

# Hospitalizations and deaths from respiratory diseases in the state of Minas Gerais: analysis of time series between 2016-2022 of public hospital records (SIH/SUS)

*Internações e óbitos por doenças do aparelho respiratório no estado de Minas Gerais: análise de séries temporais entre 2016-2022 de registros hospitalares públicos (SIH/SUS)*

Ryan Rodrigo Oliveira de Paula<sup>1</sup>, Thelma Safadi<sup>2</sup>, Luiz Otávio de Oliveira Pala<sup>2</sup>, Luciano José Pereira<sup>1</sup>

## ABSTRACT

**Objective:** To evaluate the temporal patterns of hospitalizations and deaths from respiratory diseases (RD) in Minas Gerais from 2016 to 2022. **Methods:** We conducted a data survey from the SIH-SUS/DATASUS database, focusing on hospitalizations and deaths among adults over 18 years due to RD and associated comorbidities. An autoregressive and moving average models with covariates (ARMAX) was employed to analyze these data, incorporating seasonal and intervention components. **Results:** The study found higher mortality rates among males, particularly during the pandemic years of 2020-2021, with a subsequent trend toward pre-pandemic levels in 2022. The increase in male deaths correlated with a reduction in hospitalizations for HIV, while in females, it was linked to decreases in hospitalizations for cardiovascular diseases. Additionally, a clear seasonal pattern emerged, with peaks in deaths during the winter months of June through August. **Conclusion:** Male gender is a significant risk factor for RD mortality, with increased vulnerability during winter and exacerbated by the COVID-19 pandemic.

**Keywords:** Respiratory diseases; Covid-19 pandemic; Seasonality; Health management.

<sup>1</sup> Universidade Federal de Lavras (UFLA), Faculdade de Ciências da Saúde (FCS), Departamento de Medicina, Lavras, Minas Gerais, Brazil.

<sup>2</sup> Universidade Federal de Lavras (UFLA), Instituto de Ciências Exatas e Tecnológicas (ICET), Departamento de Estatística, Lavras, Minas Gerais, Brazil.

### Responsible Editor:

Dr. Nestor Barbosa de Andrade  
Faculdade de Medicina da  
Universidade Federal de Uberlândia.  
Uberlândia/MG, Brazil.

### Corresponding Author:

Prof. Luciano José Pereira  
Universidade Federal de Lavras (UFLA),  
Setor de Bioquímica, Fisiologia e  
Farmacologia – Departamento de  
Medicina, Faculdade de Ciências da  
Saúde (FCS), Minas Gerais, Brazil.  
Email: lucianojosepereira@ufla.br

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## RESUMO

**Objetivo:** Avaliar o comportamento temporal das internações e óbitos por doenças do aparelho respiratório (DAR) no estado de Minas Gerais de 2016 a 2022. **Métodos:** Um levantamento de dados foi realizado no SIH-SUS/DATASUS considerando o número de internações e óbitos de adultos acima de 18 anos por DAR (capítulo CID-10 X) e comorbidades. Utilizaram-se modelos autorregressivos e de médias móveis com a inserção de covariáveis (ARMAX) e a presença de componentes sazonais e/ou de intervenções nas séries de óbitos. **Resultados:** Os óbitos masculinos foram superiores, com acentuação na pandemia (2020-2021) e tendência de retorno em 2022. O aumento dos óbitos em homens foi relacionado à diminuição das internações por HIV e em mulheres, a doenças cardiovasculares. Houve sazonalidade dos óbitos em períodos entre junho-agosto (inverno). **Conclusão:** O sexo masculino foi um fator de risco para mortalidade por DAR, com vulnerabilidade aumentada pelo inverno e pela pandemia da COVID-19.

