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TEMPERATURE, HUMIDITY, AND RAINFALL: HOW DO THEY CORRELATE WITH COVID-19? A REVIEW OF THE SCIENTIFIC LITERATURE

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Abstract
The SARS-CoV-2 pandemic has caught the attention of the scientific community. Most research revolves around the effects of the virus on people's health and the development of a vaccine to immunize the population. Studies on the relationship of the new coronavirus with meteorological factors such as humidity, temperature, and rainfall have also been numerous. However, the results have been ambiguous and, in some cases, contradictory. For this reason, this research aims to analyze in-depth the publications (peer-reviewed) that have studied the correlation between COVID-19 and meteorological factors, mainly. It was found that most research finds a negative relationship between cases of COVID-19 infection with temperature and humidity. There is no clear evidence linking rainfall to the spread of the pandemic. However, some results may be biased by the non-inclusion of essential variables such as population density, migration rate, family income, among others.
JEL Codes: Q53, Q54

Resumen
La pandemia del SARS-CoV-2 ha llamado la atención de la comunidad científica. La mayor parte de la investigación gira en torno a los efectos del virus en la salud de las personas y el desarrollo de una vacuna para inmunizar a la población. También han sido numerosos los estudios sobre la relación del nuevo coronavirus con factores meteorológicos como la humedad, la temperatura y las precipitaciones. Sin embargo, los resultados han sido ambiguos y, en algunos casos, contradictorios. Por ello, esta investigación tiene como objetivo analizar en profundidad las publicaciones (revisadas por pares) que han estudiado la correlación entre el COVID-19 y los factores meteorológicos, principalmente. Se encontró que la mayoría de las investigaciones encuentran una relación negativa entre los casos de infección por COVID-19 con la temperatura y la humedad. No hay evidencia clara que vincule las lluvias con la propagación del virus. Sin embargo, algunos resultados pueden estar sesgados por la no inclusión de variables esenciales como la densidad de población, la tasa de migración, el ingreso familiar, entre otras.

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INTRODUCCIÓN

The new coronavirus (SARS-CoV-2) has forced many countries to adopt policies of social isolation and prevention to stop the spread of the disease. However, despite these measures, the virus continues to spread in most countries of the world.

Although worldwide interest is focused on seeking a cure for the disease, the relationship between COVID-19 and the environment has not gone unnoticed. The reason is that certain types of viruses can be transmitted due to different factors, such as climatic conditions (temperature, rainfall, and humidity) and population density (Dalziel et al., 2018; Huang et al., 2020; Hemmes et al., 1962).

For example, Bourouiba (2020) demonstrated that under certain combinations of the environmental and physiological conditions, such as humidity and temperature, the gas cloud and its payload of pathogenic droplets of all sizes can travel up to 8 meters.

A large number of studies have focused on analyzing the correlation between meteorological variables (mainly air humidity, temperature, and rainfall) with cases of COVID-19 infection and deaths. The results have been diverse. Many studies have found evidence that meteorological variables affect the number of COVID-19 cases. However, the findings have been conflicting. Some authors have estimated a positive correlation between meteorological factors and COVID-19 cases. Other studies found a negative relation.

On the other hand, some studies have ruled out that the meteorological variables are associated in any way with the number of cases of the new coronavirus. In fact, some authors argue that non-meteorological variables (such as population density, family income, the scale of migration index, etc.) could be more decisive in explaining the spread of the disease.

This article aims to explain the research that has studied the correlation of humidity, temperature, and rainfall with the cases of COVID-19. It is essential to compare the different studies, as this will give a clearer picture to the scientific community about the relationship between these variables. Our research will also be useful for future studies to deepen these relationships, using appropriate approaches and other variables of interest (apart from the meteorological ones).

The rest of the article is structured as follows: in section 2, the method is presented. Section 3 discusses the results. Section 4 presents the discussion. Section 5 concludes.

