Association Between Temperature and Humidity With Mortality: An Ecological Study

Associação Entre Temperatura e Umidade com Mortalidade: Um Estudo Ecológico

Asociación Entre Temperatura y Humedad con la Mortalidad: Un Estudio Ecológico

RESUMO
O objetivo deste estudo foi analisar a associação entre temperatura e umidade, em relação aos óbitos por doenças cardiovasculares e pulmonares no município de Ribeirão Preto, SP, em 2019, projetando cenários futuros dessas variáveis. Foi realizado um estudo ecológico no qual os óbitos foram classificados conforme os Capítulos IX e X da Classificação Internacional de Doenças-10, segundo declarações de óbito e dados de temperatura e umidade. O Capítulo IX representou 23% e o Capítulo X 24,9% dos óbitos, sendo 53% do sexo masculino, 84% acima de 80 anos e 83,2% brancos. O maior coeficiente foi no Centro (5,8/1.000 habitantes), e junho apresentou o maior número de óbitos (242). As temperaturas variaram de 3,9°C a 39°C e a umidade de 37% a 96,5%. As baixas temperaturas e umidade foram associadas ao aumento da mortalidade, com o aumento dessas variáveis reduzindo os óbitos em 3,1% semanalmente. Ribeirão Preto tem um perfil climatológico quente e seco, com mortes principalmente por doenças respiratórias.
DESCRITORES: Mudanças climáticas; Mortalidade; Temperatura; Umidade; Doenças do trato respiratório.

ABSTRACT
The objective of this study was to analyze the association between temperature and humidity, in relation to deaths from cardiovascular and pulmonary diseases in the municipality of Ribeirão Preto, SP, in 2019, projecting future scenarios of these variables. An ecological study was carried out in which deaths were classified according to Chapters IX and X of the International Classification of Diseases-10, according to death certificates and temperature and humidity data. Chapter IX represented 23% and Chapter X 24.9% of the deaths, with 53% being male, 84% over 80 years old, and 83.2% white. The highest coefficient was in the Center (5.8/1,000 inhabitants), and June had the highest number of deaths (242). Temperatures ranged from 3.9°C to 39°C and humidity from 37% to 96.5%. The low temperatures and humidity were associated with an increase in mortality, with an increase in these variables reducing deaths by 3.1% weekly. Ribeirão Preto has a hot and dry climatological profile, with deaths mainly due to respiratory diseases.
DESCRIPTORS: Climate change; Mortality; Temperature; Humidity; Respiratory tract diseases.

RESUMEN
El objetivo de este estudio fue analizar la asociación entre la temperatura y la humedad en relación con las muertes por enfermedades cardiovasculares y pulmonares en el municipio de Ribeirão Preto, SP, en 2019, proyectando escenarios futuros para estas variables. Se realizó un estudio ecológico en el que las muertes se clasificaron según los Capítulos IX y X de la Clasificación Internacional de Enfermedades-10, basándose en certificados de defunción y datos de temperatura y humedad. El Capítulo IX representó el 23% y el Capítulo X el 24,9% de las muertes, siendo el 53% hombres, el 84% mayores de 80 años y el 83,2% blancos. El coeficiente más alto se registró en el centro de la ciudad (5,8/1.000 habitantes), y junio presentó el mayor número de muertes (242). Las temperaturas variaron de 3,9°C a 39°C y la humedad de 37% a 96,5%. Las bajas temperaturas y la humedad se asociaron con un aumento de la mortalidad, con el aumento de estas variables reduciendo las muertes en un 3,1% semanalmente. Ribeirão Preto tiene un perfil climático cálido y seco, con muertes principalmente por enfermedades respiratorias.
DESCRITORES: Cambio climático; Mortalidad; Temperatura; Humedad; Enfermedades del tracto respiratorio.

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INTRODUCTION

Climate change has several unintended consequences for the planet. The 2023 report of the Intergovernmental Panel on Climate Change (IPCC) presents projections and new scientific findings related to climate change. The effects of climate change occur regionally and globally and affect people. Climate change can have significant impacts on human health, as it is associated with extreme weather events, air quality, agricultural productivity, water supply and use and migration[1].