**Palavras-chave:** Doenças respiratórias; Pandemia COVID-19; Sazonalidade; Gestão em saúde.

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## INTRODUCTION

Respiratory diseases (RDs) contribute significantly to morbidity and mortality rates globally, representing about one-fifth of hospital admissions within Brazil's public health system (SUS), which caters to 75% of the population<sup>1</sup>. These diseases tend to surge in prevalence during the colder, drier fall and winter months<sup>2</sup>. Various factors influence the progression of RDs, including socioeconomic and demographic backgrounds, cultural contexts, existing comorbidities, and access to healthcare services<sup>3</sup>. The seasonal exacerbation of respiratory conditions primarily stems from drops in relative air humidity, with levels below 30% compromising airway integrity and immune responses, thereby elevating hospitalization and mortality rates<sup>4</sup>. Notably, the southeastern states of Brazil, with their dense populations, suffer disproportionately from RDs<sup>2</sup>.

The imposition of social distancing measures during the COVID-19 pandemic led to a reduction in RD cases<sup>5</sup>. However, analyses reveal variations in mortality between sexes<sup>2,6</sup>, reflecting differences in population characteristics, geographic areas, and the metrics considered. Such insights emphasize the value of regional temporal analyses for healthcare administrators, facilitating forecasts of healthcare expenditures to prevent system overload<sup>4</sup>, particularly in the pandemic context<sup>1</sup>. Despite its importance, data scarcity hampers effective planning for hospital care, often strained by shortages in laboratories and human resources<sup>7</sup> and disparities in outpatient and hospital treatment<sup>8</sup>.

Estimating critical periods that strain healthcare resources could aid in prioritizing interventions, thus

enhancing decision-making processes<sup>9,10</sup>. Consequently, conducting time series studies on RDs is essential, not only to assess the impact of COVID-19 on Brazil's healthcare system but also to enhance future predictions<sup>2,4,11</sup>.

This study aims to explore the temporal patterns of hospitalizations and deaths from RDs (ICD-10 - chapter X) in adults over 18 years old in Minas Gerais from 2016-2022. It examines correlations with sex (male or female) and various comorbidities (hypertension, diabetes mellitus, acute myocardial infarction, AIDS, heart failure, and obesity). This research seeks to generate hypotheses and forecasts considering the COVID-19 pandemic's implications and previous studies<sup>4</sup>.

## METHODS

The data analyzed in this study were sourced from the Hospital Information System of the Unified Health System (SIH-SUS), provided by the Department of Informatics of the Unified Health System (DATASUS)<sup>12</sup>. We organized the data into monthly time series from January 2016 to March 2022, with extraction and review occurring in the second half of 2022. A single researcher collected the data, which another team member then reviewed.

For statistical analysis, we employed autoregressive and moving average models with covariates, known as ARMAX<sup>13</sup>, articulated as follows in Equation 1:

$$Y_t = C + \sum_{i=1}^p \phi_i Y_{t-i} + \sum_{k=1}^K \beta_k X_{k,t} + e_t - \sum_{j=1}^q \theta_j e_{t-j}$$
<sup>14</sup> where  $Y_t$  denotes the number of deaths from DAR in month  $t$ ,  $C$  represents the intercept,  $X_{k,t}$  are the covariates, and  $e_t$  is the random error. Parameters  $C$ ,  $\phi_i$ ,  $\beta_k$ , and  $\theta_j$  are defined

for  $i = 1, \dots, p$ ;  $k = 1, \dots, K$ , and  $j = 1, \dots, q$ . The  $X_{k,t}$  covariates include factors to assess trends, seasonality, interventions, and other explanatory variables' effects on outcomes like hospitalizations.

