A systematic review and meta-analysis on correlation of weather with COVID-19

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This study presents a systematic review and meta-analysis over the findings of significance of correlations between weather parameters (temperature, humidity, rainfall, ultra violet radiation, wind speed) and COVID-19. The meta-analysis was performed by using 'meta' package in R studio. We found significant correlation between temperature (0.11 [95% CI 0.01–0.22], 0.22 [95% CI, 0.16–0.28] for fixed effect death rate and incidence, respectively), humidity (0.14 [95% CI 0.07–0.20] for fixed effect incidence) and wind speed (0.58 [95% CI 0.49–0.66] for fixed effect incidence) with the death rate and incidence of COVID-19 (p < 0.01). The study included 11 articles that carried extensive research work on more than 110 country-wise data set. Thus, we can show that weather can be considered as an important element regarding the correlation with COVID-19.

COVID-19 has impacted significantly over the human society in recent times. More than 25 million population is already infected and over 0.8 million are already died of by the COVID-19. Scientific organizations are currently involved in the development of possible vaccines to further stop the deadly spread of COVID-19. Weather conditions always play important roles to the enhancement or eradication of health issues. Thus, we can look for finding answer of the research question: whether weather has any correlation with COVID-19.

A study was conducted to find the possibility of correlation between weather parameters with COVID-19. However, the comments didn't conform to specific answer of weather impact on COVID-19. A study was conducted to test the impact of temperature on Australia and Egypt as a case study. It suggested that there is a relation between temperature and COVID-19. A systematic review was performed where advocacy was made in favour of low evidence for impact of temperature and humidity on COVID-19. No meta-analysis was done in this work. Harmooshi et al. investigated a generic review of 16 articles having some outcome-based impact over COVID-19. This work suggested that cool weather may affect transmissibility of COVID-19. In a prediction model was investigated for India in stating probable condition in 2020 due to COVID-19. Weather impact was found in Turkey over a 14-day long study suggested that incidence of COVID-19 could lower with high temperature and high wind speed. Thus, we can see that different articles stated their own point of view via various methods while resulting into confusion.

Methods

In this paper, we present first ever meta-analysis of impacts of weather on the death and incidence on the COVID-19. Initially, we selected vital articles from digital repositories to find resourceful information. Thus, we performed a systematic review upon proper inclusion and exclusion criteria. Secondly, we used risk assessment of the included articles in this study. Thirdly, we performed evidence certainty tests of such articles to find suitability over the significant impact analysis of weather over COVID-19. We selected five weather parameter such as, temperature, humidity, rainfall, ultra violet and wind speed to find correlation with the death rate and incidence of the COVID-19. Fourthly, we performed forest and funnel plots to investigate the heterogeneity and publication bias, respectively.

Search strategy. A comprehensive literature survey was conducted while considering articles from the following digital databases such as, PubMed, Sciedirect, IEEE Xplore, Google Scholar, and Cochrane. We used a set of combination of key words to search the articles as shown in Table 1. One independent author (PPR) performed screening of abstract and titles of the literature against the aforementioned keyword and scope of the study. Other author (PM) did the review of final selection of the articles. Evaluation of full-texts were conducted against the inclusion and exclusion criteria.
with package meta. We used metacor (cor = r, n = N, data = d, studlab = Author, sm = "ZCOR") method call to per-
tation) approach was used to evaluate the quality of evidence for each outcome as shown in Table 3. We tested 7
outcomes on the correlations between (a) temperature and COVID-19 death rate, (b) humidity with COVID-
parameters with the incidence or death rate of COVID-19. Further, we considered the evaluation criteria as
characteristics of the included studies rely in the recently performed correlation assessment between the weather
considered relative humidity out of absolute and relative humidity while performing this meta-analysis. Major
approaches used in the articles. We excluded all the articles which are published in non-indexed journals and
don't conform to the direct correlation perspective of COVID-19 with weather factors. Due to lack of minimal
availability, we exclude the correlating parameters related to the pollution, air quality index (AQI), pollination,
and sun light intensity as the weather parameters in this meta-analysis.