Changes in precipitation and temperature are expected as a result of climate change. People with cardiovascular problems, especially the elderly, are more vulnerable to heatwaves, leading to increased hospitalizations and deaths, as has been observed in some Europe cities[2,3].

A study[4] examined the correlation between excess deaths and different temperature scenarios ranging from 1.5 to 4ºC in 23 countries, and found that an increase of up to 2ºC, in line with the Paris Agreement, could lead to a significant increase in temperature-related fatalities. The number of deaths continues to rise as temperatures rise, particularly in Europe and South-east Asia. However, as temperatures decrease, these deaths fall. Another study[5] observed a similar trend in Brazil, where an increase in temperature was associated with an increase in deaths related to cardiovascular problems, while a decrease in temperature was associated with a decrease in such deaths.

A study[6] conducted in the Brazilian state of Paraná found a decrease in hospitalizations for respiratory and cardiovascular diseases, but an increase in deaths from respiratory causes. The study found that high temperatures combined with low humidity were associated with more hospitalizations for cardiovascular diseases, while low temperatures were associated with more hospitalizations for respiratory diseases. It also found that elderly people had a higher risk of suffering from both types of illness.

Numerous studies have investigated the association between temperature, humidity, and mortality in different countries, and regions, such as Latin America[7] or South Asia[8]. In Brazil, research often focused on large urban centers, and state capitals[9], rather than rural areas. The objective of this study was to analyze the potential association between temperature and humidity with deaths from cardiovascular and respiratory tract diseases in the municipality of Ribeirão Preto, SP, Brazil, using climatological data from 2019. Future scenarios were projected based on changes in these variables.

METHODS

This ecological study analyzed deaths related to chapters IX (Diseases of the circulatory system) and X (Diseases of the respiratory system) of the International Classification of Diseases (ICD-10)[10], in the municipality of Ribeirão Preto, SP, in 2019, and their association with temperature and humidity.

The data were obtained from death certificates (DC) issued by the registry offices of the municipality. The variables selected for analysis included sex (male/female), age group, ethnicity (white, black, yellow, mixed), address, and cause of death. Adresses were allocated to the six regions of the municipality (Center, East, North, West, South Zones and Bonfim Paulista district). Ethnicity was classified as white/non-white (white and yellow/brown and black). The date of death was also recorded and classified by month. The cause of death was then classified according to the 22 chapters of the ICD-10 with the two chapters mentioned above analyzed separately from the others. The data were collected between February and August of 2021.

Data of temperature and humidity were obtained from the website of the Environmental Company of the State of São Paulo (CETESB)[11]. The minimum, average and maximum values were cal-

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culated for the temperature data, while only the average values were calculated for the humidity data. The data were also grouped by month of 2019 year. Was calculated the rates by regions of the municipality per 1,000 inhabitants.

Socioeconomic data were obtained from the Brazilian Institute of Geography and Statistics (IBGE)[12] for the 2010 year. A map of the average nominal monthly income per household was created based on the census sectors defined by the IBGE. Deaths due to cardiovascular and respiratory diseases were plotted on a density map, highlighting areas with a higher incidence of deaths for each chapter. All maps were created using the QGIS 3.30.1 software.

A multiple Poisson[13] regression model was used to investigate the relationship between climate variables and the number of weekly deaths for ICD-10 Chapters IX and. The response variable was a count, and the model allowed for main effects and interactions with time (week number of the year 2019) and harmonic functions (based on sine and cosine functions to model peaks and valleys of the series). The comparison of rate trends over time is possible by examining the interaction between the variables of interest and the week. A log offset parameter (population/100,000) was used to estimate the rate. The statistical software R version 4.0.4 was employed, with a significance level of 5% was adopted.

The project was approved by the Institutional Review Board of the Ribeirão Preto Medical School, University of São Paulo (Opinion: 4,543,831). Access to death certificates was authorized by the supervising judge of the registry offices, in accordance with ethical principles, research confidentiality and the Data Protection Law (Lei 13,709/2018)[14]. This article is a part of the Mortality Studies Project in Ribeirão Preto, São Paulo, Brazil.

