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Association between the spread of COVID-19 and weather-climatic parameters

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Abstract. – OBJECTIVE: To explore whether the climate has played a role in the COVID-19 outbreak, we compared virus lethality in countries closer to the Equator with others. Lethality in European territories and in territories of some nations with a non-temperate climate was also compared.

MATERIALS AND METHODS: Lethality was calculated as the rate of deaths in a determinate moment from the outbreak of the pandemic out of the total of identified positives for COVID-19 in a given area/nation, based on the COVID-John Hopkins University website. Lethality of countries located within the 5th parallels North/South on 6 April and 6 May 2020, was compared with that of all the other countries. Lethality in the European areas of The Netherlands, France and the United Kingdom was also compared to the territories of the same nations in areas with a non-temperate climate.

RESULTS: A lower lethality rate of COVID-19 was found in Equatorial countries both on April 6 (OR=0.72 CI 95% 0.66-0.80) and on May 6 (OR=0.48, CI 95% 0.47-0.51), with a strengthening over time of the protective effect. A trend of higher risk in European vs. non-temperate areas was found on April 6, but a clear difference was evident one month later: France (OR=0.13, CI 95% 0.10-0.18), The Netherlands (OR=0.5, CI 95% 0.3-0.9) and the UK (OR=0.2, CI 95% 0.01-0.51). This result does not seem to be totally related to the differences in age distribution of different sites.

CONCLUSIONS: The study does not seem to exclude that the lethality of COVID-19 may be climate sensitive. Future studies will have to confirm these clues, due to potential confounding factors, such as pollution, population age, and exposure to malaria.

Key Words:
SARS-CoV-2, COVID-19, Warmer weather, Coronavirus, Infection, Transmission.

Introduction

The recent slowdown in quarantine for COVID-19 in Europe was driven by economic, political and social reasons. Europe is in fact facing the biggest economic downturn since the Second World War[1], which has forced many countries to return to work despite possible risks[2].

From the epidemiological point of view, the measure has left many experts perplexed. The pandemic in countries such as Spain and Italy had not yet ended at the beginning of May, and many authoritative estimations suggest a possible development with catastrophic consequences[2]. Furthermore, it has recently been ascertained that the excess mortality in some European countries compared with the previous 5 years in the period from late February to April is much higher, which can only be explained by the confirmed coronavirus deaths[3,4]. This would suggest that the epidemic is far more widespread than estimated on the basis of official data.

One of the factors that could dampen the devastating power of the epidemic could be the loss of infectiousness and/or lethality of the virus[5]. This could be related to heat, considering the arrival of summer in Europe.

Some recent works detected a lesser spread of the virus in Italy in provinces of some regions that were previously malarial, compared to the

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non-malarial provinces of the same regions[6]. The authors suggested that the previous exposure of those areas to malaria could also simply be a confounding factor, and that the real determinant associated with the lower diffusivity of the virus could have been the humid climate which is notoriously associated with a greater risk of malaria[6].

A comparison of the spread of the virus in different countries is problematic because what we know about the number of COVID-19 positives in a given nation is not (only) in a linear link to the actual presence of the virus, but other factors could have a role, such as: (1) the accuracy of the health system in identifying the cases, (2) the accuracy of data transmitted to media or international health organizations (with or without intentional manipulation by those who can influence communication), (3) the country's demographic profile, which, in the absence of certain data on the age of cases, makes it impossible to stratify this risk factor, as it is much more likely that cases in children could be asymptomatic[7].

A slightly more reliable factor regarding virus activity could be the assessment of lethality in different areas and over time, or the percentage of deaths out of the total number of cases identified. This measurement does not depend on the accuracy of the health system in identifying cases, because it is based on the cases that have already been identified, independently of the frequency of virus positivity in the population. It is thus somewhat more independent of the possible desire to hide the extent of the pandemic, because death is reported on cases already declared and, in this framework, deaths are more difficult to conceal. The problem of possible age bias remains; indeed, this is perhaps even amplified because the inauspicious outcome is more frequent in the elderly. However, this factor can be partly discussed on the basis of the results in countries with a similar geographical location but with different ages and/or on the basis of countries that extend over areas with different climates.