Assessment of risk of bias. We assessed the quality of the articles selected in this study by using the
Joanna Briggs Institute (JBI) tool. The checklist contained eight questions such as (a) were the criteria for
inclusion in the sample clearly defined, (b) were the study subjects and the setting described in detail, (c) was the
exposure measured in a valid and reliable way, were objective, (d) standard criteria used for measurement of the
condition, (e) were confounding factors identified, (f) were strategies to deal with confounding factors stated,
(g) were the outcomes measured in a valid and reliable way and (h) was appropriate statistical analysis used.
Each of the question was examined against each of the 11 articles and answer was given in ‘Yes’ and ‘No’. Overall
risk was finally specified at the bottom of Table 2 with two main answers such as, ‘Low’ and ‘Moderate’. Both the
authors (PPR and PM) independently evaluated risk and quality of each study and confusion was mitigated by
a consensus team meeting.

Data extraction and outcome measure. Data was extracted for following variables such as, (a) tem-
perture, (b) humidity, (c) rainfall, (d) ultra violet (UV) radiation and (e) wind speed. We considered two key
COVID-19 parameters such as, (a) death rate and (b) incidence. Thus, five key weather elements were used to
find association with two COVID-19 parameters for performing meta-analysis on possible weather impact on
COVID-19. Solar radiation and UV radiation were assumed to be same by considering SI unit i.e. W-m^{-2}. We
considered relative humidity out of absolute and relative humidity while performing this meta-analysis. Major
characteristics of the included studies rely in the recently performed correlation assessment between the weather
parameters with the incidence or death rate of COVID-19. Further, we considered the evaluation criteria as
mentioned in the articles to provide the meta-analysis.

Certainty measure. The GRADE (Grading of Recommendations Assessment, Development, and Evalua-
tion) approach was used to evaluate the quality of evidence for each outcome as shown in Table 3. We tested 7
outcomes on the correlations between (a) temperature and COVID-19 death rate, (b) humidity with COVID-
19 death rate, (c) temperature with COVID-19 incidence, (d) humidity with COVID-19 incidence, (e) rainfall
with COVID-19 incidence, (f) UV with COVID-19 incidence, and (g) wind speed with COVID-19 incidence.
We found the impact of each of the outcomes. We also measured the evidence of certainty using ⊕ AND/OR ⊖
combination of four symbols in terms of ‘Moderate’, ‘High’, and ‘Very High’. The points in the GRADE analysis
are considered as follows. Very High point is given to the correlation factor that shows the highest order signifi-
cance among all the included works. Similarly, High point is given to those parametrization aspects where we
notice strong evidence of measure. We give Moderate as the lowest measure to the correlating perspective having
lowest of significance.

Statistical analysis. Accessed data from 11 articles were initially recorded into the excel datasheet which
was later segregated into 7 different comma separated value CSV) files for feeding into the RStudio version 3.4.3
with package meta. We used metacor(cor = r, n = N, data = d, studlab = Author, sm = "ZCOR") method call to per-

| Paper               | Remarks on observations                                                                 |
|---------------------|-----------------------------------------------------------------------------------------|
| PubMed              | ‘COVID-19’ AND ‘COVID-19’ AND ‘Weather’ AND ‘COVID-19’ AND ‘Weather’ AND ‘Impact’ AND ‘COVID-19’ AND ‘Weather’ AND ‘Correlation’ |
| Sciencedirect       | ‘SARS-COV-2’ AND ‘Weather’ AND ‘Correlation’, ‘SARS-COV-2’ AND ‘Correlation’, ‘COVID-19’ AND ‘Temperature’ AND ‘Correlation’, ‘COVID-19’ AND ‘Humidity’ AND ‘Correlation’ |
| IEEE Xplore         | ‘COVID-19’ AND ‘Weather’ AND ‘Correlation’, ‘COVID-19’ AND ‘Correlation’, ‘SARS-COV-2’ AND ‘Weather’, ‘SARS-COV-2’ AND ‘Weather’ AND ‘Impact’ |
| Google scholar      | ‘SARS-COV-2’ AND ‘Weather’, ‘SARS-COV-2’ AND ‘Weather’ AND ‘Impact’, ‘SARS-COV-2’ AND ‘Weather’ AND ‘Correlation’, ‘SARS-COV-2’ AND ‘Correlation’, ‘COVID-19’ AND ‘Temperature’ AND ‘Correlation’, ‘COVID-19’ AND ‘Humidity’ AND ‘Correlation’, ‘COVID-19’ AND ‘UV’ AND ‘Correlation’, ‘COVID-19’ AND ‘Rainfall’ AND ‘Correlation’, ‘COVID-19’ AND ‘Wind’ AND ‘Correlation’, ‘COVID-19’ AND ‘Weather’ AND ‘Correlation’ AND ‘Meta-analysis’, ‘COVID-19’ AND ‘Weather’ AND ‘Correlation’, ‘COVID-19’ AND ‘Correlation’, ‘Review’ |
| Cochrane            | ‘SARS-COV-2’ AND ‘Weather’, ‘SARS-COV-2’ AND ‘Weather’ AND ‘Impact’, ‘SARS-COV-2’ AND ‘Weather’ AND ‘Correlation’, ‘SARS-COV-2’ AND ‘Correlation’ |