RESULTS

Ribeirão Preto had a total of 4,394 deaths in 2019. Of these deaths, 1,009 (23%) classified in Chapter IX, and 1,093 (24.9%) in Chapter X of the ICD-10, representing 47.9% of all deaths. Of these total, 53% were male, and 83.2% were white. Individuals aged 60 years and over accounted for 84% of all reported deaths (Table 1). The mean age of the deceased was 76.3 years, with a median age of 77 years. The mean age was 76.9 years for females and 71.3 tears for males.

White people represented 70.7% of the city's population and accounted for 83.5% of deaths. Non-whites represented 29.3% of the population, and only 16.4% of the deaths. The non-whites were represented by 9.9% of brown individuals and 6.5% of black individuals. The age group most affected was 70 years and over (67%) and the least affected was 20-29 years (0.6%).

Table 1- Variables analyzed from the DC in the municipality of Ribeirão Preto, SP, Brazil according to the months of 2019

	January (N=171)	February (N=150)	March (N=178)	April (N=189)	May (N=180)	June (N=242)	July (N=206)	August (N=197)	September (N=163)	October (N=129)	November (N=141)	December (N=155)	2019 (N=2101)
Age range													
0-19y	3 (1.8%)	0 (0%)	2 (1.1%)	2 (1.1%)	4 (2.2%)	5 (2.1%)	8 (3.9%)	2 (1.0%)	1 (0.6%)	1 (0.8%)	2 (1.4%)	0 (0%)	30 (1.4%)
20-29y	0 (0%)	1 (0.7%)	2 (1.1%)	2 (1.1%)	3 (1.7%)	0 (0%)	0 (0%)	0 (0%)	2 (1.2%)	1 (0.8%)	1 (0.7%)	0 (0%)	12 (0.6%)
30-39y	2 (1.2%)	1 (0.7%)	2 (1.1%)	3 (1.6%)	2 (1.1%)	4 (1.7%)	4 (1.9%)	2 (1.0%)	1 (0.6%)	3 (2.3%)	2 (1.4%)	5 (3.2%)	31 (1.5%)
40-49y	10 (5.8%)	5 (3.3%)	6 (3.4%)	5 (2.6%)	5 (2.8%)	8 (3.3%)	5 (2.4%)	6 (3.0%)	5 (3.1%)	1 (0.8%)	8 (5.7%)	12 (7.7%)	76 (3.6%)
50-59y	11 (6.4%)	21 (14.0%)	19 (10.7%)	12 (6.3%)	16 (8.9%)	19 (7.9%)	13 (6.3%)	11 (5.6%)	25 (15.3%)	15 (11.6%)	11 (7.8%)	12 (7.7%)	185 (8.8%)
60-69y	29 (17.0%)	33 (22.0%)	29 (16.3%)	35 (18.5%)	31 (17.2%)	37 (15.3%)	29 (14.1%)	32 (16.2%)	22 (13.5%)	19 (14.7%)	25 (17.7%)	37 (23.9%)	358 (17.0%)
70+y	116 (67.8%)	89 (59.3%)	118 (66.3%)	130 (68.8%)	119 (66.1%)	169 (69.8%)	147 (71.4%)	143 (72.6%)	107 (65.6%)	89 (69.0%)	92 (65.2%)	89 (57.4%)	1408 (67.0%)
Missing	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0.5%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0.0%)
Sex													
Female	86 (50.3%)	66 (44.0%)	88 (49.4%)	79 (41.8%)	100 (55.6%)	112 (46.3%)	98 (47.6%)	97 (49.2%)	80 (49.1%)	61 (47.3%)	72 (51.1%)	70 (45.2%)	1009 (48.0%)
Male	85 (49.7%)	84 (56.0%)	90 (50.6%)	110 (58.2%)	80 (44.4%)	130 (53.7%)	108 (52.4%)	100 (50.8%)	83 (50.9%)	68 (52.7%)	69 (48.9%)	85 (54.8%)	1092 (52.0%)
Ethnicity													
White	149 (87.1%)	120 (80.0%)	152 (85.3%)	159 (84.1%)	154 (85.6%)	190 (78.5%)	170 (82.5%)	173 (87.8%)	140 (85.9%)	106 (82.2%)	115 (81.6%)	125 (80.6%)	1753 (83.5%)
Non-White	22 (12.8%)	29 (19.4%)	26 (14.6%)	30 (15.9%)	26 (14.4%)	52 (21.5%)	35 (17%)	23 (11.7%)	23 (14.1%)	23 (17.9%)	26 (18.4%)	30 (19.4%)	345 (16.4%)
Missing	0 (0%)	1 (0.7%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0.5%)	1 (0.5%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (0.1%)