METHODOLOGY

According to Sardin and Peters (2018), the method used in the literature review consists of two steps: (i) identify the literature to be studied, through a search in databases combined with a set of rules to select the relevant information from the literature, and (ii) map the content of the selected literature by extracting information using a set of questions. These two steps are described below.

Identification of literature

The Scopus, Science Direct, and Google Scholar databases were searched for literature during May 2020, using the following sentences: "Correlation between temperature and COVID-19", "Correlation between Humidity and COVID-19", "Correlation between rainfall and COVID-19".

The following selection rules were established to select a set of relevant and manageable studies among the identified pieces of literature:

- Inclusion of only published (peer-reviewed) studies online, in their final version or in press.
- Inclusion of studies from any geographical area.
- Exclusion from studies in languages other than English or Spanish.

- Exclusion of studies on the analysis of meteorological variables and cases of COVID-19 that have not numerically quantified the relationship.

Assignment of content

The content of the selected studies was mapped by extracting information through the following questions:

- Where was the study conducted?
- What methodology did the authors implement?
- Did they consider non-meteorological variables in their studies? If yes, were these variables significant?
- Did they analyze the correlation between COVID-19 infections and temperature? If yes, what type of correlation did they establish?
- Did they analyze the correlation between COVID-19 infections and humidity? If yes, what type of correlation did they establish?
- Did they analyze the correlation between COVID-19 infections and rainfall? If yes, what type of correlation did they establish?
- Did they analyze the correlation between deaths from COVID-19 and temperature? If yes, what type of correlation did they establish?
- Did they analyze the correlation between deaths from COVID-19 and humidity? If yes, what type of correlation did they establish?
- Did they analyze the correlation between deaths from COVID-19 and rainfall? If yes, what type of correlation did they establish?

RESULTS

Summary of publications

The rules for selecting the literature described in the previous section generated a list of 32 publications. Considering the short period from the onset of the pandemic to date, a relatively acceptable number was considered.

Study location and implemented methodology

According to the literary review, almost 25% of the correlation studies between meteorological variables (mainly) and cases of COVID-19 are from China, followed by those from USA, Brazil and Spain. On the other hand, six studies carried out an analysis for a group of countries. These studies are from Sobral et al. (2020), Wu et al. (2020), Demongeot et al. (2020), Sarmadi et al. (2020), Lin et al. (2020) and Iqbal et al. (2020b).

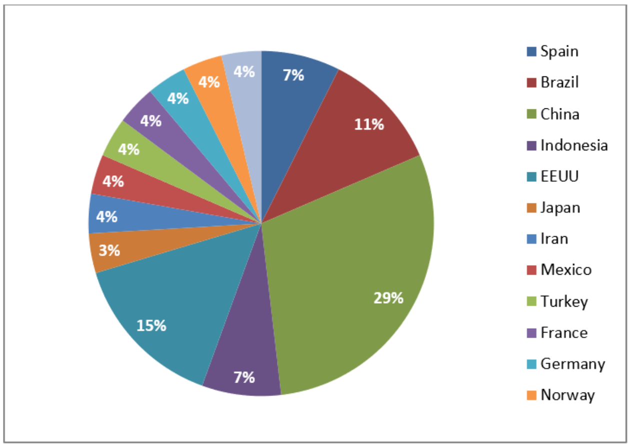

Figure 1. Percentage of studies by location.

Figure 2 shows the main methodologies implemented in the studies. The most widely used approach was the Spearman's correlation test (9 times), followed by the Generalized Additive Model (GAM) and Linear regression model.

