Investigaciones Geográficas • Instituto de Geografía • UNAM
eISSN: 2448-7279 • DOI: dx.doi.org/10.14350/rig.60178 • ARTICLES
Num. 104 • April • 2021 • e60178
www.investigacionesgeograficas.unam.mx

COVID-19: Do weather conditions influence the transmission of the coronavirus (SARS-CoV-2) in Brasília and Manaus, Brazil?

COVID-19: ¿Las condiciones climáticas influyen en la transmisión del coronavirus (SARS-CoV-2) en Brasilia y Manaus, Brasil?

Francisco Antonio Coelho Junior,* Pedro Marques-Quinteiro** y Cristiane Faiad***

Recibido: 13/06/2020. Aprobado: 6/11/2020. Publicado: 25/02/2021.

Abstract. The global outbreak of coronavirus SARS-CoV-2 (COVID-19) disease is affecting every part of human lives. Several researchers investigated to understand how temperature, humidity and air pollution had an influence on COVID-19 transmission. Transmission of COVID-19 due to temperature and humidity is a pertinent question. There is a lack of study of Covid-19 in tropical climate countries. This study aims to analyze the correlation between weather and Covid-19 pandemic in Brasília and Manaus, two states of Brazil. The research topic is important to know how the climate affects or predisposes the spread of COVID-19. This knowledge will provide elements to decision-makers regarding health and public health standards and decisions. This study employed a secondary data analysis of surveillance data of Covid-19 from the Ministry of Health of Brazil and weather from the National Institute of Meteorology of Brazil. These are Brazilian public organizations that, on a daily basis, record this information on a systematic basis of dates. They are central federal organizations, responsible for data analysis and public policy planning to combat Covid-19. The data are reliables and obtained from reliable government sources. We systematically record all information for 51 days, during a period of high disease growth in the country. The components of weather include low temperature (°C), high temperature (°C), temperature average (°C), humidity (%), and amount of rainfall (mm). Pearson-rank correlation test showed that high temperature (r=.643; p<.001), low temperature (r=.640; p<.001) and humidity (r=.248; p<.005) were significantly correlated with deaths caused by Covid-19 pandemic used for data analysis. Social isolation rate (β = -.254; p<.001) and daily record of new cases (β = .332; p<.001), with adjusted R-squared of .623, were the predictors of deaths acummuled by Covid-19. The finding serves as an input to reduce the incidence rate of Covid-19 in Brazil. Statistical results show evidence of the relationship between climate elements and COVID-19 indicators, such as the number of deaths, spread of contamination and social isolation rate. The study of dimensions of climate as a seasonal pattern and its relationship to COVID-19 benefits epidemiological surveillance. The more geographic spaces are known, more will help to understand the differences in disease behavior in different places. The results of this research showed that environmental conditions influence the contagion and speed of transmission of Covid-19. Policies that contribute to benefits to health and sustainability need to be planned. The contribution of climate and other factors,

* Corresponding author. Associate Professor at the Department of Administration and the Post-Graduate Program in Administration at the University of Brasília, Brazil. ORCID: http://orcid.org/0000-0002-1820-5448. ResearcherID: AAE-1455-2020. E-mail: fercoepsi@gmail.com; acoelho@unb.br
**Assistant Professor at the Department of Social and Organizational Psychology at the William James Institute (ISPA-Instituto Universitário, Lisbon). ORCID: http://orcid.org/0000-0001-9385-8476. ResearcherID: K-1896-2015. E-mail: pedromquinteiro@gmail.com; pquinteiro@ispa.pt
*** Assistant Professor at the Department of Clinical Psychology and the Post-Graduate Program in Social, Work and Organizational Psychology at the University of Brasília, Brazil. ORCID: http://orcid.org/0000-0002-8012-8893. ResearcherID: B-8818-2017. E-mail: crisfaiad@gmail.com; faiad@unb.br

such as air pollution, for example, require additional studies. Environmental changes, such as climate change and biodiversity, must also be investigated for their impact on human health. Acting in prevention, including the promotion of socially acceptable behaviors on the part of the population, seems to be the best way to deal with Covid-19.

Keywords: Covid-19; Coronavirus; Temperature; Humidity; Rainfall; Brazil

Resumen. El brote mundial de la enfermedad por SARS--CoV-2 (COVID-19) está afectando todos los aspectos de la vida humana. Este estudio tiene como objetivo analizar la correlación entre factores del clima y la pandemia de Covid-19 en Brasilia y Manaos, dos estados de Brasil. El tema de investigación es importante para conocer cómo el clima afecta o predispone el contagio por COVID-19. Y aporta elementos a los tomadores de decisiones en cuanto a normas y decisiones sanitarias y de salud pública. Se empleó un análisis de datos secundarios de datos de vigilancia de COVID-19 del Ministerio de Salud de Brasil y el clima del Instituto Nacional de Meteorología de Brasil. Se registró sistemáticamente toda la información durante 51 días, durante un período de alto crecimiento de la enfermedad en el país. Los componentes del clima incluyen baja temperatura (°C), alta temperatura (°C), temperatura promedio (°C), humedad (%) y cantidad de lluvia (mm). La prueba de correlación de rango de Pearson mostró que la temperatura alta ($r = .643$; $p < .001$), la temperatura baja ($r = .640$; $p < .001$) y la humedad ($r = .248$; $p < .005$) se correlacionaron significativamente con muertes causadas por la pandemia de Covid-19 utilizada para el análisis de datos. La tasa de aislamiento social ($\beta = -.254$; $p < .001$) y el registro diario de nuevos casos ($\beta = .332$; $p < .001$), con un R cuadrado ajustado de .623, fueron los predictores de muertes acumuladas por COVID -19.

Palabras clave: COVID-19, coronavirus, temperatura, humedad, lluvia, Brasil

INTRODUCTION

The coronavirus disease 2019 (Covid-19) has significantly impacted everyday life worldwide (Hopkins, 2020; Sohrabi et al., 2020; Xu et al. 2020). Reason for transmission of COVID-19 is not yet clearly understood (Ghosh et al., 2020).

Covid-19 is a respiratory epidemic caused by the coronavirus Family (2019-nCoV). As it is a virus with a high contagion power (Andersen et al. 2020; Li et al. 2020; Yongjiana et al. 2020), and devastating action (Xi et al., 2020; Zhu et al., 2020), science has focused on investigating its characteristics (Lian et at. 2020; Rodriguez-Morales et al. 2020; Wang et al. 2020).

