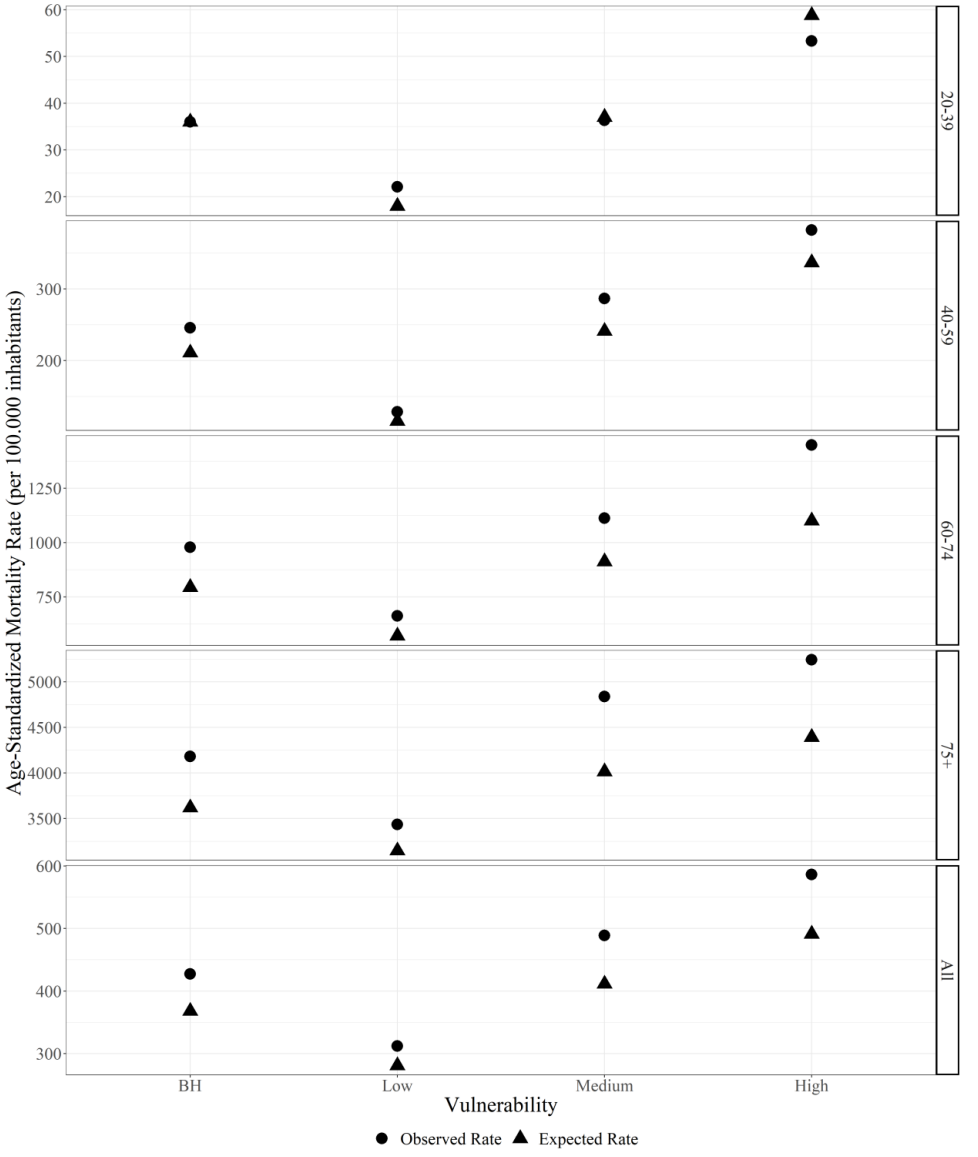

Figure 3. Age-standardized mortality rates by natural causes per 100,000 inhabitants, by age groups and all ages, in Belo Horizonte, between the 10th and 43rd epidemiological weeks of 2020.

874 per 100,000 inhabitants, respectively, in the three vulnerability groups—hundreds of times greater than the rates among the youngest (20–39 years), which was 2, 5 and 6 per 100,000 inhabitants for the same groups, vulnerability wise.

DISCUSSION

This study confirms the hypothesis of a differential increase in mortality by natural causes and by COVID-19 in populations in greater social vulnerability in Belo Horizonte in 2020 and, mainly, among older adults, with urgent implications in the vaccination strategy of the population.

The excess deaths by natural causes have the COVID-19 pandemic as main cause, as shown by the overlap between the moving averages of mortality by natural causes and by COVID-19 in the municipality. In a context of low testing for the identification of cases and lack of standardization of death certificates, the excess mortality is a tool for health managers, being a reliable indicator of the magnitude of the pandemic, as it reflects its direct and indirect effects on local mortality[20].