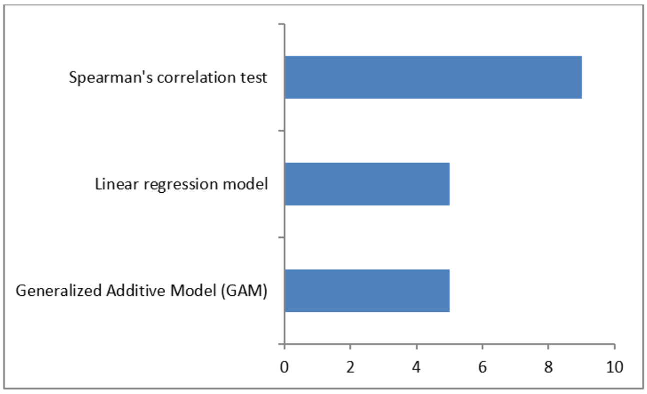

Figure 2. Main methodologies implemented (number of times).

Non-meteorological variables included in the studies

Of the 32 studies analyzed, only 12 supplemented their analysis by including non-meteorological variables. On this, the population density was the most widely used non-meteorological variable, followed by population size.

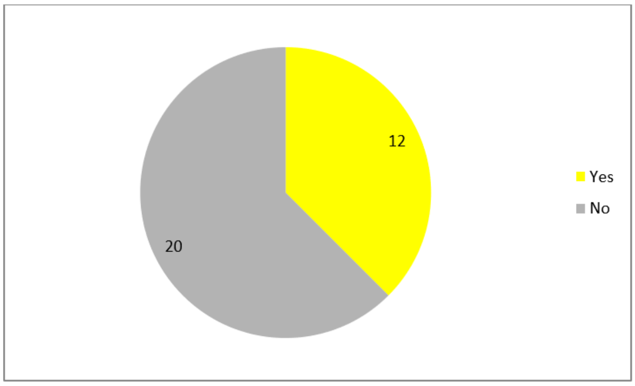

Figure 3. Number of studies that included non-meteorological variables.

On the other hand, Table 1 presents a summary of the studies analyzed. The most studied correlation was that of COVID-19 infections and temperature. Different results are presented in this category. Authors like Sobral et al. (2020), Prata et al. (2020), Liu et al. (2020), Shi et al. (2020), Qi et al. (2020), Wu et al. (2020), Ujiie et al. (2020), Méndez-Arriaga (2020), Tobías and Molina (2020), Şahin (2020), Demongeot et al. (2020), Sarmadi et al. (2020), Li et al. (2020), Runkle et al. (2020), Lin et al. (2020), Rendana (2020), Iqbal et al. (2020b), and Rosario et al. (2020) conclude that temperature is negatively correlated with COVID-19 cases. That is, the speed of the contagion decreases with increasing temperature. However, Prata et al. (2020) highlight that the observed negative linear correlation occurs in the temperature range below 25.8 ° C. Above that temperature, the correlation becomes flat (non-existent). Méndez-Arriaga (2020) also clarifies that this negative correlation occurs in phase 1 of the disease.

Other authors such as Tosepu et al. (2020), Bashir et al. (2020), Xie and Zhu (2020), and Menebo (2020) found a positive correlation between temperature and COVID-19 cases. Xie and Zhu (2020) clarify that this relationship occurs when the ambient temperature is below 3 °C. On the other hand, the study of Shahzad et al. (2020) and Auler et al. (2020) found mixed results. Shahzad et al. (2020) mention that in Hubei, Hunan, and Anhui, provinces of China, the correlation is positive, while in the Zhejiang and Shandong provinces, the relationship becomes negative. Finally, Briz-Redón & Serrano-Aroca (2020), Iqbal et al. (2020a), Mollalo et al. (2020), Jahangiri et al. (2020), Yao et al. (2020) and To et al. (2021) concluded that the temperature does not correlate with COVID-19 cases. In the work of Iqbal et al. (2020a), the covariance was explicitly analyzed. The authors suggest that the increase in temperature played no significant role in containing the spread of COVID-19 in Wuhan, China.