Based on recomendations provided by the World Health Organization (WHO, 2020a; WHOb, 2020), spontaneous quarantine was established in Brazil (i.e., citizens engaged in quarantine by their own initiave) since no formal lockdown had been adopted for most of the country, except specific states of Brazil such as Maranhão or Fortaleza.

Research has already tested the effect of weather aspects (Gutiérrez-Hernández & García, 2020; Saadat, Rawtani & Hussain, 2020; Tobias et al. 2020; Tosepu et al., 2020) and temperature (Bannister-Tyrrell et. al 2020; Ma et al., 2020; Shahzad et al., 2020) related to the speed of propagation of the virus (Al-Rousan & Al-Najjar, 2020; Bariotakis et.al, 2020; Bukhari & Jameel, 2020; Dantas et. al. 2020; Le et al. 2020; Liu et al. 2020). Surprisingly, there is still no consensus as to whether lower temperatures favor the spread of the virus in tropical countries, or whether higher temperatures are capable of decimating the vírus (Altamimi & Ahmed, 2019; Igbal et al. 2020)

According to Chan et.al. (2011), Alvarez-Ramirez and Meraz (2020), Araújo and Naimi (2020), Bashir et. al. (2020), Wang et. al. (2020) and Zhu and Xie (2020), the role played by temperature and humidity in the speed and in the spread of the vírus remains unclear. Motivated by the need to address this gap in current knowledge about different elements of the propagation of Covid-19, this research aims to answer the following research question: Does the relative humidity of the air influence the speed at which the virus spreads? To answer these research question, the current study has examined data collected in two representatives Brazilian regions: Amazonas (the capital is Manaus), considered one of the Brazilian cities with the highest average relative humidity; and Brasília, the capital of Brazil.

Brazil has over 500 municipalities, with Brasília and Manus being the 3rd and the 7th most populated (Brazilian Institute of Geography and Statistics, 2020). Brasília it is one of the Brazilian

cities in which drought and low air humidity are more common during most of the year (National Institute of Meteorology (2020a). Between may and october, it has a characteristic desert climate, with low humidity and higher temperatures during the day. Differently, Manaus is wet and humid for most of the year (National Institute of Meteorology, 2020b). Additionally, Manaus concentrates the service given to indigenous populations in the Amazon, and is one of the most affected regions by forest fires during the summer months. As a consequence, respiratory problems, especially in children, are very common between may and september.

As cited earlier, many studies have observed that there are optimal temperature conditions that benefit the spreading of the coronavirus (e.g. Ma et al., 2020). We consider the discussion by Prata, Rodrigues and Bermejo (2020), signaling that the interaction between warmth and humidity is another interesting factor to investigate in tropical climate zones. Since Brazil has continental dimensions, it was decided to stratify data from two Brazilian capitals that differed in some weather conditions. Both cities are similar in most relevant parameters, except the average relative of the air and amount of rainfall.

MATERIALS AND METHODS

Study area

This study included 2 cities, Brasília and Manaus, two state capitals of Brazil. The Federal District is constituted by the capital of Brazil, Brasilia, and by some satellite cities located around Brasilia.

According to data from the Brazilian Institute of Geography and Statistics, the Federal District has an estimated population of 3,015,268 people. In the last demographic census, in 2010, Brasília had approximately 560 thousand people.

Manaus, located in the North of Brazil, is the capital of the state of Amazonas. According to BIGS data, Amazonas has an estimated population of 4,144,597 people. Much of this population is indigenous. Manaus, capital of the state, had a population in 2010 of approximately 1.802.014 people.

This paper is focused on these two Brazilian capital cities because of the difference, in terms of humidity, between them. Figure 1 shows a map with the location of the cities of the study and presents as the basis of the map the types of climate of the spaces where these cities are located.

Manaus, with 11.401 km², is the most populous city in Amazonas, in the North Region and in the entire Brazilian Amazon. It is considered the most influential city in the so-called Western Amazon. It is the city that has a significant impact on the performance of activities related to trade in the region, as well as industry, research and technology activities throughout the region. It is considered a regional metropolis. The climate of Manaus is considered to be a humid tropical monsoon, with an average annual temperature of 27°C and relatively high humidity, with annual rainfall around 2,300 millimeters (mm). The proximity to the Amazon rainforest usually avoids extreme heat spikes and makes the city humid.

Brasília is the federal capital of Brazil and the seat of government of the Federal District. The capital is located in the Midwest region of the country, on the central plateau. Brasília is the house of the executive, legislative and judiciary powers. It has the largest listed area in the world, with approximately 112.5 square kilometers. According to data from the National Institute of Meteorology, the climate in Brasilia is tropical with a dry season, with average monthly temperatures always above 18 ° C and annual rainfall of approximately 1.480 mm (mm). During the dry season (April to September), it is common for the relative humidity levels to be often below 30%, well below the ideal considered by the World Health Organization (WHO, 2005), of 60%.

Data collection

The study population is the daily number of cumulative confirmed cases of Covid-19 in the 2 state capital cities, as officially reported by the Ministry of Health of Brazil (Brazilian Ministry of Health, 2020a) from April 14 to June 3, 2020. Data regarding the number of infected by Covid-19, the number of new cases and the cumulative number of deaths were extracted through the ministry's

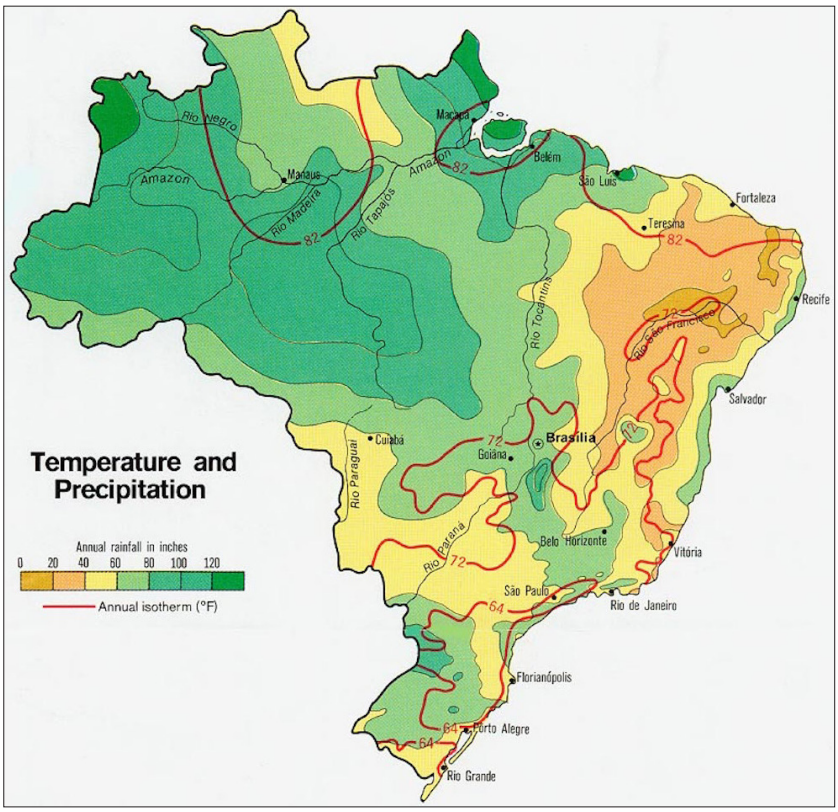

Figura 1. Types of climate in Brasília (DF) and Manaus (AM). Source: Brazilian Institute of Geography and Statistics IBGE (cnae.ibge.gov.br).