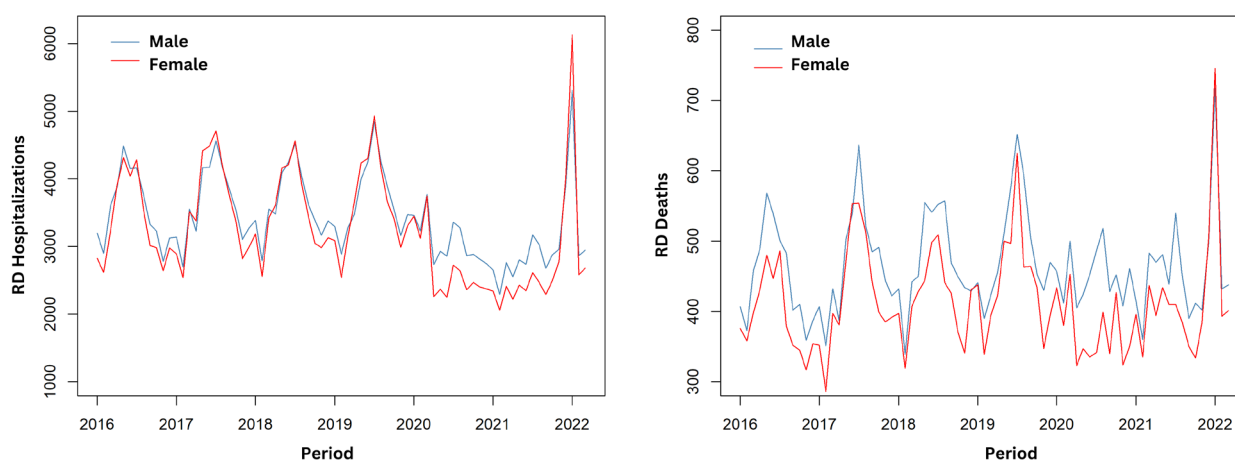
We define an intervention as any event that might alter the time series' behavior, aiming to quantify its impact<sup>15</sup>. Literature describes methods for analyzing interventions and seasonal components<sup>15</sup>. In this study, we controlled for monthly seasonality using binary variables and introduced additional binary variables as needed to assess intervention impacts.

The inherent ordering of time series data necessitates a modeling approach distinct from that used in cross-sectional studies<sup>16</sup>. This approach considers that past observed values of death can influence and be influenced by variables  $X_{k,t}$ . For example, the number of male deaths in a specific month  $t$  might relate to the number of hospital admissions due to Diabetes Mellitus at  $t-1$ .

We used the Gnu Regression, Econometrics and Time-series Library (Gretl) and R for model adjustments and data analysis. Parameter estimates were derived using the exact maximum likelihood method, with standard errors calculated from the Hess matrix. We set the alpha level at 5% to assess the statistical significance of the parameters. Additionally, we evaluated model residuals using the Ljung-Box test<sup>13,17</sup>.

## RESULTS

During the study period, RDs caused a total of 65,826 deaths in the state of Minas Gerais, comprising 34,878 men (53%) and 30,948 women (47%). The total number of hospitalizations for the same cause during this period reached 499,731, with 256,566 men (51.3%) and 243,165 women (48.7%), as depicted in Figure 1A. By calculating the simple ratio of the number of deaths to hospitalizations, we derived a lethality rate of 13.60% for males and 12.71% for females. Both male and female deaths and hospitalizations exhibited annual seasonality.



**Figure 1.** Hospitalizations (A) and deaths (B) by RDs in Minas Gerais from January 2016 to March 2022, categorized by sex.

Comparison of the male and female death curves by RDs (Figure 1B) reveals that, throughout the analyzed period, male deaths consistently exceeded female deaths. However, between 2020-2021, both curves declined, with the gap widening due to a more pronounced decrease in female deaths. By 2022, the curves converged once again.

Table 1 presents the results of the regression model for analyzing the monthly number of male deaths from RD. According to Equation 1, we express the model as follows:

$$\hat{Y}_t = 113,833 + 0,396Y_{t-1} + 0,112 X_{1,t} - 0,600X_{2,t} + 75,970X_{3,t} + 21,880X_{4,t} + e_t,$$

where  $X_{(1,t)}$  and  $X_{(2,t)}$  denote hospital admissions for RD and HIV, respectively.  $X_{(3,t)}$  is a binary variable that assumes a value of 1 in July 2021 and 0 in other months, while  $X_{(4,t)}$  is another binary variable, taking the value 1 in August and 0 otherwise.

We observed that the explanatory variables related to hospitalizations due to comorbidities, such as essential hypertension, diabetes mellitus, acute myocardial infarction, heart failure, and obesity, lacked statistical significance and were thus excluded from the model. Conversely, the number of male deaths in a given month was positively correlated with the death count from the preceding month, with an estimated magnitude of  $\phi_1 = 0.396$ . This suggests, for example, that an increase in deaths in December is likely if there was a rise in the average number of deaths in November. Additionally, a seasonal peak in deaths is associated with the month of August, approximately 22 deaths, as verified in Figure 2A. This figure presents a box plot of the monthly number of male AIDS-related deaths (RD), highlighting a trend of increasing deaths from March, peaking in July and August, followed by a decline. A significant rise in the number of male RD deaths was also recorded in July 2021, estimated at about 76 deaths. This increase was analyzed through the inclusion of an intervention variable for July 2021 in the model (Table 1).