For the case of humidity and its relationship with COVID-19 cases, most studies found a negative correlation (Liu et al., 2020; Qi et al., 2020; Wu et al., 2020; Şahin, 2020). Four studies concluded that humidity does not correlate with COVID-19 cases (Tosepu et al., 2020; Bashir et al., 2020; Rendana, 2020; Rosario et al., 2020). Meanwhile, Auler et al. (2020) and Lin et al. (2020) found mixed results. According to Auler et al. (2020), an increase in humidity is negatively correlated with the cases of COVID-19 in São Paulo and Rio de Janeiro. However, the correlation becomes positive when all cities in Brazil are considered in the analysis. On another note, Lin et al. (2020) mentioned that when the temperature is low, humidity is positively correlated with COVID-19 cases. The opposite happens when the temperature is high.

Regarding rainfall and its relationship with COVID-19 cases, most studies found no evidence of a linear association between these variables (Tosepu et al., 2020; Mollalo et al., 2020; Bashir et al., 2020; Rendana, 2020; Rosario et al., 2020). However, the study by Sobral et al. (2020) concluded that cases of the new coronavirus are positively associated with rainfall while the study by Menebo (2020) found a negative correlation.

Analyzing the SARS-CoV-2 mortality cases and their relationship with temperature, the literature showed mixed results. On the one hand, Ma et al. (2020) and Bashir et al. (2020) found a positive relation. While Wu et al. (2020), Sarmadi et al. (2020), Rendana (2020) and Iqbal et al. (2020b) evidenced a negative correlation.

In the case of humidity, the studies found a negative relationship (Wu et al., 2020; Ma et al., 2020; Biktasheva, 2020). In other words, an increase in humidity could help reduce the cases of mortality from COVID-19. Finally, no evidence was found that the rainfall was related to the cases of mortality caused by COVID-19 (Sobral et al., 2020; Bashir et al., 2020; Rendana, 2020).

Table 1.

Correlation between Covid-19 cases and meteorological variables.

Authors	Country/Study location	Methodology	Non-meteorological variables included in the study	Correlation between infections by COVID-19 and Temperature	Correlation between COVID-19 infections and Humidity	Correlation between infections by COVID-19 and rainfall	Correlation between deaths from COVID-19 and temperature	Correlation between deaths from COVID-19 and humidity	Correlation between deaths from COVID-19 and rainfall
Sobral et al. (2020)	Countries affected by COVID-19	- Panel data	-Population density. -Exposure time (significant)	Negative	Not analyzed	Positive	Not found	Not analyzed	Not found
Briz-Redón & Serrano-Aroca (2020)	Spain provinces	- Integrated Nested Laplace Approximation (INLA)	- Population density. -Population by age - Number of travelers -Number of companies	Not found	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Prata et al. (2020)	Sub-tropical cities of Brazil	-Generalized Additive Model (GAM) - Polynomial (cubic) regression model - Spearman's correlation test	- Population density. (significant). -Estimated population (significant)	Negative[1]	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Liu et al. (2020)	30 provincial capital cities of China.	- Generalized linear models with negative binomial distribution - Random effects meta-analysis	- Migration scale index	Negative[2]	Negative	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Iqbal et al. (2020a)	Wuhan (China)	-Novel methods of Wavelet Transform Coherence,	None	Not found[3]	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed

		Partial and Multiple Wavelet Coherence.							
Tosepu et al. (2020)	Jakarta (Indonesia)	- Spearman's correlation test	None	Positive	Not found	Not found	Not analyzed	Not analyzed	Not analyzed
Ma et al. (2020)	Wuhan (China)	-GAM with a quasi-Poisson link function	None	Not analyzed	Not analyzed	Not analyzed	Positive[4]	Negative	Not analyzed
Mollalo et al (2020)	USA	- Linear regression model. - Spatial lag model (SLM). - Spatial error model (SEM). -Geographically weighted. regression (GWR) - Multiscale GWR (MGWR).	- Income inequality (significant). -Average family income (significant). - Proportion of black women (significant). -Proportion of nurse practitioners (significant).	Not found	Not analyzed	Not found	Not analyzed	Not analyzed	Not analyzed
Shi et al. (2020)	31 provinces of China	-Locally weighted regression and smoothing scatterplot (LOESS). -Distributed lag nonlinear models (DLNMs). -Random-effects meta-analysis	None	Negative	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Qi et al. (2020)	30 provinces of China	-Generalized Additive Model (GAM)	None	Negative	Negative	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Bashir et al. (2020)	New York (USA)	- Kendall´s correlation test	None	Positive[5]	Not found	Not found	Positive[6]	Not found	Not found