official website (Brazilian Social Isolation Index, 2020). Meteorological data (humidity, minimum temperature, maximum temperature and amount of rainfall) were collected from the National Institute of Meteorology authority (National Institute of Meteorology, 2020b), in Brazil.

Data related to the percentage of social isolation in the cities of Brasília and Manaus were collected from the Brazilian map of Covid-19 (Brazilian Ministry of Health, 2020b), through the daily index of social isolation. This index is updated daily, and is used officially by Brazilian governors, in order to monitor the level of social isolation in the municipalities of which they govern. All data were collected daily, during the 51 days of extraction of dates and longitudinal analysis that were contemplated during this research.

Statistical analysis

A descriptive analysis was performed, with numerical variables described using means, standard deviations, and distributions. Student's t test was used to compare two independent samples (data from Manaus and Brasília). A linear regression model (LRM) was used to calculate the relationships between meteorological and geographic data (low temperatures, high temperatures, humidity and daily amount of rainfall), the percentage of social isolation by city and daily data updated by the Ministry of Health of the government of Brazil on the situation of Covid-19 (number of new cases and number of accumulated deaths) in these two cities (Brasília and Manaus).

RESULTS AND DISCUSSION

Descriptive analysis

Table 1 shows, comparatively, the daily cumulative meteorological evolution by the indicators of temperature (low or high), amount of rainfall and humidity in the period between april 14 and

Table 1. Daily cumulative meteorological evolution in Brasília/DF and Manaus/AM.

	Brasília				Manaus			
	hightemp	lowtemp	Rh	Pi	hightemp	lowtemp	Rh	Pi
14 April 2020	26.9	18.9	55	0	30.6	23.4	67	16.2
15 April 2020	22.9	17.5	95	0.1	31.2	24.5	66	0
16 April 2020	21.2	17.8	87	31	31.4	25.8	67	0
17 April 2020	26.7	17.7	67	4.7	32	24.8	64	0.8
18 April 2020	25.1	18.9	71	7.5	26.5	23.6	78	3
19 April 2020	26.1	18.9	66	0	32	23.9	60	0.1
20 April 2020	24.5	19	67	0	31.2	25.2	91	0
21 April 2020	24.1	17.8	87	2.1	33	24.2	60	27.2
22 April 2020	23.7	17.8	91	8	31.1	25.6	72	0
23 April 2020	23.3	18.9	88	22.7	32.3	25.4	84	0
24 April 2020	25.5	19	75	30.2	32.8	25.2	70	1.1
25 April 2020	25	16.9	59	0	26.8	23.2	96	17.2
26 April 2020	24.8	14.7	54	0	32.3	23.4	61	160.8
27 April 2020	25.3	16.2	50	0	32.4	25.5	66	0
28 April 2020	25.1	15.6	52	0	31.1	23.9	74	24.8
29 April 2020	25.4	13.4	45	0	33.1	24.5	59	0.5
30 April 2020	25.7	14	49	0	32.1	26.2	65	0
01 May 2020	26.5	13.9	45	0	33.1	25.7	62	12.8
02 May 2020	21.3	13.4	39	0	32.1	25.9	95	1.1
03 May 2020	27.7	13.1	35	0	32.8	24.9	63	3.9
04 May 2020	27.2	13.2	33	0	32.1	24.2	65	4.9
05 May 2020	28.5	14	39	0	31.7	25.6	78	0
06 May 2020	27.5	15.5	41	0	26	23.4	83	1.6
07 May 2020	23.6	17.2	69	0	31.7	24	73	26.2
08 May 2020	24.1	17.1	64	0.2	30.8	23.7	64	3.8
09 May 2020	21.8	16	66	0	31.9	24.9	56	0.1
10 May 2020	24.9	14.8	53	0	32.8	25.2	72	9.4
11 May 2020	25.2	12.8	41	0	32.8	25.3	61	24.4
12 May 2020	24.9	13.9	50	0	32.8	24.8	63	32.4
13 May 2020	26.6	14.5	56	0	31.1	24.8	79	0.2
14 May 2020	25.9	15	71	0	29.8	24.3	94	1.4
15 May 2020	25.5	16.9	61	5.9	33.2	24.9	58	29.4
16 May 2020	26.3	17.6	78	1.5	33	25.6	61	4.2
17 May 2020	24.3	15.8	68	18.8	32.1	25.8	79	1.1
18 May 2020	25.2	16.1	61	0	33.3	25.6	84	0

Table 1. Continue.

	Brasília				Manaus			
	hightemp	lowtemp	Rh	Pi	hightemp	lowtemp	Rh	Pi
19 May 2020	23.1	16	60	0	29.5	25.2	80	30.6
20 May 2020	22.1	16.7	70	0	32.7	25	64	21.2
21 May 2020	26.1	14.6	48	0	33.5	25.4	60	0
22 May 2020	26.1	15.3	57	0	33	25.4	63	0
23 May 2020	27.7	16.6	47	0	32.1	25.4	68	6
24 May 2020	26.5	17.6	53	0.3	29.9	24.4	72	72.3
25 May 2020	26	17.6	58	0.2	30.8	24.8	68	0
26 May 2020	25.3	14.1	44	0	31.2	24.9	68	0
27 May 2020	26.8	9.3	31	0	32.4	25.9	58	0
28 May 2020	26.3	10.1	39	0	32.6	25.8	60	0
29 May 2020	24.1	10.5	39	0	33	25.9	62	0
30 May 2020	23.3	10.3	44	0	**	**	**	0
31 May 2020	25.1	9.4	41	0	**	**	**	0
01 June 2020	26	12.7	40	0	28.7	23.2	92	0.2
02 June 2020	26.2	13.3	43	0	31.3	23.8	66	23
03 June 2020	27.9	14.4	41	0	32.3	25.4	66	0
Minimum	25.0	14.0	31.0	0.0	26.0	24.0	56.0	0.0
Maximum	26.0	19.0	95.0	31.0	33.0	25.0	96.0	23.0
Average	25.7	16.1	56.5	1.0	31.7	24.5	70.1	1.5
St. deviation	0.58	2.12	16.11	5.09	2.56	0.71	10.77	5.01
Median	26.0	16.0	54.0	0.0	33.0	24.5	66.0	0.0