Table 1. Keywords used for literature search.
form the fixed-effect and random effect model study. We used Fisher’s z transformed correlations to find meta-
analysis. Here, r, N and d represent the CSV columns named as r, N and the CSV itself, respectively. Where, r and
N (sample size) of the specific CSV stored the correlation values in (+) and/or (-) terms and days of experiment
by individual article, respectively. 95% confidence interval (CI) was measured for each of the articles. Wang et al.
(2020a), Wang et al. (2020b), Meo et al. (2020a), and Meo et al. (2020b) were sub-set wise used of the Wang et al.
(2020) and Meo et al. (2020) articles, respectively. Fixed and random weight of each of the article was computed.
We found heterogeneity (I²) and τ² as the level of heterogeneity and measure of dispersion of true effect sizes
under the given assumptions that the true effect sizes were bell-shaped and normally distributed, respectively.
We used the forest() method to derive the forest plots for seven different scenarios of correlation meta-analysis
with help of the Fisher’s z transformed correlations.

Results
Study selection and characteristics. The article reporting and record keeping task was finalized on
August 6, 2020. All the included papers belong to the initial to recent COVID-19 impacts i.e. December 1,
2019–June 5, 2020. Based on initial record screening, we found 453 articles. We remove 381 irrelevant articles
and later moved with 72 records. Due to irrelevance to weather parametric data selection, measurement and
study approaches, we excluded 27 articles. Out of 45 articles, upon full-text screening we found improper statis-
tical data and insignificant association between weather and COVID-19, we rejected 14 articles. Rest of the 37 articles were focused on either parametric or descriptive statistical association studies between the weather and COVID-19. However, 23 were found to be nonconclusive toward correlation between weather and COVID-19 which were later on rejected. Out of 14 articles, only 11 were finally included in this meta-analysis. All the studies discussed about some sort of correlation factor with one or more weather parameters comprising of temperature, humidity, rainfall, UV and wind speed with the COVID-19 death rate or incidence level in various parts of the globe. The articles conducted studies in different zones of countries belonging to Wuhan, China, mainland China, India, USA, Japan, Jakarta, Indonesia, Australia, Canada, Iran and more than 110 countries. The article mainly used the Pearson’s correlation coefficient, cohort study, Spearman’s rank correlation logarithmic estimation, generalized additive model (GAM) and Fama–Macbeth regression statistical techniques. Out of 11 only 1 article remarked about the basic reproduction number i.e. \( R_0 \) in conjunction to the weather parameters for possible impact on the COVID-19 incidence.

**Survey of articles.** Table 4 presents the comparison between the articles included in this study. Wang et al. (2020a) and Wang et al. (2020b) represent a single article but two different works related to China and USA. Similarly, Meo et al. (2020) performed studies on 10 hottest and 10 coldest countries, thus two versions of citations were used into the further works such as Meo et al. (2020a) and Meo et al. (2020b) representing hot and cool countries, respectively.