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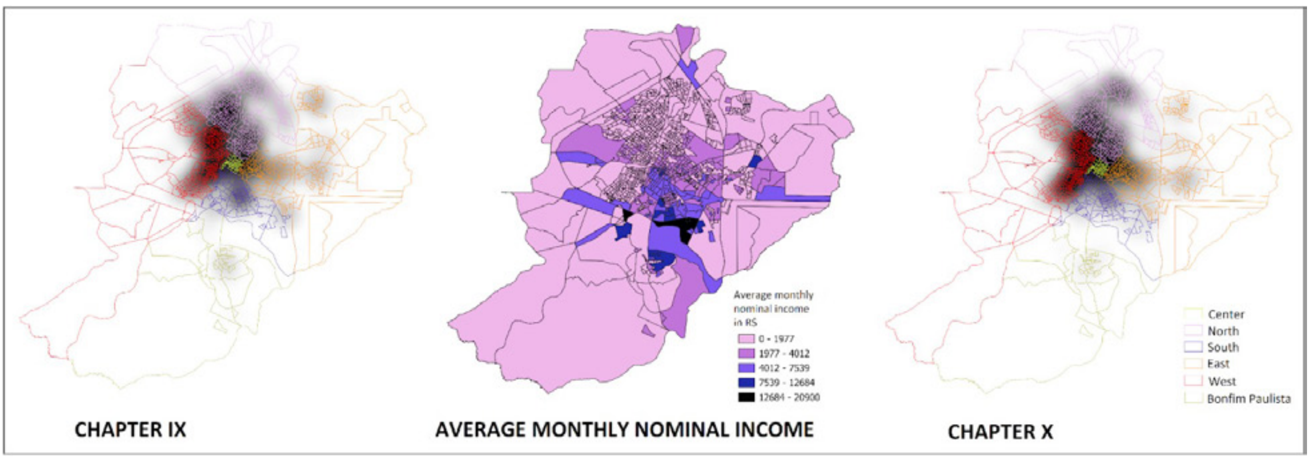
Zone													
Bonfim Paulista	4 (2.3%)	0 (0%)	3 (1.7%)	1 (0.5%)	1 (0.6%)	1 (0.4%)	7 (3.4%)	1 (0.5%)	2 (1.2%)	2 (1.6%)	0 (0%)	4 (2.6%)	26 (1.2%)
Center	8 (4.7%)	8 (5.3%)	14 (7.9%)	9 (4.8%)	9 (5.0%)	10 (4.1%)	11 (5.3%)	10 (5.1%)	4 (2.5%)	5 (3.9%)	10 (7.1%)	9 (5.8%)	107 (5.1%)
East	25 (14.6%)	25 (16.7%)	24 (13.5%)	30 (15.9%)	28 (15.6%)	39 (16.1%)	38 (18.4%)	43 (21.8%)	28 (17.2%)	22 (17.1%)	17 (12.1%)	31 (20.0%)	350 (16.7%)
North	68 (39.8%)	58 (38.7%)	61 (34.3%)	85 (45.0%)	72 (40.0%)	121 (50.0%)	80 (38.8%)	66 (33.5%)	63 (38.7%)	44 (34.1%)	61 (43.3%)	53 (34.2%)	832 (39.6%)
West	44 (25.7%)	47 (31.3%)	59 (33.1%)	46 (24.3%)	49 (27.2%)	46 (19.0%)	49 (23.8%)	54 (27.4%)	45 (27.6%)	43 (33.3%)	40 (28.4%)	45 (29.0%)	567 (27.0%)
South	21 (12.3%)	12 (8.0%)	17 (9.6%)	18 (9.5%)	21 (11.7%)	25 (10.3%)	21 (10.2%)	22 (11.2%)	21 (12.9%)	13 (10.1%)	12 (8.5%)	13 (8.4%)	216 (10.3%)
Missing	1 (0.6%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0.5%)	0 (0%)	0 (0%)	1 (0.7%)	0 (0%)	3 (0.1%)
ICD-10													
IX	75 (43.9%)	71 (47.3%)	83 (46.6%)	89 (47.1%)	88 (48.9%)	119 (49.2%)	90 (43.7%)	92 (46.7%)	78 (47.9%)	70 (54.3%)	72 (51.1%)	82 (52.9%)	1009 (48.0%)
X	96 (56.1%)	79 (52.7%)	95 (53.4%)	100 (52.9%)	92 (51.1%)	123 (50.8%)	116 (56.3%)	105 (53.3%)	85 (52.1%)	59 (45.7%)	69 (48.9%)	73 (47.1%)	1092 (52.0%)

