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The Climate in the European Union and the Enlarged European Region is a Determinant of the COVID-19 Case Fatality Ratio

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Abstract: Climate could influence the COVID-19 pandemic, but while no evidence has been advanced on the influence of colder climates, some studies have provided data to support a possible heat-related protective factor. The objective is to verify whether areas with a Cold Temperate Climate (TC) have a higher Case Fatality Ratio (CFR) for COVID-19 than areas with a Cold Climate (CC) or with a Mediterranean Climate (MC) in the European Union and the Enlarged European Region. Countries or regions were subdivided into 3 groups according to the Köppen climate classification system: TC (Cfa, Cfb and Cfc in the Köppen system); MC (Csa, Csb); CC (D and E in the Köppen system). The total number of cases and the total number of deaths were detected on 13 August 2020 on the COVID-19 Map - Johns Hopkins Coronavirus Resource Center-the CFR was thus calculated by area. Living in TC areas is strongly associated with risk of a high Case Fatality Ratio for COVID-19, OR for MC =0.42, IC 95% 0.41-0.43; OR for CC=0.33, IC 95% 0.33-0.35. The results are confirmed in the EU, OR per MC=0.85, CI 95% 0.84-0.87; OR per CC=0.63, IC 95% 0.61-0.65.The study found that the IC in a humid temperate climate is associated with higher CFR with respect to the coldest and warmest temperate climates in Europe. This does not appear to be the only determinant of the pandemic.

Keywords: climate; COVID-19; CFR; enlarged EU; pandemic.

1. Introduction

It has been hypothesized that the climate could influence the progress of the COVID-19 pandemic. In particular, it has been assumed that the coldest and hottest climates can counter the pandemic. However, apart from some anecdotal considerations [1], no evidence has been

advanced on the influence of colder climates. Studies on the influence of warmer climates have been restricted to analyses relating to changes within single nations [2] and therefore lacking situations of high variability that could confirm the factor independently of specific confounding factors. It has also been found that the lethality of the virus was lower in equatorial areas than in the rest of the world [3], even though in this case, one must consider that fact that there are few equatorial nations and their COVID-19 incidence rate is quite different (countries with no cases are almost all equatorial but they are also isolated islands). The trend in a few nations with high incidence (i.e., Singapore) may have influenced the overall results of the study. Therefore, it is difficult to extend the result to other situations that present extremely high variability for this parameter in countries with similar weather. It is well known that a comparison of the incidence of COVID cases in different countries poses numerous difficulties that are not easily overcome. The number of known cases in a given country could, in fact, be biased by several factors such as (1) accessibility to tests in its health system, (2) reliability of data transmitted to institutional research bodies and international health organizations (with or without intentional manipulation), (3) the country's demographic profile with more or less extension of ages at risk. A somewhat more reliable factor in assessing virus activity could be the assessment of the Case-Fatality Ratio in different areas. The case Case-Fatality Ratio of COVID is the proportion of deaths from COVID in a given country or area divided by the total amount of people diagnosed with COVID in this country/area in a given period [4]. The Case-Fatality Ratio (CFR) is not directly related to accuracy in identifying cases; in fact, it is based on the cases already identified. It is independent of the incidence rate of the disease in a given population. It may be less biased by errors in communication and a desire to hide the pandemic's extent because death is counted as declared cases, which are thus somewhat more difficult to conceal. However, the Case-Fatality Ratio can be influenced, albeit indirectly, by the efficiency of the health system because the many diagnostic tests conducted in a particular country could lead to the identification of a greater share of mild cases, which could lower the rate, widening the denominator, regardless of the aggressiveness of the virus. However, this possible bias may be partially disputed if a possible climate-related trend was confirmed in nations with comparable health systems.

The objective of this study is to verify whether areas with a Cold Temperate climate have a higher Case Fatality Ratio for COVID-19 than areas with a cold climate (therefore colder on average) or with a Mediterranean climate (therefore warmer on average) in the European Union and the Enlarged European Region. The specific analysis of the European Union allows the hypothesis to be verified in a context of states with comparable national health systems, while the enlarged European Region allows the hypothesis to be verified in a broader context, which is, therefore, less affected by other possible confounding variables.