**Overall outcomes.** Table 5 presents overall outcome from this study. Correlation between the temperature and COVID-19 death rate was measured as (a) fixed effect model: 0.11 (95% CI, 0.01–0.22) and (b) random effect model: 0.21 (95% CI – 0.14–0.52) with \( p < 0.01 \). Similarly, humidity and COVID-19 correlation were
Correlation between temperature with death rate of COVID-19
Out of three articles, two showed positive correlation of temperature with death rate of COVID-19. One article showed negative correlation with the death rate with COVID-19 i.e. in hottest countries.
(3 OBSERVATIONAL STUDIES) ⊗⊗⊙ Moderate

Correlation between humidity with death rate of COVID-19
Out of three articles, all papers showed negative correlation of humidity with death rate of COVID-19.
(3 OBSERVATIONAL STUDIES) ⊗⊗⊗ Very high

Correlation between temperature with incidence of COVID-19
Out of ten articles, seven showed positive correlation of temperature with incidence of COVID-19. Studies of Meo et al. in both hot and cool countries in their study revealed negative correlation with incidence of COVID-19 with average yearly temperature.
(10 OBSERVATIONAL STUDIES) ⊗⊗⊙ Moderate

Correlation between humidity with incidence of COVID-19
Out of ten articles, four showed negative correlation of humidity with incidence of COVID-19. Three articles revealed positive correlation with incidence of COVID-19. Changes in weather in both hot and cool countries showed negative correlation.
(10 OBSERVATIONAL STUDIES) ⊗⊗⊙ Moderate

Correlation between rainfall with incidence of COVID-19
Two out of three studies showed positive correlation between rainfall and incidence of COVID-19. One study showed negative correlation.
(3 OBSERVATIONAL STUDIES) ⊗⊗⊙ Moderate

Correlation between UV with incidence of COVID-19
One out of two studies showed high negative correlation between UV radiation and incidence of COVID-19. Overall correlation is negative.
(2 OBSERVATIONAL STUDIES) ⊗⊗ ⊗ ⊗ High

Correlation between windspeed with incidence of COVID-19
All of three articles showed positive correlation between windspeed and incidence of COVID-19.
(3 OBSERVATIONAL STUDIES) ⊗⊗⊗ Very high

Table 3. GRADE evidence profile table.

Measured as $-0.13$ (95% CI, $-0.23$–0.03) and $-0.13$ (95% CI, $-0.23$–0.03) for fixed and random effect model, respectively against $p$-value at 0.53.

In case of weather and COVID-19 incidence correlation aspect, we found that temperature had $0.22$ (95% CI, 0.16–0.28) and $0.23$ (95% CI, 0.01–0.42) for fixed and random study, respectively. We found that humidity had positive correlation with the COVID-19 incidence at $p<0.01$. Rainfall had minimal positive correlation with COVID-19 incidence having $0.04$ (95% CI, $-0.09$–0.16) and $0.03$ (95% CI, $-0.10$–0.17) for fixed and random, respectively. Correlation between UV and COVID-19 incidence was measured as $-0.09$ (95% CI, $-0.23$–0.06) for fixed and $-0.14$ (95% CI, $-0.43$–0.18) for random model. Wind speed was found to have positive correlation with the incidence of COVID-19 such as, $0.58$ (95% CI, 0.49–0.66) and $0.62$ (95% CI, $-0.17$–0.92).

Heterogeneity ($I^2$) was mostly observed with the temperature, humidity (COVID-19 incidence) and wind speed variables i.e. 90%, 96% and 98%, respectively. Complete homogeneity i.e. ($I^2=0$) was found in the humidity with the death rate of COVID-19 with zero $\tau^2$. $I^2$ of rainfall was found as 16% against the COVID-19 incidence.

Figures 2, 3, 4, 5, 6, 7, and 8 present the forest plots of seven different correlation aspects of weather parameters with COVID-19 death rate and incidence.

Discussion
To best of our knowledge, herein presented systematic review and meta-analysis is the first ever work to find answer of correlation between weather on COVID-19. Our meta-analysis is the first to analyse the effect of weather on the death rate and incidence of COVID-19. Based on our meta-analysis we found correlation between weather on the COVID-19. Temperature and humidity are most crucial weather factors that are string enough to impact over the death rate and incidence of COVID-19. All the articles included into this study adhere to the weather centric approaches to the COVID-19. All the articles performed their research during December, 2019 to June, 2020. Thus, a long-time duration was covered in our meta-analysis to come at genuine and effective conclusion about possibility of weather impact on COVID-19. Correlation parameters were used in this study to disseminate direct relationship between the weather and COVID-19.