To verify the hypothesis whether the climate could play a role in the diffusion of COVID-19, the objective of this work is to compare mortality rate at two different times in countries in which the majority of inhabitants reside nearer to the Equator than the other nations. Moreover, a separate analysis will focus on lethality in the metropolitan territories of some European countries comparing it to territories in the same nations located in areas with an intemperate climate.

Materials and Methods

The main measure of the study is the lethality of COVID-19, calculated as the percentage of deaths in a given moment out of the total of identified positives for COVID-19 in a given area or nation, calculated on the basis of the data reported on the COVID-John Hopkins University website[8].

This measure was calculated for countries in which the majority of the inhabitants resides within the 5th parallels North and South (near the Equator) on two dates with a month's difference (6 April and 6 May 2020) and compared with those of all the other countries.

Lethality will be analyzed separately in three European countries (The Netherlands, France and the United Kingdom) comparing the lethality in the metropolitan territories with lethality in the territories of the same nations located in areas with an intemperate climate and/or in hotter non-temperate climates.

The difference in lethality between countries and between areas with temperate or non-temperate weather was calculated as odds ratios. Confidence Intervals 95% were calculated using Miettinen's simplified method. The difference between temperate *vs.* non-temperate areas was measured by means of Fisher's exact or chi square test when criteria of applicability were respected.

In countries where there was a difference on the median age of the population in non-temperate climates compared to Europe, we conducted, where possible, a differentiated analysis including only non-metropolitan areas where the median age of the population was no less than 7 years compared with the central population (the median age of each area was found in world meters[9] or index mundi[10]).

Results

The countries with the majority of the inhabitants within the 5th parallels North and South (near the Equator) were: Ecuador, Equatorial Guinea, Sao Tomé and Prince, Gabon, Congo Brazzaville, Uganda, Kenya, Rwanda, Burundi, Somalia, Maldives, Seychelles, Indonesia, Singapore, Malaysia, Brunei, Timor Leste, Papua, Salomon Islands, Nauru, Kiribati, Marshall, Samoa and Tuvalu. Table I shows the lethality of COVID-19 in these countries compared to all the other countries measured on 6 April 2020 and 6 May 2020.

Table I. The Lethality of COVID-19 in Equatorial countries compared to all other countries.

Country	Deaths	Alive	Total COVID-19	%	OR	CL 95%	χ^2 (p)
Equatorial Countries on 6 April	454	10,836	11.290	4.0	0.72	0.66-0.80	45.237 $p < 0.0001$
Others on 6 April	69,335	1,199,421	1.268.756	5.5			
Total on 6 April	69,789	1,210,257	1.280.046	5.4			
Equatorial Countries 6 May	2.673	71,873	74.546	3.6	0.48	0.47-0.51	1361.5 $p < 0.00001$
Others on 6 May	257,814	3,389,419	3.647.233	7.1			
Total on 6 May	260,487	3,461,292	3.721.779	7.0			

In Equatorial countries a lower lethality rate of COVID-19 was found both on 6 April (OR=0.72 CI 95% 0.66-0.80) and on 6 May (OR=0.48, CI 95% 0.47-0.51), with a strengthening over time of the protective effect linked to residence.

Table II shows three European countries (The Netherlands, France and the United Kingdom) and compares the lethality in metropolitan territories with the territories of the same nations located in areas with a non-temperate climate. For the UK: Falklands Island, British Virgin Islands, Anguilla, Montserrat, Cayman (Bermuda and Gibraltar were not included because they are in temperate climate areas. The comparison was carried out with and without The Falklands as the climate on this island is not temperate but cold); for the Netherlands: Aruba, Curacao, Bonaire, St Marteen; for France: Martinique, Guadeloupe, Saint Barts, St Martin, Tahiti and the Polynesian Islands, Réunion, Mayotte, New Caledonia, French Guyana.