The number of hospitalizations for RDs significantly correlated with an increase in RD deaths, with a coefficient of 0.112. This indicates that higher RD hospitalizations are associated with increased RD deaths, as expected. Conversely, HIV-related hospitalizations exhibited an inverse

relationship with RD deaths, represented by a coefficient of -0.600; thus, fewer HIV hospitalizations correlated with more RD deaths. Figure 3A illustrates the trends in HIV hospitalizations over the analyzed period. From 2016 to early 2019, monthly male HIV-related hospitalizations in Minas Gerais typically ranged from 110 to 160. In 2019, this number dropped to between 70 and 90 monthly hospitalizations. The years 2020 and 2021 saw a further decrease to 30 to 60 monthly hospitalizations. However, by 2022, the number began to revert to earlier levels.

Table 2 presents the results of the analysis of the monthly number of female deaths from RDs. The explanatory variables related to the number of hospitalizations due to diabetes mellitus, acute myocardial infarction, HIV, and obesity were not statistically significant and thus were excluded from the model. We observed a 12-month seasonal correlation of -0.253 for deaths from RD in females, indicating a tendency for the number of deaths to decrease in the same month of the following year compared to the current year, assuming other effects remain constant.

Among the significant covariates for the number of RD deaths, the number of hospitalizations for the same cause showed a coefficient of 0.100, suggesting that an increase in

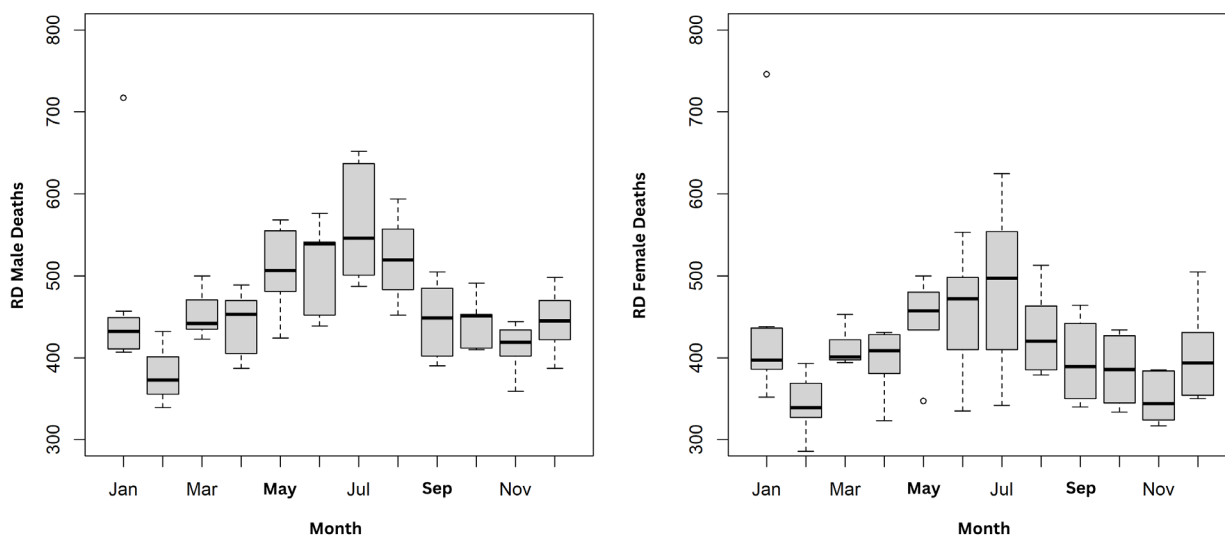
hospitalizations for RD correlates with a rise in RD deaths. Conversely, the number of hospitalizations for essential hypertension had a negative impact on RD deaths, with a coefficient of -0.369, indicating that fewer hospitalizations for essential hypertension are associated with more RD deaths. Similarly, a decrease in the number of hospitalizations for heart failure, with a coefficient of -0.099, suggests an expected increase in RD deaths.