Note. *high temp = high temperature (°C); low temp = low temperature (°C); rh = relative humidity of the air (%); pi = amount of rainfall (mm); ** = not informed

june 3, 2020. The data are collected daily (Brazilian Institute of Geography and Statistics, 2020), comparing indicators of Brasília and Manaus. It is observed (National Institute of Meteorology, 2020a) that Brasília started to suffer the effects of the dry period, whereas Manaus was characterized as a rainy period, in which temperatures were higher than Brasília.

Table 2 shows the daily cumulative the confirmed cases of Covid-19, new cases, confirmed deaths, new deaths and the percentage of social isolation from april 14 to june 3, 2020. The data about the social isolation (Brazilian Social Isolation Index, 2020) too were collected daily, comparing indicators of Brasília and Manaus.

Data about the number of recovered and the number of cases being monitored were not available when the information was extracted from the Brazilian government databases. It should be noted that the average percentage of social isolation was around 45% on average. The number of new infections and deaths has been growing exponentially over the days. The rapid spread of the virus justified the need to adopt quarantine (social isolation) as the main strategy of prevention.

Table 2. Daily cumulative indicators about Covid-19 in Manaus/AM and Brasília/DF.

	Brasília					Manaus				
	Cf	Nc	Cd	Nd	Si	Cf	Nc	Cd	Nd	Si
14 April 2020	651	13	17	2	46,8	1295	189	81	19	52,4
15 April 2020	682	31	17	0	47,5	1350	55	92	11	52,7
16 April 2020	716	34	20	3	45,7	1459	109	107	15	49,0
17 April 2020	746	30	20	0	43,5	1531	72	127	20	50,1
18 April 2020	762	16	24	4	47,8	1593	62	134	7	53,7
19 April 2020	827	65	24	0	54,2	1664	71	156	22	60,2
20 April 2020	872	45	24	0	46,3	1772	108	156	0	52,5
21 April 2020	881	9	24	0	53,6	1809	37	163	7	56,3
22 April 2020	946	65	25	1	45,0	1958	149	172	9	50,4
23 April 2020	963	17	25	0	45,8	2286	328	193	21	51,2
24 April 2020	989	26	26	1	43,3	2481	195	207	14	50,7
25 April 2020	1013	24	26	0	46,1	2678	197	233	26	56,7
26 April 2020	1066	53	27	1	52,8	2722	44	246	13	57,8
27 April 2020	1146	80	27	0	44,5	2738	16	256	10	50,3
28 April 2020	1213	67	28	1	44,1	2899	161	274	18	50,3
29 April 2020	1275	62	28	0	43,0	3091	192	288	14	48,4
30 April 2020	1356	81	30	2	42,1	3273	182	312	24	47,9
01 May 2020	1466	110	30	0	49,3	3491	218	357	45	52,9
02 May 2020	1566	100	31	1	44,4	3658	167	368	11	50,7
03 May 2020	1649	83	33	2	49,6	4072	414	396	28	54,0
04 May 2020	1768	119	33	0	43,7	4344	272	418	22	48,3
05 May 2020	1818	50	33	0	42,4	4804	460	459	41	47,4
06 May 2020	1906	88	34	1	42,2	5474	670	532	73	49,2
07 May 2020	2258	352	35	1	42,9	5897	423	563	31	48,0
08 May 2020	2442	184	37	2	40,1	6034	137	604	41	46,8
09 May 2020	2576	134	39	2	42,5	6743	709	660	56	48,5
10 May 2020	2682	106	42	3	45,4	7198	455	680	20	50,0
11 May 2020	2783	101	44	2	42,9	7264	66	691	11	49,0
12 May 2020	2979	196	46	2	42,8	7877	613	726	35	48,7
13 May 2020	3192	213	48	2	42,1	8630	753	757	31	49,1
14 May 2020	3416	224	51	3	41,9	9410	780	809	52	47,9
15 May 2020	3787	371	55	4	41,2	9713	303	888	79	46,4
16 May 2020	4140	353	56	1	44,7	10297	584	920	32	49,1
17 May 2020	4368	228	59	3	51,8	10407	110	949	29	55,1
18 May 2020	4619	251	66	7	42,5	10660	253	951	2	48,1

Table 2. Continue.

	Brasília					Manaus				
	Cf	Nc	Cd	Nd	Si	Cf	Nc	Cd	Nd	Si
19 May 2020	4853	234	72	6	42,1	11051	391	999	48	46,9
20 May 2020	5161	308	77	5	41,2	11643	592	1057	58	45,3
21 May 2020	5542	381	84	7	41,2	12317	674	1094	37	45,6
22 May 2020	5948	406	90	6	39,9	12967	650	1127	33	44,3
23 May 2020	6251	303	95	5	43,3	13624	657	1176	49	48,6
24 May 2020	6638	387	104	9	51,4	13881	257	1182	6	51,9
25 May 2020	6930	292	114	10	42,1	13979	98	1190	8	44,7
26 May 2020	7210	280	124	10	41,1	14402	423	1248	58	44,3
27 May 2020	7761	551	133	9	40,5	14800	398	1272	24	43,9
28 May 2020	8300	539	142	9	40,8	15769	969	1314	42	43,9
29 May 2020	8722	422	154	12	39,2	17492	1723	1349	35	42,2
30 May 2020	9474	752	162	8	42,3	18139	647	1366	17	44,3
31 May 2020	9780	306	170	8	49,5	18293	154	1366	0	50,7
01 June 2020	10510	730	171	1	40,8	18367	74	1371	5	43,8
02 June 2020	11256	746	177	6	40,4	18981	614	1390	19	41,7
03 June 2020	12251	231	179	2	39,5	*	*	*	*	40,4
Minimum	651.0	9.0	17.0	0.0	39.2	1295.0	16.0	81.0	0.0	40.4
Maximum	12251.0	752.0	179.0	12.0	54.2	18981.0	1723.0	1390.0	79.0	60.2
Average	3766.8	212.7	63.4	3.2	44.3	7765.5	357.5	668.5	26.6	49.1
St. deviation	3231.9	196.6	49.9	3.3	3.8	5618.4	316.3	445.4	18.7	4.2
Median	2576.0	134.0	39.0	2.0	43.0	6388.5	255.0	632.0	22.0	49.0

Note. cf = confirmed cases (absolute frequency); nc = new cases (absolute frequency); cd = confirmed deaths (absolute frequency); nd = new deaths (absolute frequency); si = percentage of social isolation (%); *not informed.