The excess mortality by natural causes in Belo Horizonte was 16.1%, higher in the medium and high vulnerability tracts. However, the number of deaths by COVID-19 was responsible for a smaller share of the excess deaths by natural causes in areas of high vulnerability compared to areas of low and medium vulnerability. This suggests a underdiagnosis of COVID-19 in these areas, potentially due to unequal access to health services and diagnostic tests, as already shown in other Brazilian cities[21]. Alternatively, there may have been an additional increase in deaths by other natural causes as an indirect consequence of the pandemic in areas of greater social vulnerability[22].

The SMR, that is, the relationship between expected and observed mortality, answers an important etiological question by showing that 16% of the excess deaths in Belo Horizonte were directly or indirectly caused by the pandemic. However, it does not answer an important question for managers regarding the impact of measures to reduce mortality, including vaccination. This impact was evidenced in our study by the difference between observed and expected mortality rate by COVID-19, this differential mortality three times greater (95 per 100 thousand inhabitants) in the tracts of higher vulnerability when compared to those of lower vulnerability (31 per 100 thousand inhabitants).

Socioeconomic inequalities are the main determinants of the occurrence and distribution of diseases and deaths worldwide and, in Belo Horizonte, this inequality—which was already crystal clear before the pandemic—was exacerbated by it[23,24]. People who live in most vulnerable areas are the population group with the greatest risk of exposure not only because they usually work in essential services, but also because they have difficulties with physical distance and hygiene inherent to their housing and transportation conditions. In addition, the comorbidities that increase the lethality of COVID-19, such as cardiovascular diseases, diabetes and obesity, are more prevalent in groups with worse socioeconomic conditions[25]. Finally, there is still less access by the most vulnerable

population to health services: a disparity also accentuated by the pandemic. Thus, the data gathered in this study reinforce the need to include socioeconomic criteria when defining vaccine prioritization.

As for age groups, inequalities in mortality are present, even to varying degrees, in people over 40 years of age, in which the lethality by COVID-19 is already known to be greater than in the younger people[26]. Therefore, our findings are consistent with the highest mortality among older adults found in other countries. In the USA, the lethality of COVID-19 ranged from 10 to 27% among the aged 85+ years, and from 3 to 11% for those aged 65–84 years, but had rates below 1% among adults aged 20-54 years[26]. However, among the most vulnerable older adults, mortality rates were many times higher than in the other groups, which reinforces the need to prioritize the vaccine for this group in the context of dose scarcity. Even in developed countries, it is already argued that disregarding socioeconomic heterogeneity among the older adults can deepen social inequalities[24].

The methodology of this study should be highlighted. Differences between age structures by HVI were considered when performing the demographic projection. In addition, the standardization of mortality rates by age allowed the comparison between the groups of HVI with different age structures, leading to the evidence of higher mortality among the older adults in the most vulnerable tracts, which generally concentrate a lower number of older adults and, consequently, of deaths[27].

This study has limitations inherent to its design. There is a probable underestimation of deaths by COVID-19 obtained from SIM, which may also imply an underestimation of the actual difference between mortality by COVID-19 in socially vulnerable areas, with less access to diagnosis and health care.[1] The analysis was performed only up to the 43rd EW, the last week with data updated, revised and made available by the SMS-BH, but the addition of others is unlikely to change the direction or magnitude of the findings. The growth rate applied to determine the population of each census sector was uniform, based on the only demographic study available in the municipality[18].Although we expect an uneven population growth rate between the areas of HVI, in the absence of updated information, we believe that the approach adopted offers the best possible parameter for age distribution in the population strata of interest. Although the confidence intervals of estimates have not been calculated, both the magnitude and the gradients of the differences between the groups strongly suggest that the discrepancies found are real. We also point out that the HVI is calculated for a group of people residing in a given continuous geographic area, with no differences identified between its residents. The parameters used to compose this index refer to the last census of 2010. Even though there were changes in the period, this study proves that the inequality persists.

In summary, our study points to the highest mortality during the COVID-19 pandemic in areas of high and medium social vulnerability, especially among older adults. Thus, the next stages of vaccination should prioritize areas of greatest social vulnerability in Belo Horizonte—where almost two thirds of all deaths occurred—while maintaining the other priorities proposed by the Brazilian government, as a strategy for a greater and earlier impact in morbidity and mortality due to the disease in the municipality. We emphasize

the importance of this proposal for both the better use of available doses of the vaccine and its feasibility, given the municipality's experience in articulating health surveillance actions with territorial bases defined in areas covered by the Family Health Strategy[28].

The Belo Horizonte administration was a pioneer in adopting restrictive measures aimed at protecting the population. Prioritizing vaccination to older adults in the most vulnerable areas will benefit all citizens of the municipality, as in addition to the greater reduction in deaths, there will be more rational spending and availability of health resources.

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