Figures 3B and 3C depict the trends in hospitalizations for primary essential hypertension and heart failure in females, showing a downward trend from 2016 to early 2019, a slight increase in 2019, followed by a more marked decline in 2020 and 2021. In 2022, the trend reversed towards an increase.

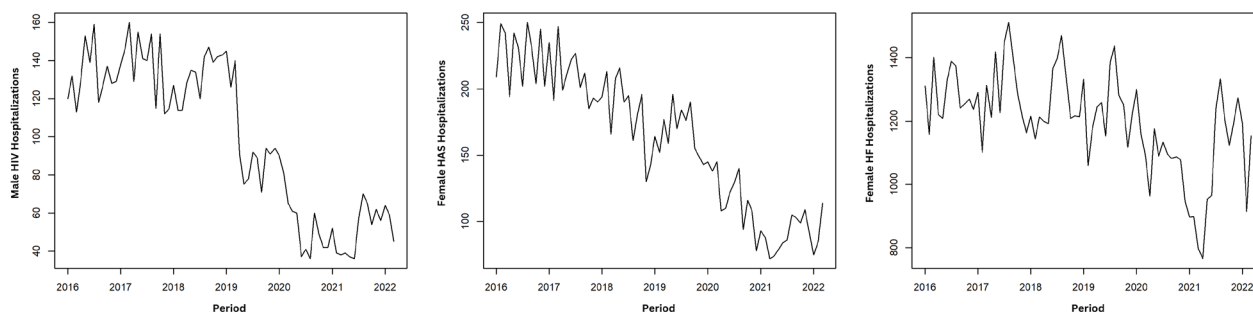
Table 2 also reveals a yearly seasonal component in female RD deaths, with peaks observed in June (398), July (416), and August (397). Figure 2B confirms this pattern, illustrating an upward trend in deaths from March, with peaks in June, July, and August, followed by a subsequent decline. Additionally, we noted a significant increase in female RD deaths in October 2020. We estimated this increase at 87 deaths and assessed it by incorporating an intervention variable for October 2020 into the model.

**Table 1.** Estimated coefficients for the regression model analyzing time series of male deaths from RDs in Minas Gerais, Brazil.

Parameters	Coefficient	Standard error	P-value
Constant	113,833	20,769	<0,001
$\emptyset_1$	0,396	0,118	<0,001
RD Hospitalizations	0,112	0,006	<0,001
HIV Hospitalizations	-0,600	0,112	<0,001
July/2021	75,970	21,482	<0,001
August	21,880	8,854	0,013



**Figure 2.** Monthly distribution of male (A) and female (B) deaths from RDs in Minas Gerais.



**Figure 3.** Hospitalizations for HIV in males (A) and for hypertension (B) and heart failure (C) in Females in Minas Gerais from January 2016 to March 2022.

**Table 2.** Estimated coefficients for the regression model analyzing time series of female deaths from RDs in Minas Gerais, Brazil.

Parameters	Coefficient	Standard error	P-value
$\emptyset_1$	-0,253	0,063	<0,001
January	385,310	41,945	<0,001
February	327,480	36,399	<0,001
March	372,341	40,56	<0,001
April	349,666	39,117	<0,001
May	379,550	43,506	<0,001
June	398,096	43,373	<0,001
July	416,354	48,548	<0,001
August	397,678	48,225	<0,001
September	379,403	44,317	<0,001
October	353,512	42,561	<0,001
November	330,246	40,352	<0,001
December	359,099	41,691	<0,001
Admission RD	0,100	0,005	<0,001
Admission HAS	-0,369	0,095	0,0001
Admission HF	-0,099	0,039	0,012
October/2020	87,099	27,039	0,001

## DISCUSSION

Males exhibited a higher prevalence of hospitalizations and deaths from RD throughout the study period. The pattern persisted in absolute values and seasonal terms from 2016 to 2019. Between 2020 and 2021, during the peak of the COVID-19 pandemic, hospitalizations declined for both sexes, yet the reduction in male hospitalizations was less pronounced, clearly exceeding that of females and reverting to prior trends by early 2022. The male sex is a risk factor for RD, primarily due to less frequent health care-seeking behavior, which impedes early diagnosis and treatment. Additionally, males face higher occupational risks, greater exposure to alcohol and tobacco, and lack the protective effects of female hormones and the X chromosome, which

enhance innate and adaptive immunity. Consequently, males are more vulnerable to infections and more likely to develop critical illnesses or die<sup>18-21</sup>.