Figure 2 regards the frequency of confirmed cases over 51 days. The red and blue lines on the graph on the right show a steep increase in the number of confirmed cases over 51 days. The red line on the graph on the left shows a linear decrease in the number of confirmed cases as the level of social isolation increases. The blue line on the graph on the left shows a quadratic trend where the number of confirmed cases is at its highest value for extreme low and extreme high levels of social isolation.

Figure 3 regards the frequency of confirmed deaths over 51 days. The red and blue lines on the graph on the right show a steep increase in the number of confirmed deaths over 51 days. The red line on the graph on the left shows a linear decrease in the number of confirmed deaths as the level of social isolation increases. The blue line on the graph on the left shows a quadratic trend where the number of confirmed deaths is at its highest value for extreme low and extreme high levels of social isolation.

According to the data showed in Table 3, the lowest average temperature in Brasília was 15.34° C, while in Manaus it was 24.85°C. The highest average temperature in Brasília was 25.23° C and in

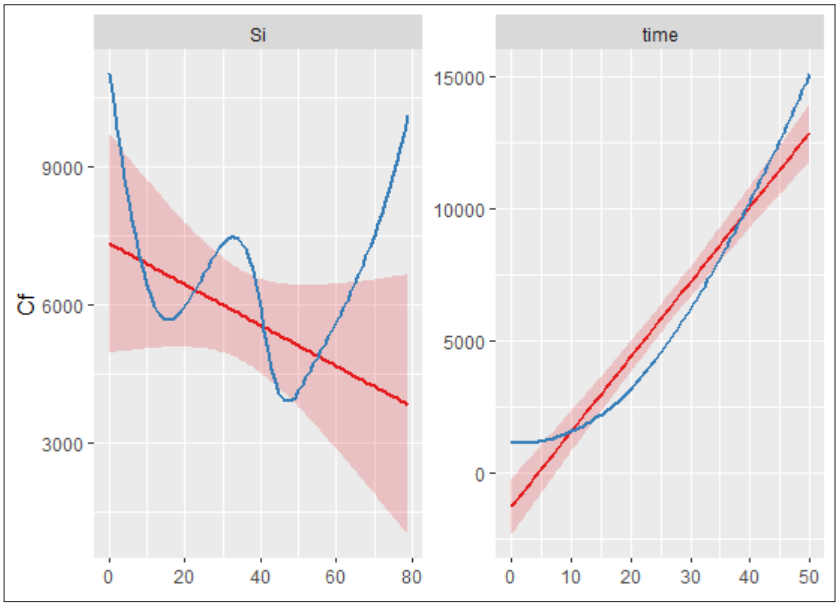

Figure 1. Frequency of confirmed cases x % of social isolation.

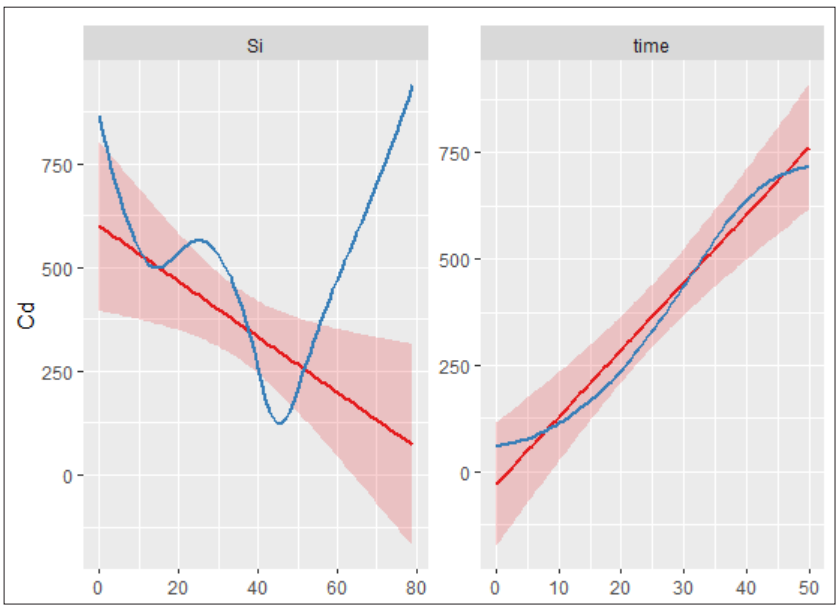

Figure 2. Frequency of confirmed deaths x % of social isolation.

Manaus 31.59° C. The average of the humidity was, in general, higher more in Manaus than Brasília. The average of the humidity relative of the air in Brasília was 58.53%, and 70.14% in Manaus. Data are showed in Tables 3 and 4.

In order to compare the indicators raised between the two cities, we decided to run comparative tests between them. As the data refer to specific indicators for each city, without any dependence or complementarity between them, the t test was used to compare independent samples. Table 5 shows the Student's t test was used to compare two independent samples (data from Manaus and Brasília).

There was difference statistically significant between indicators related to low temperature, humidity, amount of rainfall, confirmed cases of Covid-19 and confirmed deaths of Covid-19.

Table 3. Statistics descriptives of date from Brasília/DF.

Variables	Mean	Standard error	Number of observations
Population	3015268.00	.000	51
Accumuled cases	3766.78	3231.937	51
New cases	212.73	196.596	51
Confirmed deaths	63.37	49.863	51
Percentage of social isolation (%)	44.310	3.7932	51
Low Temperature (°C)	15.339	2.5828	51
High Temperature (°C)	25.233	1.6764	51
Humidity (%)	58.53	16.111	51
Amount of rainfall (mm)	2.612	7.1804	51

Table 4. Statistics descriptives of date from Manaus/AM.

Variables	Mean	Standard error	Number of observations
Population	2182763.00	.000	51
Accumuled cases	7.765.54	5618.418	50
New cases	357.50	316.311	50
Confirmed deaths	668.52	445.364	50
Percentage of social isolation (%)	49.065	4.1677	51
Low Temperature (°C)	24.845	.8334	49
High Temperature (°C)	31.592	1.6970	49
Humidity (%)	70.14	10.766	49
Amount of rainfall (mm)	11.018	25.4144	51

Table 5. Analysis of variance with test t comparing data from Manaus and Brasília.