		- Spearman's correlation test							
Wu et al. (2020)	166 countries	-Generalized Additive Model (GAM)	- Median age of the national population. - Global Health Security Index. -Human Development Index. -Population density	Negative	Negative	Not analyzed	Negative	Negative	Not analyzed
Shahzad et al. (2020)	10 provinces of China	- Quantile-on-quantile (QQ) approach	None	Positive[7] and Negative[8]	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Xie and Zhu (2020)	122 cities of China	-Generalized Additive Model (GAM)	None	Positive[9]	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Ujiie et al. (2020)	Japan	-Poisson regression analysis	-Monthly number of incoming visitors from China. (significant) -Dependence rate of old age. (significant)	Negative	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Auler et al. (2020)	São Paulo, Rio de Janeiro, Brasilia, Manaos and Fortaleza (Brazil)	- Principal component analyses (PC) and canonical correlation	None	Positive[10] and Negative[11]	Positive[12] and Negative[13]	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Jahangiri et al. (2020)	Provinces of Iran	-Receiver Operating Characteristics (ROC)	-Population size (significant)	Not found	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Méndez-Arriaga (2020)	31 states of Mexico and their capital	-Spearman's non-parametric test	None	Negative[14]	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed

Tobías and Molina (2020)	Barcelona (Spain)	-Distributed-lag model. - Quasi-Poisson regression model	None	Negative	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Şahin (2020)	9 cities of Turkey	-Spearman's correlation test	-Population size	Negative	Negative	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Yao et al. (2020)	224 cities in China	Chi-squared test	None	Not found	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Demongeot et al. (2020)	21 countries and in the French administrative regions	-Autoregressive integrated moving average (ARIMA) model	None	Negative	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Biktasheva (2020)	German federal states	-Linear regression model	None	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Negative	Not analyzed
Menebo (2020)	Oslo (Norway)	-Spearman's correlation test	None	Positive[15]	Not analyzed	Negative	Not analyzed	Not analyzed	Not analyzed
Sarmadi et al. (2020)	Countries affected by COVID-19	-Bivariate correlation and regression test	-Size of the population -Gross domestic product -Geographical position	Negative	Not analyzed	Not analyzed	Negative	Not analyzed	Not analyzed
To et al. (2021)	Canada	-Linear regression model	None	Not found	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Li et al. (2020)	USA	- Linear regression model -Logistic regression	-Race	Negative	Not analyzed	Not analyzed	Not found	Not analyzed	Not analyzed
Runkle et al. (2020)[16]	USA	- Distributed Lag Nonlinear Model	None	Negative	Positive[17]	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Lin et al. (2020)	-Singapore -Philippines -Japan -United State	-SEIR model	-Population -Hospital beds -Nurses -Physicians	Negative	Positive[18] and Negative [19]	Not analyzed	Not analyzed	Not analyzed	Not analyzed

	-England -Spain -Australia -South Africa								
Rendana (2020)	-Jakarta (Indonesia)	-Spearman's correlation test	None	Negative	Not found	Not found	Negative	Not found	Not found
Iqbal et al. (2020b)	Countries affected by COVID-19	-Linear regression model	None	Negative	Not analyzed	Not analyzed	Negative	Not analyzed	Not analyzed
Rosario et al. (2020)	Rio de Janeiro (Brazil)	-Spearman's correlation test	None	Negative	Not found	Not found	Not analyzed	Not analyzed	Not analyzed