Despite an overall reduction in hospitalizations for RD during the COVID-19 pandemic, males continued to be disproportionately affected compared to females. This decrease may reflect changes in population behavior, including lower hospital care-seeking and the implementation of epidemiological control measures such as social distancing, promotion of hand hygiene, and the use of masks and alcohol gel<sup>22-23</sup>. The resurgence of the pattern observed from 2016 to 2019 in 2022 could be linked to the relaxation of pandemic control measures, including the removal of mask mandates in Minas Gerais and shortened periods of social isolation for suspected COVID-19 cases<sup>24-25</sup>.

HIV-related hospitalizations exhibited an inverse relationship with the number of RD deaths in men, as did the hospitalizations due to primary essential hypertension and heart failure-related hospitalizations with RD deaths in women. These results suggest that the pandemic led to a decrease in hospitalizations for various causes<sup>26</sup>, possibly due to social isolation, reduced medical care-seeking, and changes in health system organization. This also supports the observed trend toward returning to the pre-pandemic values of 2016-2019 in 2022, following the relaxation of pandemic control measures<sup>23</sup>. Similar patterns appear in other studies, which show a reduction in cardiovascular disease hospitalizations, possibly due to fear of contracting the virus, thereby leading to an increase in COVID-19 hospitalizations, a respiratory disease<sup>27</sup>. These factors may elucidate the adverse effects of essential hypertension and heart failure on the number of RD deaths in women.

Additionally, we noted that RD deaths in both males and females displayed seasonal trends during the winter months of June, July, and August, typical of the southern hemisphere<sup>2</sup>. We observed a more pronounced frequency of these deaths in males. Winter in the Southeast region of Brazil features lower relative air humidity and increased air pollution due to wildfires, which renders the respiratory system more susceptible to environmental conditions. Consequently, infectious or harmful agents more readily penetrate the respiratory tract, leading to increased severity and, therefore, a higher number of hospitalizations<sup>4,28</sup>.

We observed an increase of 76 deaths among males in July 2021 and 87 deaths among females in October 2020. Despite a decrease in hospitalizations during this period, we noted a corresponding increase in the number of deaths. The Pan American Health Organization (PAHO) indicates that direct factors, such as COVID-19 itself, or indirect factors, like decreased access to prevention and early treatment of certain conditions, influenced the rise in deaths during the pandemic<sup>29</sup>. These factors may explain the observed increases in RD deaths reported in this study. Furthermore, we could link the rise in respiratory deaths during the pandemic to the underreporting of COVID-19 deaths<sup>30</sup>.

In conclusion, males are a risk factor for RD mortality, with increased vulnerability during winter and the COVID-19 pandemic. Specifically, during the pandemic, hospitalizations for comorbidities such as HIV and cardiovascular diseases corresponded to lower RD mortality in men and women, respectively. This trend likely resulted from an increase in Covid-19 hospitalizations coupled with a decrease in hospitalizations for other causes, as hospitals aimed to minimize the exposure of patients with serious illnesses to high-risk environments for Covid-19 contamination.

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## AUTHORS' CONTRIBUTIONS

Author contributions are structured according to the taxonomy (CRediT) described below:

*Conceptualization, funding acquisition, project administration, resources, supervision, manuscript writing:* Luciano José Pereira. *Data curation, investigation, manuscript writing:* Ryan Rodrigo Oliveira de Paula. *Formal analysis, methodology, software, validation, visualization, and manuscript writing:* Thelma Sáfyadi and Luiz Otávio de Oliveira Pala.

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