Our meta-analysis included more than 110 country data regarding weather impact on the coronavirus spread and deaths. As the articles carries extensive research during initial phase and mid phase of COVID-19 in most of the countries, this meta-analysis is far more effective to provide more specific answer to correlation-related questions which were frequently asked in near past. With involvement of the JBI tools and GRADE evidence profile, presented meta-analysis serves as an indispensable literature in the current context of COVID-19 incidence.

In this meta-analysis, we assumed the correlation values to be most effective than other alternatives due to its straightforward nature of relationship measurement approach. We depended our study over the fixed and random effect models aside the heterogeneity and dispersion of true size effects. Significant forest plots were obtained for the (a) temperature versus death rate, (b) temperature versus incidence, (c) humidity versus incidence, and (d) wind speed versus incidence of COVID-19 i.e. air borne. Though, impact of UV radiation over the incidence of COVID-19 was computed but negative correlation was observed. It means that with more UV radiation lesser incidence of COVID-19 can be found. Similarly, rainfall has a positive correlation with COVID-19 incidence.
We didn’t know the exact reason why such behaviour i.e. non-significance was observed. We can hypothesize that higher rainfall increases relative humidity in air thus a greater number of cases can be seen due to COVID-19. One surprising result was found in our meta-analysis i.e. negative correlation between humidity with death rate and daily cases but not temperature.

Our work has some limitations including availability of plentiful research on weather correlation with COVID-19. This study restricted us to conduct meta-analysis on available articles where some of them were taken from various preprint servers. Thus, risk of rejection of those articles were not accurately considered, even though we used JBI and GRADE methods. We can also say that hot countries with high average temperature and humidity play important role to reduce R0 of COVID-19.

Table 4. Comparison of literature included in this study.

| Paper       | Year | Zone/country           | Variables                                                                 | Time period                                      | Technique used                  | Remarks on observations                                                                 |
|-------------|------|------------------------|---------------------------------------------------------------------------|--------------------------------------------------|----------------------------------|----------------------------------------------------------------------------------------|
| Ma et al    | 2020 | Wuhan, China           | Temperature, Diurnal Temperature Range (DTR), Relative Humidity, Absolute Humidity, Air Pollutants | 20 January, 2020–29 February, 2020               | Generalized Additive Model      | Correlation between COVID-19 death rate and weather parameters, positive correlation with DTR and negative with humidity |
| Wang et al  | 2020 | China, USA             | Temperature, Relative Humidity, Population Density, GDP per capita, Fraction of population aged ≥ 65 years | 19 January, 2020–10 February, 2020, 15 March, 2020–25 April, 2020 | Effect on basic reproductive number (R0), Fama-Macbeth Regression | Estimated that R0 declines about 0.89 in total, temperature and humidity play important role to reduce R0 of COVID-19 |
| Islam et al | 2020 | 310 Regions of 116 County | Temperature, Relative Humidity, Wind Speed | 8 January, 2020–12 March, 2020 | Estimation of adjusted incidence rate (IRR) Temperature, relative humidity, and wind speed has low incidence of COVID-19 | Significant negative association between the temperature and humidity with the COVID-19 |
| Qi et al    | 2020 | China                  | Temperature, Relative Humidity, Wind Speed                                | 1 December, 2019–11 February, 2020              | Generalized Additive Model, Exponential Moving Average | Significant decrease in in death rate and daily cases in hot countries than cool countries |
| Meo et al   | 2020 | 10 Hottest Countries, 10 Coolest Countries | Temperature, Relative Humidity | 29 December, 2019–12 May, 2020 | Descriptive Statistics | Temperature is significantly correlated with COVID-19 daily cases |
| Rashed et al| 2020 | 16 Prefecture, Japan   | Temperature, Relative Humidity                                            | 16 April, 2019–25 May, 2020                    | Spearman’s Rank Correlation     | Impact of multivariate parameters on COVID-19 |
| Tosepu et al| 2020 | Jakarta, Indonesia     | Temperature, Relative Humidity, Rainfall                                   | 1 January, 2020–29 March, 2020                  | Spearman’s Rank Correlation     | Temperature and humidity play important role to reduce R0 of COVID-19                 |
| Bashir et al| 2020 | New York, USA          | Temperature, Relative Humidity, Rainfall, Wind Speed, Air Quality          | 1 March, 2020–12 April, 2020                    | Kendall’s Rank Correlation, Spearman’s Rank Correlation | Temperature and air quality significantly associated with COVID-19 death rate and daily cases |
| Vinoj et al | 2020 | Delhi, India           | Temperature, Relative Humidity, Specific Humidity, UV Radiation            | 20 April, 2020–5 June, 2020                     | Pearson’s Correlation           | Positive correlation with temperature and humidity with UV radiation in COVID-19       |
| Sajadi et al| 2020 | 50 Cities One Each from 50 Countries | Temperature, Relative Humidity | 1 January, 2020–10 March, 2020 | Cohort Study                    | Correlation with temperature and humidity was observed in COVID-19                     |
| Xu et al    | 2020 | 37,39 Locations from Australia, China, Canada, Iran, USA         | Temperature, Relative Humidity, Rainfall, Wind Speed, UV Radiation, O3, SO2, DTR, Air Pressure | 12 December, 2019–22 April, 2020 | Logarithmic Estimation | Relationship with temperature, humidity, rainfall, windspeed, UV radiation found with incidence of COVID-19 |