					95% confidence interval of the difference	
	F	Sig.	t	df	Lower	Upper
percentage of social isolation	.123	.725	6.026	100	3.19	6.32
temperature minimum	40.425	.000	24.559	98	8.74	10.27
temperature maximum	.128	.721	18.847	98	5.69	7.03
humidity	8.141	.005	4.947	98	8.15	19.07
amount of rainfall	10.941	.001	2.273	100	1.07	15.74
confirmed cases	23.439	.000	4.395	99	2193.47	5804.04
conffirmed deaths	152.743	.000	9.643	99	480.63	729.66

Only high temperature did'not show a statistically significant difference between Brasília and Manaus.

According to discussion provided by Gutiérrez-Hernández and García (2020) and Iqbal et al. (2020), our results suggest that there is possible relationship between the weather and the number of deaths related to Covid-19. In Table 6 we present the averages obtained for Brasília and Manaus, with the t test, as well as the size of the 'Cohen's d effect' for independent samples.

We then decided to check the indicators of correlation between the variables analised. We want to identify their degree of relationship between the two cities analyzed. We decided to present Pearson's correlation, indicating that there is linearity between the indicators. Pearson´s indicators were stronger than Spearman´s. Table 7 shows the Pearson's correlation coefficients among the variables.

The higher temperatures were correlated significantly with new cases of Covid-19 (r=.288). Low temperatures were correlated positively with confirmed deaths by Covid-19 (r=.640). New cases are correlated negatively with the percentage of social isolation (r=, -.268). These findings are similar to others findings (Bashir et al., 2020; Liu et.al., 2020).

The data sugests that the lower the percentage of isolation, the greater the tendency to be infected by Covid-19. Whereas causality assumptions can not be made with the scores of correlations, these results suggest that some indicators could explain

Table 6. Averages with test t and Cohen´s d effect size.

	Manaus			Brasília			
	N	Mean	Standard error	N	Mean	Standard error	Cohen's d
Percentage of social isolation	51	49.065	4.1677	51	44.310	3.7932	.05972
Temperature minimum	49	24.845	.8334	51	15.339	2.5828	.27538
Temperature maximum	49	31.592	1.6970	51	25.233	1.6764	.01911
Humidity	49	70.14	10.766	51	56.53	16.111	.05043
Amount of rainfall	51	11.018	25.4144	51	2.612	7.1804	.02579
Confirmed cases	50	7765.54	5618.418	51	3766.78	3231.937	.04530
Conffirmed deaths	50	668.52	445.364	51	63.37	49.863	.12319

Table 7. Pearson's correlation coefficients among the variables.

	Cd	Si	Mintemp	Maxtemp	Rh	Pi	Cf	Nc	Pp
Cd	1								
Si	.050	1							
Mintemp	.640**	.528**	1						
Maxtemp	.643**	.416**	.823**	1					
Rh	.248*	.411**	.609**	.176	1				
Pi	.110	.327**	.213*	.180	.141	1			
Cf	.877**	-.234*	.266**	.389**	-.028	.009	1		
Nc	.539**	-.268**	.168	.288**	-.080	-.096	.653**	1	
Pp	-.696**	-.516**	-.927**	-.885**	-.447**	-.222*	-.404**	-.268**	1

Note. cd = confirmed deaths; si = percentage of social isolation; min temp = low temperature; max temp = high temperature; rh = humidity; pi = amount of rainfall cf = confirmed cases; nc = ne cases; pp = population; **p<.001; *p<.005.

the number of confirmed deaths from Covid-19 in both Brazilian cities

To further address the research question outlined in the introduction of this study, a linear regression model was tested. The dependent variable was defined as the 'number of accumulated deaths' and all other indicators (meteorological, geographical and social) were tested as independent variables. The goal was to identify whether some of the indicators measured could be predictors of the number of deaths accumulated over the 51 days of observation and information collection in Brasília and Manaus. The data are shown in Table 8.

The only statistically significant predictors of the cumulative number of Covid-19 deaths were the percentage of social isolation (β = -.254) and the daily record of new cases of the vírus (β = .332). The R-squared of was 0.646, the adjusted R-squared was .623. No wheater indicator contributed significantly to the prediction of the number of accumulated deaths resulting from Covid-19 in Brasília and Manaus.

It is noted, on the other hand, that the negative Beta in the percentage of social isolation suggests that it is a predictor of the number of accumulated deaths resulting from Covid-19 in Brasília and Manaus. This corroborates, according to the recommendations of WHO (2020a) and WHO (2020b), the importance of adopting the strategy of preventing to the contagion adopting social isolation.

It is noteworthy remember that in none of these cities, Manaus and Brasília, the lockdown strategy was yet adopted. Findings suggest, according to Shahzad et. al. (2020), Tosepu et. al. (2020), Wang et. al. (2020) and Zhu and Xie (2020), that wheather factors have a reasonable contribution to explaining the behavior of the Covid-19, at least for this model tested. Although the correlations suggested that there was an influence between wheather indicators with the number of deaths by Covid-19, none of these indicators contributed significantly as a predictor in the tested model. Obviously, new research needs to be done in order to test these predictive relationships in other Brazilian cities that have less or more humidity relative of the air.

CONCLUSIONS AND RECOMENDATIONS

We conducted this research considering two theoretical premises: the first one, about the importance of trying to understand the behavior of Covid-19 in two Brazilian cities whose percentage of relative humidity was very diferente between them; and the second, considering the lack of a study of Covid-19 in tropical climate countries.

To achieve our purpose, we explored linear relationships between wheather indicators (low temperatures, high temperatures, humidity and amount of rainfall), social indicators (rate of social isolation) and indicators related to the contagy and

Table 8. Regression coefficients for the model.

	B	Standard error	B	T	Sig.
Constant	-286.691	472.233	-	-.607	.545
Si	-23.978	7.916	-.254**	-3.029	.003
Lowtemp	45.165	16.722	.532**	2.701	.008
Hightemp	24.166	19.614	.200	1.232	.221
Rh	.271	3.268	.009	.083	.934
Pi	1.709	1.508	.075	1.133	.260
Nc	.535	.117	.332***	4.584*	.000

Note: r = .763; r2 = .646; r2 adjusted= .623 **p < 0.01; Note. Dependent variable: cd (confirmed deaths of Covid-19); si = percentage of social isolation; min temp = low temperature; max temp = high temperature; rh = humidity; pi = amount of rainfall; nc = new cases.

spread of dissemination of Covid-19 (number of new cases, number of confirmed cases and number accumulated deaths) over 51 days of observation and recording of secondary information.