Source: Database from Death Certificates. Elaborated by authors.

The North Zone had the highest total number of deaths (39.6%), but, when analyzing the rates, the most affected region was the Center (5.8/1,000 inhabitants). The rates for other regions were 4.1/,1000 in the North Zone; 3.7/1,000 in the South Zone; 3.1/1,000 in the West Zone; 2.7/1000 in the East Zone; and the lowest was 2.2/1000 in Bonfim Paulista district.

Despite the high number of deaths, the regions were relatively evenly distributed across the municipality, with minor variations. The district of Bonfim Paulista recorded more deaths related to circulatory diseases of the circulatory system than to diseases of the respiratory system. When analyzing from the city Center, it is noticeable that diseases of circulatory system spread more towards the southern part of the South Zone, and a similar pattern is observed in the East Zone, particularly in the border region with the North Zone, in the peripheral areas. It is clear, therefore, that although the pattern of diseases in the two systems is homogeneous, the circulatory system is present in more regions than the respiratory system, albeit with a lower number of deaths. With regard to income, although a similar pattern is observed, a conclusive relationship cannot be established. However, it can be observed that in the South Zone, there is a greater concentration of wealth, with fewer deaths related to the respiratory system and more deaths related to the circulatory system. Even in Bonfim Paulista, where the income level is high, there are more deaths in Chapter IX (Figure 1).

Figure 1- Maps of Kernel density of deaths from IX and X chapters of ICD-10 in 2019, and monthly income and average age of people by census in Ribeirão Preto, SP.



Source: Database from Death Certificate from Civil Registry Office of Ribeirão Preto, SP. IBGE (2011).

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The months with the highest number of deaths were June (242) and July (206), and the lowest were November (141) and October (129).

In 2019, the average temperature record in Ribeirão Preto was 25.3ºC, the minimum with a 3.9ºC and a maximum of 39ºC. June and July were the months with the lowest average temperatures, with July having a higher standard deviation (3.54ºC), indicating greater temperature variability, making it the coldest month. On the other hand, January, September had the highest stand deviation (4.47ºC), surpassing October in temperature variability and reaching the highest temperature (34.5ºC). Thus, July was the coldest month and recorded the lowest temperature of the year (3.9C). While September was the hottest month, it was also the only one to reach 39ºC (Table 2).

Table 2- Average, minimum and maximum temperatures, and average humidity during the year 2019 in Ribeirão Preto, SP, Brazil.