Table 5. Overall outcome.

| Outcome       | Sample size | COVID-19 parameters | Pooled Correlation (95% CI) | Fixed effect model | Random effect model | I² (%) | τ²    | p Value |
|---------------|-------------|----------------------|-----------------------------|--------------------|--------------------|--------|-------|---------|
| Temperature   | 356         | Death rate           | 0.11 (0.01–0.22)            | 0.21 (−0.14–0.52)  | 90          | 0.1186 | <0.01 |
|               | 897         | Incidence            | 0.22 (0.16–0.28)            | 0.23 (0.01–0.42)  | 90          | 0.1312 | <0.01 |
| Humidity      | 356         | Death rate           | −0.13 (−0.23–0.03)          | −0.13 (−0.23–0.03) | 0            | 0     | 0.53  |
|               | 897         | Incidence            | 0.14 (0.07–0.20)            | 0.16 (−0.20–0.48) | 96          | 0.3936 | <0.01 |
| Rainfall      | 265         | Incidence            | 0.04 (−0.09–0.16)           | 0.03 (−0.10–0.17) | 16          | 0.0025 | 0.3   |
| UV            | 187         | Incidence            | −0.09 (−0.23–0.06)          | −0.14 (−0.43–0.18) | 74          | 0.0394 | 0.05  |
| Wind Speed    | 241         | Incidence            | 0.58 (0.49–0.66)            | 0.62 (−0.17–0.92) | 98          | 0.6116 | <0.01 |
Figure 3. Forest plot of COVID-19 death rate with humidity.

| Study              | Total | COR  | 95%-CI          | Weight (fixed) | Weight (random) |
|--------------------|-------|------|-----------------|----------------|-----------------|
| Ma et al. (2020)   | 41    | -0.32| [-0.57; -0.01]  | 11.0%          | 11.0%           |
| Meo et al. (2020a) | 136   | -0.10| [-0.27; 0.07]   | 38.7%          | 38.7%           |
| Meo et al. (2020b) | 136   | -0.08| [-0.24; 0.09]   | 38.7%          | 38.7%           |
| Bashir et al. (2020)| 43    | -0.20| [-0.48; 0.10]   | 11.6%          | 11.6%           |

Fixed effect model: 356
Random effects model: 356
Heterogeneity: $I^2 = 0\%$, $\tau^2 = 0$, $p = 0.53$;

Figure 4. Forest plot of COVID-19 incidence with temperature.