We built a generalized linear model to better understand the behavior of the growth curve of Covid-19 and the role of each factor to explain trends. The linear model predicted R-square adjusted was a reasonable 0.623., indicating that the model explains approximately 62% of Covid-19 confirmed cases in Manaus and Brasília.

Of course, there are other factors that may contribute to explain the increase in the number of Covid-19 cases in Brasília and Manaus. Can air quality influence the speed at which the virus spreads? Can air pollution influence the speed of propagation of Covid-19? In metropolitan regions is the speed of spread of the virus greater than in regions of more isolated forests?

The effectiveness of public policies in each state, for example, can also be an antecedent variable. Social isolation, use of masks and social distance are the main strategy to prevent the vírus in Brazil. In regions where commercial activities have already resumed, is the speed of propagation and contamination of the virus greater?

The T test showed that there are differences in the behavior of the data due to being in Brasília or Manaus. Therefore, specificities between these two regions need to be tested again. The spread of Covid-19 in Brazil is very fast, so the results of this study will be useful in efforts to prevent the spread of Covid-19 disease.

DECLARATION OF CONFLICTS OF INTEREST

The authors declared that they have no conflict of interests.

FUNDING

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

AL-Rousan, N., y Al-Najjar, H. (2020). Nowcasting and Forecasting the Spreading of Novel Coronavirus 2019-nCoV and Its Association with Weather Variables in 30 Chinese Provinces: A Case Study. *SSRN Electronic Journal.* https://doi.org/10.2139/ssrn.3537084

Altamimi, A. y Ahmed, A. E. (2019). Climate factors and incidence of Middle East respiratory syndrome coronavirus. *Journal of Infection and Public Health, 13*(5), pp. 704-708. https://doi.org/10.1016/j.jiph.2019.11.011

Alvarez-Ramirez, J. y Meraz, M. (2020). Role of meteorological temperature and relative humidity in the January-February 2020 propagation of 2019-nCoV in Wuhan, China. *MedRxiv.* https://doi.org/https://doi.org/10.1101/2020.03.19.20039164

Andersen, K. G., Rambaut, A., Lipkin, W. I., Holmes, E. C., y Garry, R. F. (2020). The proximal origin of SARS-CoV-2. *Nature Medicine, 89*(1), pp. 44–48. https://doi.org/10.1038/s41591-020-0820-9.

Araújo, M. B., y Naimi, B. (2020). Spread of SARS-CoV-2 Coronavirus likely to be constrained by climate. *MedRxiv.* https://doi.org/10.1101/2020.03.12.20034728

Bannister-Tyrrell, M., Meyer, A., Faverjon, C., y Cameron, A. (2020). Preliminary evidence that higher temperatures are associated with lower incidence of COVID-19, for cases reported globally up to 29th February 2020. *MedRxiv.* https://doi.org/https://doi.org/10.1101/2020.03.18.20036731

Bariotakis, M., Sourvinos, G., Castanas, E. y Pirintsos, S. A. (2020). Climatic influences on the worldwide spread of SARS-CoV-2. *MedRxiv.* https://doi.org/https://doi.org/10.1101/2020.03.19.20038158

Bashir, M. F., Ma, B., Bilal, Komal, B., Bashir, M. A., Tan, D., y Bashir, M. (2020). Correlation between climate indicators and COVID-19 pandemic in New York, USA. *Science of The Total Environment, 728*. https://doi.org/10.1016/j.scitotenv.2020.138835

Brazilian Institute of Geography and Statistics. (2020). *Conheça cidades e estados do Brasil*. Available on https://cidades.ibge.gov.br/.

Brazilian Ministry of Health. (2020a). *Painel Coronavírus.* Available on https://covid.saude.gov.br/

Brazilian Ministry of Health. (2020b). *Covid-19 no Brasil.* https://covid-insumos.saude.gov.br/paineis/insumos/painel.php

Brazilian Social Isolation Index. (2020). *Mapa brasileiro da Covid-19*. Available on https://mapabrasileirodacovid.inloco.com.br/pt/

Bukhari, Q., y Jameel, Y. (2020). Will Coronavirus Pandemic Diminish by Summer? *SSRN.Elsevier*, https://doi.org/10.2139/ssrn.355699

Chan, K. H., Peiris, J. S. M., Lam, S. Y., Poon, L. L. M., Yuen, K. Y., y Seto, W. H. (2011). The Effects of Temperature and Relative Humidity on the Viability of the SARS Coronavirus. *Advances in Virology*, Article 734690, https://doi.org/10.1155/2011/734690

Dantas, G., Siciliano, B., França, B.B., Silva, C.M., y Arbilla, G. (2020). The impact of COVID-19 partial lockdown on the air quality of the city of Rio de Janeiro, Brazil. *Science of the Total Environment,* 729, https://doi.org/10.1016/j.scitotenv.2020.139085

Ghosh, A., Nundy, S., Ghosh, S. y Mallick, T. K. (2020). Study of COVID-19 pandemic in London (UK) from urban contexto. *Cities*, *106,* 1-9, https://doi.org/10.1016/j.cities.2020.1029288

Gutiérrez-Hernández, O. y García, L.V. (2020). ¿Influyen tiempo y clima en la distribución del nuevo coronavirus (SARS CoV-2)? Una revisión desde una perspectiva biogeográfica. *Investigaciones Geográficas, 73*, 31-55. https://doi.org/10.14198/INGEO2020.GHVG

Hopkins, J. (2020). *Coronavirus Research Center*, John Hopkins University of Medicine, https://coronavirus.jhu.edu/map.html

Iqbal, N., Fareed, Z., Shahzad, F., He, X., Shahzad, U. y Lina, M. (2020). Nexus between COVID-19, temperature and exchange rate in Wuhan City: new findings from Partial and Multiple Wavelet Coherence, *Sci. Total Environ., 729*, Article 138916

Le, N.K., Le, A.V., Parikh, J., Brooks, J.P., Gardellini, T. y Izurieta, R. (2020). Ecological andhealth infrastructure factors affecting the transmission and mortality of COVID-19. *BMC Infect. Dis.*, https://doi.org/10.21203/rs.3.rs-19504/v1 .