[1] Linear correlation in the range of less than 25.8 ° C. Plane above 25.8 ° C.
[2] Both for ambient temperature and daytime temperature.
[3] Covariance was specifically analyzed. The authors suggest that the increase in temperature played no significant role in containing the spread of COVID-19 in Wuhan.
[4] Daytime temperature.
[5] Average and minimum temperature.
[6] Average temperature.
[7] For Hubei, Hunan and Anhui.
[8] For Zhejiang and Shandong.
[9] When the ambient temperature is less than 3 ° C.
[10] All cities
[11] Manaos, Rio de Janeiro, São Paulo.
[12] All cities.
[13] São Paulo, Rio de Janeiro.
[14] Phase 1.
[15] Maximum temperature and normal temperature.
[16] Significant relationships between meteorological variables and COVID-19 cases were found only in the locations of Albany, GA, New Orleans, LA, New York City, NY, and Chicago, IL.
[17] With short-term specific humidity.
[18] When the temperature is low.
[19] When the temperature is high.

DISCUSSION

The pandemic caused by the new coronavirus has generated unprecedented impacts in most countries of the world. Since its first appearance in Wuhan, China, many related studies have been published. Although most of these studies have been in the health field, the relationship between COVID-19 and the environment has not gone unnoticed.

One of the topics most studied by researchers in the environmental field has been the relationship between COVID-19 cases and meteorological factors such as temperature, humidity, and rainfall. The results have been diverse and, in some cases, contradictory.

This research aims to expose and discuss the results of studies that have analyzed the relationship between the new coronaviruses and meteorological factors. For this, 32 peer-reviewed scientific publications were analyzed.

Our analysis shows that the majority of studies have been carried out for the countries most affected by the pandemic, such as China, the USA, Brazil, Spain, among others. The authors have used a variety of approaches for correlation analysis, from simple methods such as the Spearman's correlation test to more complete methods such as Generalized Additive Model (GAM), Locally weighted regression and smoothing scatterplot (LOESS), Wavelet Transform Coherence, Partial and Multiple Wavelet Coherence, among others.

For the relationship between temperature and COVID-19 cases, most studies favor a negative relationship. That is, the speed of the contagion decreases with increasing temperature. For example, the study by Tobías & Molina (2020), found that an average increase of 1 ° C in maximum temperature in Barcelona (Spain), decreased the incidence rate of infections by 7.5% (95% CI = [12.3; 2.6]) the same day (delay 0). If this is true, with the arrival of spring and summer in the northern hemisphere a decrease in the rate of progression of COVID-19 would be expected. On the contrary, the southern hemisphere is at risk of more severe outbreaks in the coming months.

Authors such as Demongeot et al. (2020) point out that although the speed of infection indeed decreases with temperature in the country or region, this occurs only in the early stages of the virus. In the later stages of the epidemic, the relationship between temperature and cases of infection is not clear. The studies by Méndez-Arriaga (2020) and Holtmann et al. (2020) confirm this theory. Additionally, other authors such as Prata et al. (2020) highlight that the observed negative linear correlation occurs only in the temperature range below 25.8 ° C. Above that temperature, the correlation becomes non-existent. This result was observed in some sub-tropical cities in Brazil.

Other studies found a positive relationship between COVID-19 cases and temperature (Tosepu et al., 2020; Bashir et al., 2020; Xie and Zhu, 2020; Menebo, 2020). Analyzing these four studies, it can be seen that none of them considered other variables than meteorological variables. As Briz-Redón and Serrano-Aroca (2020) point out, studies that have only considered meteorological factors for their analysis could have unreliable results. According to the authors, non-meteorological factors such as population density, population by age, number of travelers, and the number of companies should be considered.