| Study              | Total | COR  | 95%-CI          | Weight (fixed) | Weight (random) |
|--------------------|-------|------|-----------------|----------------|-----------------|
| Wang et al. (2020a)| 23    | 0.23 | [0.20; 0.59]    | 2.3%           | 6.9%            |
| Wang et al. (2020b)| 42    | 0.02 | [-0.29; 0.32]   | 4.5%           | 7.9%            |
| Islam et al. (2020)| 65    | 0.83 | [0.73; 0.98]    | 7.2%           | 8.5%            |
| Meo et al. (2020a) | 136   | -0.02| [-0.18; 0.15]   | 15.4%          | 9.0%            |
| Meo et al. (2020b) | 136   | 0.34 | [0.18; 0.48]    | 15.4%          | 9.0%            |
| Qi et al. (2020)   | 73    | 0.04 | [-0.19; 0.27]   | 8.1%           | 8.6%            |
| Rashed et al. (2020)| 40   | 0.20 | [-0.12; 0.48]   | 4.3%           | 7.9%            |
| Tosepu et al. (2020)| 89   | 0.39 | [0.20; 0.55]    | 10.0%          | 8.7%            |
| Vinju et al. (2020)| 47    | -0.43| [-0.64; -0.16]  | 5.1%           | 8.1%            |
| Sajadi et al. (2020)| 70   | 0.51 | [0.31; 0.67]    | 7.8%           | 8.5%            |
| Xu et al. (2020a)  | 133   | -0.04| [-0.21; 0.13]   | 15.1%          | 9.0%            |
| Bashir et al. (2020)| 43    | 0.27 | [-0.04; 0.53]   | 4.6%           | 8.0%            |

Fixed effect model: 897
Random effects model: 897
Heterogeneity: $I^2 = 90\%$, $\tau^2 = 0.1312$, $p < 0.01$;

Figure 5. Forest plot of COVID-19 incidence with humidity.

| Study              | Total | COR  | 95%-CI          | Weight (fixed) | Weight (random) |
|--------------------|-------|------|-----------------|----------------|-----------------|
| Wang et al. (2020a)| 23    | 0.01 | [-0.41; 0.42]   | 2.3%           | 7.7%            |
| Wang et al. (2020b)| 42    | 0.01 | [-0.30; 0.31]   | 4.5%           | 8.2%            |
| Islam et al. (2020)| 65    | 0.97 | [0.95; 0.98]    | 7.2%           | 8.4%            |
| Meo et al. (2020a) | 136   | -0.17| [-0.33; 0.00]   | 15.4%          | 8.6%            |
| Meo et al. (2020b) | 136   | -0.08| [-0.25; 0.09]   | 15.4%          | 8.6%            |
| Qi et al. (2020)   | 73    | 0.04 | [-0.19; 0.27]   | 8.1%           | 8.4%            |
| Rashed et al. (2020)| 40   | -0.68| [-0.82; -0.47]  | 4.3%           | 8.2%            |
| Tosepu et al. (2020)| 89   | 0.00 | [-0.21; 0.21]   | 10.0%          | 8.5%            |
| Vinju et al. (2020)| 47    | 0.39 | [0.12; 0.61]    | 5.1%           | 8.3%            |
| Sajadi et al. (2020)| 70   | 0.50 | [0.30; 0.66]    | 7.8%           | 8.4%            |
| Xu et al. (2020a)  | 133   | -0.00| [-0.17; 0.17]   | 15.1%          | 8.6%            |
| Bashir et al. (2020)| 43    | -0.11| [-0.40; 0.20]   | 4.6%           | 8.2%            |

Fixed effect model: 897
Random effects model: 897
Heterogeneity: $I^2 = 96\%$, $\tau^2 = 0.3936$, $p < 0.01$. 

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and relative humidity are more prone to get affected by new incidences of COVID-19 in coming days. It can be estimated that during coming winter may provide some relief to the people of the world. However, more research should be conducted to better support our meta-analysis conclusions.

**Conclusion**

We found some strong correlations between weather over the incidence of COVID-19. The meta-analysis can be useful for the policy makers of the government and health incorporations to take prior decisions before the possible surge of COVID-19 cases depending on the weather forecasting mechanism. We urge the medical professionals and weather analysts to further investigate the findings of this article as the a priori information to mitigate the COVID-19 pandemic.

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Author contributions

P.M. gathered data and designed the experiments. P.P.R. wrote the paper and performed the analysis. All authors

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Competing interests
The authors declare no competing interests.

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