Li, Q., Guan, X., Wu, P., Wang, X., Zhou, L., Tong, Y. y Wong, J.Y. (2020). Early transmission dynamics in Wuhan, China, of novel coronavirus–infected pneumonia. *N. Engl. J. Med., 382*(13), 1199-1207, https://doi.org/10.1056/NEJMoa2001316

Lian, J., Jin, X., Hao, S., Cai, H., Zhang, S., Zheng, L. y Zhang, Y (2020). Analysis of Epidemiological and Clinical features in older patients with Corona Virus Disease 2019 (COVID-19) out of Wuhan. *Clinical Infectious Diseases, 242*, https://doi.org/10.1093/cid/ciaa242

Liu, J., Zhou, J., Yao, J., Zhang, X., Li, L., Xu, X., He, X., Wang, B., Fu, S., Niu, T., Yan, J., Shi, Y., Ren, X., Niu, J., Zhu, W., Li, S., Luo, B. y Zhang, K. (2020). Impact of meteorological factorson the COVID-19 transmission: a multi-city study in China. *Sci. Total Environ*, *729*, https://doi.org/10.1016/j.scitotenv.2020.138513Elsevier .

Ma, Y. Zhao, J. Liu, X. He, B. Wang, S. y Fu, S., B. (2020). Effects of temperature variation and humidity on the death of COVID-19 in Wuhan, China. *Science of The Total Environment, 724*, Article 138226

National Institute of Meteorology. (2020a). *Condições de tempo registradas nas capitais até às 18 UTC*. Available on http://www.inmet.gov.br/portal/index.php?r=tempo/condicoesTempoCapitais

National Institute of Meteorology. (2020b). *Centro de previsão de tempo e estudos climáticos*. Available on http://bancodedados.cptec.inpe.br

Prata, D.N., Rodrigues, W., & Bermejo, P.H. (2020). Temperature significantly changes COVID-19 transmission in (sub)tropical cities of Brazil. *Sci. total. Environment, 729*. https://doi.org/10.1016/j.scitotenv.2020.1388620048-9697

Rodriguez-Morales, A.J., Gallego, V., Escalera-Antezana, J.P., Méndez, C.A., Zambrano, L.I., Franco-Paredes, C., Suáreza, J.A., Rodriguez-Enciso, H.D., Balbin-Ramon, G.J., Savio-Larriera, E., Risquez, A. y Cimerman, S. (2020). COVID-19 in Latin America. The implications of the first confirmed case in Brazil. *Travel Med. Infec. Dis*, *35*, https://doi.org/10.1016/j.tmaid.2020.101613

Saadat, S., Rawtani, D. y Hussain, C.M. (2020). Environmental perspective of COVID-19. *Science of Total Environment, 728*, https://doi.org/10.1016/j.scitotenv.2020.138870

Shahzad, F., Shahzad, U., Fareed, Z., Shujahat, N., Hashmi, H. y Ahmad, F. (2020), Asymmetric nexus between temperature and COVID-19 in the top ten affected provinces of China: A current application of quantile-on-quantile approach. *Science of total environment, 236*, https://doi.org/10.1016/j.scitotenv.2020.139115

Sohrabi, C., Alsafi, Z., O'Neill, N., Khan, N., Kerwan, M., Al-Jabir, A. y Agha, R. (2020). World Health Organization declares global emergency: A review of the 2019 novel coronavirus (COVID-19), *International Journal of Surgery, 76*, 71-76.

Tobias, A., Carnerero, C., Reche, Massagué, J., Via, M., Minguillón, M.C., Alastuey, A. y Querol, X. (2020). Changes in air quality during the lockdown in Barcelona (Spain) one month into the SARS-CoV-2 epidemic. *Sci. Total Environ., 726*, Article 138540, 10.1016/j.scitotenv.2020.138540

Tosepu, R., Gunawan, J., Effendy, D.S., Lestari, H., Bahar, H., P. y Asfian, P. (2020). Correlation between weather and Covid-19 pandemic in Jakarta, Indonesia. *Sci. Total Environ., 725*, Article 138436, 10.1016/j.scitotenv.2020.138436

Wang, C., Horby, P.W., Hayden, F.G. y Gao, G.F. (2020). A novel coronavirus outbreak of global health concern. *Lancet, 395*, 470-473.

Wang, M., Jiang, A., Gong, L., Lu, L., Guo, W., Lu, L., Guo, W., Li, C., Zheng, J., Li, C., Yang, B., Zeng,

J., Chen, Y., Zheng, K. y Li, H. (2020). Temperature significantly change COVID-19 transmission in 429 cities. *medRxiv*. https://doi.org/10.1101/2020.02.22.20025791.

WHO. (2005). World Health Organization. Global update 2005. *Particulate matter, ozone, nitrogen dioxide and sulfur dioxide.* http://www.euro.who.int/InformationSources/Publications/Catalogue/20070323_1.

WHO. (2020a). World Health Organization. *WHO director-general's opening remarks at the media briefing on COVID-19*. https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at--the-media-briefing-on-covid-19---11-March-2020

WHO. (2020b). World Health Organization. *Novel coronavirus (2019-nCoV)*. http://www.euro.who.int/en/health-topics/health-emergencies/novel-coronavirus-2019-ncov_old

Xi, J., Xu, K., Jiang, P., Lian, J., Hao, S., Jia, H. y Chen, D. (2020). Virus strain of a mild COVID-19 patient in Hangzhou representing a new trend in SARS-CoV-2 evolution related to Furin cleavage site. *Emerging Microbies & Infections, 9,* https://doi.org/10.1080/22221751.2020.1781551

Xu, Z., Shi, L., Wang, Y., Zhang, J., Huang, L., Zhang, C., Liu, S., Zhao, P., Liu, H. y Zhu, L. (2020). Pathological findings of COVID-19 associated with acute respiratory distress syn-drome. *Lancet Respir. Med., 8*(4), pp. 420-422. https://doi.org/10.1016/S2213-2600(20)30076-X

Yongjiana, Z., Jingubc, X., Fengmingb, H. y Liqingb, C. (2020). Association between short-term exposure to air pollution and COVID-19 infection: evidence from China. *Science of the Total Environment, 727*, https://doi.org/10.1016/j.scitotenv.2020.138704 .

Zhu, Y. y Xie, J. (2020). Association between ambient temperature and COVID-19 infection in 122 cities from China. *Science of the Total Environment,* 724, https://doi.org/10.1016/j.scitotenv.2020.138704.7D.N .

Zhu, N., Zhang, D., Wang, W., Li, X., Yang, B., Song, J. y Lu, R. (2020). A novel coronavirus from patients with pneumonia in China, 2019. *The New England Journal of Medicine, 382* (8), 10.1056/NEJMoa2001017