	January (N=31)	February (N=28)	March (N=31)	April (N=30)	May (N=31)	June (N=30)	July (N=31)	August (N=31)	September (N=30)	October (N=31)	November (N=30)	December (N=31)	2019 (N=365)
Minimum temperature													
Average (SD)	21.8 (1.52)	21.3 (1.12)	21.0 (1.13)	19.3 (2.50)	16.7 (4.03)	14.2 (1.84)	11.9 (3.54)	15.0 (1.87)	19.0 (1.79)	20.9 (1.40)	21.6 (1.25)	21.8 (1.09)	18.7 (3.94)
Median [Min, Max]	22.3 [18.5, 23.9]	21.3 [19.1, 23.9]	21.1 [17.6, 22.7]	19.6 [13.2, 23.1]	18.0 [7.90, 22.2]	14.0 [11.1, 21.6]	12.6 [3.90, 17.0]	14.8 [11.2, 19.3]	18.6 [14.0, 23.1]	20.8 [18.7, 24.1]	21.4 [19.1, 24.0]	22.1 [19.2, 24.0]	20.1 [3.90, 24.1]
Missing	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (10.0%)	4 (12.9%)	0 (0%)	0 (0%)	7 (1.9%)
Maximum temperature													
Average (SD)	34.3 (2.34)	32.1 (3.65)	31.7 (2.32)	31.7 (2.19)	29.8 (2.66)	29.2 (2.45)	28.2 (3.20)	29.5 (5.05)	34.3 (4.47)	34.6 (2.96)	32.6 (2.85)	32.0 (2.54)	31.6 (3.71)
Median [Min, Max]	34.9 [28.5, 37.6]	31.7 [21.9, 38.0]	32.3 [25.8, 34.8]	32.2 [25.6, 35.1]	31.0 [22.9, 32.7]	28.8 [23.1, 38.0]	28.6 [19.1, 31.9]	31.4 [16.1, 35.6]	35.3 [20.7, 39.0]	35.5 [27.6, 37.7]	33.0 [23.7, 37.9]	32.0 [24.9, 35.5]	31.8 [16.1, 39.0]
Missing	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	4 (13.3%)	4 (12.9%)	0 (0%)	0 (0%)	8 (2.2%)
Average temperature													
Average (SD)	28.1 (1.54)	26.7 (2.07)	26.3 (1.28)	25.5 (1.63)	23.3 (2.87)	24.4 (3.03)	20.0 (2.82)	22.3 (2.73)	26.7 (2.77)	27.7 (1.83)	27.1 (1.79)	26.9 (1.46)	25.3 (3.24)
Median [Min, Max]	28.3 [23.9, 30.4]	26.2 [21.4, 30.7]	26.5 [23.6, 28.3]	25.5 [21.9, 28.8]	23.8 [17.0, 27.5]	25.1 [18.0, 29.8]	20.9 [13.2, 24.2]	23.0 [15.2, 25.9]	27.4 [19.1, 30.2]	28.4 [24.0, 30.8]	27.3 [22.4, 30.5]	26.8 [22.7, 28.8]	26.0 [13.2, 30.8]
Missing	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	4 (13.3%)	4 (12.9%)	0 (0%)	0 (0%)	8 (2.2%)
Average humidity													
Avrage (DP)	62.5 (6.07)	69.1 (10.1)	68.6 (7.12)	66.9 (7.81)	66.7 (4.97)	61.0 (2.80)	57.8 (6.29)	55.5 (9.93)	52.4 (12.2)	55.0 (8.77)	64.2 (9.50)	68.2 (6.97)	62.4 (9.67)
Median [Min, Max]	60.5 [53.0, 80.0]	68.0 [50.5, 96.5]	69.5 [52.5, 83.0]	67.0 [55.0, 88.0]	67.0 [56.0, 76.5]	60.8 [56.5, 71.0]	57.5 [49.0, 83.0]	52.5 [40.0, 84.5]	49.5 [37.0, 87.0]	52.0 [42.5, 71.0]	62.8 [47.5, 89.0]	69.0 [56.0, 85.0]	61.8 [37.0, 96.5]

Source: Database from Death Certificate from Civil Registry Office of Ribeirão Preto, SP. CETESB.