Each British non-temperate territory showed a median age less than 7 compared to the metropolitan territories (in which the median age was 40.2 years); only Montserrat showed a difference of almost seven years (median 33.8 years). The Dutch non-temperate territories had a median age (41.5) close to that of the European territory (median 43.3). In France, in contrast, compared to the metropolitan areas (median 42.3 years) only Martinique (median 47.0), Guadeloupe (43.7), Réunion (35.9) and St. Barts (47.7) had a comparable population, while Mayotte (24.1), French Guyana (25.1), New Caledonia (33.6) and Saint Martin (32.8) were much younger.

On April 6 (Table III) both the non-temperate areas of the United Kingdom (analyzing data with or without the Falkland Islands) and those of France had lower COVID-19 lethality compared to the European territories of the motherland: France OR=0.2, CI 95%, UK OR=0.1-0.3 CI 95% not calculable, p<0.0001; the UK without the Falklands OR=0, CI 95%

Table II. Lethality in European territories compared to the lethality in areas of the same nations located in areas with a non-temperate climate, 6 April 2020.

Country	Death	Alive	COVID-19	Lethality %	OR	CI 95%	Fisher
The United Kingdom near Europe	11,347	78,244	89,591	12.6			
The Falklands, British Virgin Islands Anguilla, Montserrat, Cayman	0 (0)	75	75 (62) *	0	0	NC	< 0.0001 (< 0.0001)*
Continental Netherlands	2,833	23,879	26,712	11.9			
Aruba, Curacao, Bonaire, St. Maarten°°	10	151	161	6.2	0.5	0.3-1.1	0.072
Continental France	14,986	123,001	137,877	10.9			
Martinique, Guadeloupe, St. Barts, St. Martin, Tahiti, Polynesia, Réunion, Mayotte, New Caledonia, French Guyana	23	881	904	2.5	0.2	0.1-0.3	< 0.0001

Legend: UL without Falklands, °France only Réunion, Martinique, Guadeloupe, St Barthelemy.

Table III. Lethality in European territories compared to the lethality in areas of the same nations located in areas with a non-temperate climate, 6 May 2020.

Country	Death	Alive	COVID-19	Lethality %	OR	CI 95%	Chi square
The United Kingdom near Europe	30,150	172,206	202,356	14.9			
The Falklands, British Virgin Islands,	3	106	109	2.7	0.2	0.01-0.51	12.68
Anguilla, Montserrat, Cayman	(3)*		(96)*	(3.1)*	(0.2)*	(0.1-0.5)*	< 0.0001
Continental Netherlands	5,221	36,297	41,518	12.5			
Aruba, Curacao, Bonaire,	14	185	199	7.0	0.5	0.3-0.9	5.40
St. Maarten°°							$p = 0.010$
Continental France	25,538	145,156	170,694	15.0			
Martinique, Guadeloupe, St. Barts.,	40						
St. Martin, Tahiti, Polynesia,	(27)*	1,718	1,758	2.3	0.13	0.10-0.18	22168.7
Réunion, Mayotte, New Caledonia,			(765)*		(0.2)	(0.1-0.3)	< 0.0001
French Guyana							(78.5
							< 0.0001)*

Legend: UL without Falklands, °France only Réunion, Martinique, Guadeloupe, St Barthelemy.

not calculable Fisher's exact test $p<0.0001$). In the Netherlands, such an effect was not achieved but the difference between the European Netherlands and the Caribbean was at the limit of statistical significance (OR=0.5, CI 95% 0.5-1.1). However, a month later, a clear difference is noted with markedly higher lethality in Europe, in France (OR=0.13, CI 95% 0.10-0.18), the Netherlands (OR=0.5, CI 95% 0.3-0.9) and the UK (OR=0.2, CI 95% 0.01-0.51). The UK figure was confirmed even when the analysis was conducted without the Falkland Islands (OR=0.2, CI 95% 0.1-0.5), therefore in warm non-temperate areas. The figure was confirmed in France if the difference was calculated in the territories with an average age comparable to European France (Reunion, Guadeloupe, Martinique, St. Barts) (OR=0.2, CI 95% 0.1-0.3).