Other studies concluded that there was no significant relationship between cases due to COVID-19 and temperature (Briz-Redón & Serrano-Aroca, 2020; Iqbal et al., 2020a; Mollalo et al., 2020; Jahangiri et al., 2020; To et al., 2020; Yao et al., 2020). Holtmann et al. (2020) argue that the non-significant correlation found by Yao et al. (2020) maybe because the study used a basic reproduction number from a variety of cities in China, and this basic reproduction number could be confused by numerous factors.

Most studies found a negative correlation with the number of COVID-19 cases and humidity (Liu et al., 2020; Qi et al., 2020; Wu et al., 2020; Şahin, 2020). Four studies concluded that humidity does not correlate with cases of the new coronavirus (Tosepu et al., 2020; Rendana, 2020; Rosario et al., 2020 and Bashir et al., 2020). Meanwhile, Auler et al. (2020) and Lin et al.

(2020) found mixed results. Lin et al. (2020) mention that the positive correlation between humidity and COVID-19 cases occurs when the temperature is low; the opposite happens when the temperature is high.

Most studies found no evidence of a significant relation between rainfall and COVID-19 cases (Tosepu et al., 2020; Mollalo et al., 2020; Bashir et al., 2020; Rendana, 2020; Rosario et al., 2020). Only four studies found significant correlations, although with different results. On the one hand, Sobral et al. (2020) determined a positive correlation between rainfall and COVID-19 spread cases, while Menebo's (2020) research found a negative correlation. According to the latter authors, one hypothesis for the association found could be that rainfall (compared to sunny weather) reinforces the rule of "staying at home."

According to our review, the relationship between death cases from COVID-19 and meteorological variables has been little studied. In summary, it could be affirmed that for the relationship between fatal cases of the new coronavirus and temperature, the results are mixed. For the relationship between humidity and cases of death from COVID-19, the balance leans towards a negative relationship. Finally, no evidence was found that rainfall was correlated with cases of death from COVID-19 (Sobral et al., 2020; Bashir et al., 2020; Rendana, 2020).

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Our literature review allows us to conclude that more research is needed to elucidate better the role of meteorological variables in the spread of the COVID-19 epidemic. As mentioned by Briz-Redón and Serrano-Aroca (2020), the currently available data on the epidemic is subject to a high degree of uncertainty. The number of confirmed cases is underestimated globally, and comparisons between countries, cities, or regions are difficult to determine due to differences in data collection procedures or health policies.

On the other hand, given the number of mixed results found, it is important to highlight the inclusion of non-meteorological variables in the analysis. This could help control the heterogeneity of the analyzed localities, even more so when the analysis extends to an entire country or group of countries. Furthermore, and as Soares et al. (2012) mentions, cross-country studies could have some measurement error due to the high spatial variability when estimating a fixed temperature exposure for large geographic areas. Therefore, the results should be interpreted with caution.

It is also important to note that measuring the effect of climate-related covariates on virus transmission is very complex. In fact, the weather generally affects various aspects of daily human life, such as transportation options or leisure activities, among many others. Therefore, the interaction between climatic conditions and human behavior can be a confounding factor of the real relationship between environmental conditions and the spread of the virus (Briz-Redón & Serrano-Aroca, 2020).

Although the evidence shows a clear trend towards a negative relationship between temperature and COVID-19 cases, it is important to highlight that this is a simple correlation. Therefore, there is no scientific reason to conclude that there is a causal relationship between meteorological variables and cases of transmission of the new coronavirus.

Future studies could deepen the interaction between meteorological and demographic variables against the spread of COVID-19. Here it is worth paying attention to the recommendations of Jahangiri et al. (2020). They suggest that cities/provinces with a population of more than 1.7 million have stricter controls and inspections of their population.

Finally, it is recommended that future research analyze other regions that have not yet been studied (such as Italy, Russia or Peru), but have been hit hard by the pandemic. These studies must consider longer time periods and should not be limited to the implementation of simple correlation approaches such as the Spearman and Kendall tests, but instead, use more comprehensive approaches that allow the integration of meteorological and non-meteorological variables into the propagation analysis of COVID-19.

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