As regards humidity, the annual average was 62.4%, with the lowest value in September (52.4%) and the highest in February (69.1%). In both months, the lowest and highest humidity levels were 37% and 96.5%, respectively.

Regarding the deaths in Chapters IX and X, and only Chapter X with temperature, the analysis of Poisson model indicates that for each degree increase in minimum temperature, a 3.1% decrease in the average weekly deaths is expected. For each degree increase in minimum temperature, a reduction of 3.3% on mortality for both sexes is expected. For humidity, for each additional unit is associated with a 3.1% reduction in average weekly deaths for both chapters. About ethnicity, Chapter X shows a 65.5% reduction in the average minimum temperature for non-whites. For humidity, each additional unit corresponds to 69.7% reduction in weekly deaths.

Regarding the ethnicity, there were more deaths in winter weeks and fewer in summer months for both Chapters analyzed. However, the increase in winter deaths is greater in Chapter X than in Chapter IX, and this is more pronounced when deaths are analyzed in relation to humidity. Poison also shows an increase in deaths during the

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colder months.

Regarding the regions of the municipality, although the values of deaths differ among them, it is observed that the Center region is more homogeneous. In the East and South Zones there is an inverse relationship, where an increase in one is accompanied by a decrease in the other, except for a few weeks in the warmer months. The North and West Zones show the same pattern as the other Zones, but with a higher number of deaths. Due to the low number of deaths, the district of Bonfim Paulista was not included in this analysis.

DISCUSSION

The results of this study provide insight into the relationship between mortality and weather conditions. Although June had the highest number of deaths, July was the month with the lowest temperature and had one of the lowest humidity levels. On the other hand, the lowest Chapter IX deaths was observed in October, which coincided with the month with the highest temperatures but relatively low humidity. November had the lowest number of deaths in both Chapters, but no association was found with either low or high temperature or humidity levels. In other words, the fall/winter periods had an increase in deaths, especially for Chapter X. It was observed that as the minimum temperature increased, fewer deaths can occur. Regarding humidity, there were also fewer deaths for each additional unit, mainly due to diseases of the respiratory system.

It is worth noting that although September had the highest temperature and the lowest humidity, it was not the month with the highest number of deaths. Moreover, July was the month with the lowest temperature and the highest number of deaths, in both Chapters IX and X.

A study that examined the projected effects of climate change on cardiovascular mortality in several Brazilian cities found a decrease in mortality during periods of low temperatures and an increase mortality during periods of high temperatures, in all the locations analyzed[10]. Otherwise, a study conducted in several locations worldwide, including Brazil, showed more mortality associated with cold temperatures, than by hot temperatures[15]. A study conducted in the municipality of São Paulo demonstrated that colder temperatures were associated with an increase in mortality in cardiovascular mortality, while higher temperatures were linked with an increase in respiratory-related mortality. Additionally, the study found that females had a higher risk of mortality due to heat, while males had a higher risk due to cold[16].

A study conducted in a Chinese city analyzed deaths associated with colder and hotter temperatures found that hotter temperatures had a significantly larger and more immediate effect on the number of deaths, while colder temperatures had a delayed, but more persistent effect over time[17]. The difference between more deaths in cold or heat may be due to acclimatization and adaptation of populations in different regions of the world[18]. Elderly people exposed to the high temperatures had a 27% risk of death, while exposure to low temperatures increased the risk by 16%. It was estimated that 4.7% of deaths were due to cold weather, while 2.8% were due to heat. Therefore, cold weather had a greater impact on mortality among older adults. The authors suggested the implementation of proactive measures in cities with significant temperature fluctuations[9].

In this study, it was found that 84% of the deaths analyzed belonged to individuals aged 60 years or older. Of these, 919 aged 80 years or more (52%). When analyzing the incidence in each age group, 60-79 and 80+, significant differences were observed. Chapter IX had a higher number of deaths among the elderly in the first age group (54%), while Chapter X had a higher proportion of deaths among those in the second age group (61%). This comparison with individuals over 80 years old is due to the life expectancy in 2019, which was 76.4 years, according to the State Data Analysis System Foundation (SEADE)[19]. Furthermore, the population in this age group is growing, representing 1.5% of the Brazilian population in the year analyzed[20]. Cardiovascular diseases and cerebrovascular diseases stand out in relation to Chapter IX, while pneumonia stands out in relation to Chapter X.