Discussion

The study shows that COVID-19 has a higher lethality rate in temperate zones than in countries around the Equator. It is unlikely that this depends on a different phase of the viral epidemic in the two areas compared because the data is confirmed after a month and even reinforced.

Some of the countries bordering the equator, and in particular those that contribute the highest number of COVID-19 cases to the analyses conducted in the present study, show a median age that is much lower than that of the United States (median 37.6) and many of the European states that are the greatest contributors to the present analysis in terms of cases and deaths (Italy 47.3 median age, Spain 44.9 years; UK 40.2 years, French 42.3 years); i.e., Indonesia 29.7 median age; Ecuador 27.9 years, Malaysia 30.3 years. However, the trend of lower lethality is strongly confirmed in Singapore where there are only 20 deaths out of 20,198 positives (lethality 0.1%) on 6 May. Singapore has a median age of 42.2 years, comparable to that of the European states and clearly older than that of the USA, where instead the lethality was 73,573 deaths out of 1,231,992 infected (lethality 6.0%, OR Singapore 0.02, CI 95% 0.01-0.03).

The data therefore seem to suggest that the lower lethality near the Equator cannot be totally attributed to a difference in the age of the populations concerned, and therefore only by the fact that the risk form of a fatal outcome would be rare at the equator. In fact, being elderly in itself is a lethal risk factor[11,12] but being elderly is also associated with a greater probability of comorbidity with cardiovascular diseases, diabetes mellitus and cancer, all further risk factors[13-16].

However, a lower lethality rate in warm climates is confirmed by the internal comparison between the three nations – the UK, France and the Netherlands – in which the (larger) European parts of the COVID-19 virus demonstrate a percentage of many more victims than in the tropical parts.

In the case of the UK and the Netherlands, however, the median age of the tropical parts, albeit not to a large extent, is less than that of the European areas of the same nations. This does not apply to France where the trend is also confirmed in regions, such as Guadeloupe and Martinique, where the median age is even higher than those of

the motherland, probably due to numerous French pensioners who have settled in the hot regions of their nation.

The comparison between the nations nullifies, at least in part, the differences due to a bias effect, identified only in the wealthy classes. The percentage of unidentified and untreated cases might show high mortality. This can happen in countries with a low quality of national health system.

This can happen in countries without a national health system and with large wealth gaps.

In the case of the UK, the analysis is confirmed with or without the inclusion of the Falkland Islands. This inclusion seems apparently absurd (because it is a colder region of the motherland), however, even in nations of the far north, such as Iceland and the Faroes, as well as in the territories of Northern Canada, lower lethality seems suggested.

The Falkland Islands are one of the few areas analyzed by the present study where malaria was not endemic. However, also in two other "warm" areas analyzed by the present study (French Polynesia and New Caledonia) and where mortality was 0 out of 78 confirmed cases, malaria was not endemic.

Thus, this low correlation suggests that an effect due to the heat rather than a previous endemic malaria that determines the protective factor.

Our study has evident limitations: first of all, it was not possible to carry out a stratified analysis for the frequency of the outcome determinants (primarily, age and comorbidity) in the different positive samples; influences due to other environmental factors (i.e., pollution) cannot be excluded[16] and the association with malaria was not adequately studied.

In this context, the study presents only a heuristic value and the hypotheses that it seems to suggest will however be confirmed (or not) by the evolution of the pandemic in the coming months[17,18].

The results, however, seem to be in agreement with a recent Brazilian study[5] that "indicated that temperatures had a negative linear relationship with subjects testing positive with the number of confirmed cases". In fact, the curve flattened at a threshold of 25.8°C.

Conclusions

The study does not seem to exclude the fact that the lethality of COVID-19 may be climate sensitive. Future studies will have to confirm such clues, given potential confounding factors, such as pollution, population age, and exposure to malaria.

If this hypothesis is confirmed, the interruption of the lockdown in Southern Europe, where the hot season is beginning, may not cause the catastrophe some have predicted.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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