A study comparing the effects of temperature on mortality in Hong Kong found that low temperatures had a stronger effect on cardiovascular and respiratory deaths. High temperatures were associated with female mortality. Hong Kong has a large economic disparity among districts, and the study found that people belonging to the lower conditions had higher respiratory deaths. The elderly population is more vulnerable to extreme temperatures[21].

Studies investigating the association between climate change and mortality are becoming increasingly important worldwide. In addition to the importance of developing public policies that mitigate environmental impacts on population health, these research studies should identify which populations are most vulnerable in their respective areas. The elderly, who are living longer, are affected by climate change, with long-term health consequences. Davies[22] emphasizes this by pointing out that there is an excess of heat-related deaths among individuals aged 65 and over. Natural disasters also have a significant impact on a large proportion of the elderly population.

There is a need for studies that investigate the relationship between air pollutants in Ribeirão Preto. The municipality receives a large daily influx of population from neighbouring cities, whether for work or leisure, mostly

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using private vehicles, which further increases the daily fleet of automobiles.

> "In addition, the concave urban topography leads to the accumulation of pollutants at a certain height in the sky, without efficient dispersion, especially during periods of milder temperatures and low humidity."

It would be relevant to investigate whether this situation is related to the high number of deaths from pulmonary diseases, which accounted for 24.9% of the total analyzed for the year, which differs from the pattern observed globally, where the majority of the deaths are related to diseases of the circulatory system[23].

The maps created in this study revealed a small discrepancy between cardiovascular and pulmonary deaths. However, when the data from 2010 census14 were analyzed, it was found that the Central region had the highest average age among the residents of the municipality. In addition, the highest age groups among females were not restricted to the city Center, but extended to the census sectors in the southern and eastern regions. For males, fewer census sectors with higher age groups were identified in the city Center, and the dispersion to other areas was also lower, regardless of the region.

Research analyzing these areas is helps to understand which regions need more attention from governments to promote more equitable health outcomes. In addition to developing public policies to address the effects of climate change, it's critical to empower and engage the community, and foster critical engagement among the population to ensure that everyone has access to quality health care and can live longer, healthier lives.

One of the strengths of this study is its analysis of different regions within the city, which helps to identify variations in rates. This approach is commendable, as it allows for a better understanding of priority areas that require targeted public policies, especially for those in need.

However, a weakness of this study is that it relies on data from only one year to analyze deaths from cardiovascular and respiratory diseases. Being limited to this period makes it is difficult to determine whether the observed mortality patterns are representative of the city as a whole or are influenced by specific weather conditions. The census data used may not be consistent with recent census updates that occurred after the pandemic. Further research should explore the impact of climate change on the city, considering a boundary time frame and examining both related issues. This is the first study to link climate and mortality in Ribeirão Preto, and only was used only one year was used for analysis.

CONCLUSIONS

This study has provided valuable insights into the impact of climate change on health outcomes. The results highlight the important role that climatic factors play in public health and show an increase in mortality associated with the worst weather conditions. The analysis showed that periods of high temperature and low humidity were associated with increased deaths, and that a reduction in temperature and an increase in humidity contribute to a reduction in deaths from diseases related to Chapters IX and X.

In conclusion, the findings of this study highlight the urgent need for public health strategies that proactively address the health vulnerabilities exacerbated by climate change. This includes raising public awareness, improving access to health care, and implementing preventive measures against temperature-related health risks. Ultimately, promoting a multidisciplinary approach involving environmental science, public health, and urban planning will be critical to developing resilient communities capable of withstanding the challenges posed by a changing climate. Future studies may provide more data on deaths and climatological data in the community, including heat waves that occurred in the years following this analysis.

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