2. Materials and Methods

The subdivision of the European Union's climatic regions and the enlarged European area was carried out according to Chen's classification (2020), which was based on the original scheme by Köppen (1936). Peri-European desert areas were excluded [5, 6]. The regions were divided into 3 groups: Humid Temperate (corresponding to the Cfa, Cfb, and Cfc areas of the Köppen classification); Mediterranean (Csa, Csb areas of the Köppen classification); Cold (areas D and E of the Köppen classification). The total number of cases was detected on 13 August 2020 on the COVID-19 Map-Johns Hopkins Coronavirus Resource Center (detected 2020). The total number of deaths was thus calculated as the Case-Fatality Ratio for the

countries with different climatic areas (Italy and Spain). Although France has only one Region (Midi-Provence-Côte d'Azur) belonging to the Mediterranean area, it was not possible to calculate the differentiated data because no data was provided. The role of climatic zones as a possible determinant was calculated in terms of odds ratio; the 95% confidence limits were calculated using the simplified Miettinen method. A hot, humid climate was considered as a pivot for the other two climates. The comparison with cold climate countries was conducted with and without Russia; in fact, the frequency of cases in this single state is many times greater than that of all the others belonging to the same climate group. Suppose the results of the two evaluations did not agree. In that case, one could, therefore, hypothesize the presence of a specific factor independent of the climate.

3. Results and Discussion

Table 1 shows the European Union regions/countries and of the enlarged European area divided by Humid Temperate (1a), Mediterranean (1, b), and Cold climate. For each nation or Region (in nations with different climate regions such as Spain and Italy), the number of cumulative cases and the number of global deaths for COVID are reported as recorded on 13 August 2020 on the COVID-19 Map - Johns Hopkins Coronavirus Resource Center [7]. The Case-Fatality Ratio obtained by accumulating the data in tables in the different areas is as follows: for the regions with a humid climate, 9.92% in the enlarged European area and 9.90% in the European Union; for regions with a Mediterranean climate, 4.89% in the enlarged European area and 4.43% in the European Union; for regions with a Mediterranean climate, 2.25% (3.60% without Russia) in the enlarged European area and 5.87% in the European Union.

Table 1 a. Case Fatality Ratio in the European Union and enlarged European Regions with humid temperate weather.

Region /Country	Total Cases	Global Deaths on 13 August 2020	Case Fatality Ratio
Abruzzo EU	3,516	472	
Marche EU	6,976	987	
Emilia Romagna EU	30,220	4,298	
Umbria EU	1,517	80	
Toscana EU	10,707	1,137	
Piedmont EU	31,956	4,138	
Valle d'Aosta EU	1,217	146	
Lombardy EU	97,054	16,833	
Veneto EU	20,801	2,092	
PA Bolzano EU	2,779	292	
PA Trento EU	4,998	405	
Friuli VG EU	3,461	348	
Catalonia EU	89,909	5,706	
Aragon EU	19,418	991	
Navarra EU	7,713	531	
La Rioja EU	4,333	366	
Pays Vasco EU	19,009	1,553	
Cantabria EU	2,824	220	
Asturias EU	2,733	334	
France (Provence Not Available) EU	230,874	30,247	
Belgium EU	75,647	9,900	
The Netherlands EU	61,118	6,182	
Luxemburg EU	7,300	122	
Germany EU	220,859	9,213	
Poland EU	53,676	1,830	
Slovakia EU	2,690	31	
Czechia UE	19,075	391	
Hungary UE	4,768	605	

Region /Country	Total Cases	Global Deaths on 13 August 2020	Case Fatality Ratio
Romania UE	65,177	2,807	
Bulgaria UE	13,893	342	
Ireland EU	26,838	1,174	
Slovenia EU	3,641	348	
Denmark EU	15,070	621	
N. Macedonia	12,217	530	
Montenegro	3,813	73	
Serbia	28,751	658	
Bosnia Herzegovina	14,691	553	
Kosovo	10,419	341	
United Kingdom	315,581	46,791	
San Marino	669	42	
Andorra	977	53	
Total EU	1,161,767	104,742	9.02%
Total	1,548,885	153,783	9.92%

Table 1 b. Case Fatality Ratio in the European and Peri-European Regions with Mediterranean Weather.

Region /Country	Total Cases	Global Deaths on 13 August 2020	Case Fatality Ratio
Sardinia EU	1,462	134	
Sicily EU	3,603	284	
Molise EU	479	23	
Basilicata EU	477	28	
Puglia EU	4,793	554	
Calabria EU	1,304	97	
Campania EU	5,143	440	
Liguria EU	10,330	1,569	
Lazio EU	8,920	868	
Portugal EU	53,223	1,764	
Galicia EU	10,480	662	
Castilian y Leon EU	22,169	284	
Madrid EU	83,606	8,464	
Castilla La Mancha EU	19,582	3,037	
Valencian Community EU	15,934	1,442	
Murcia EU	3,116	149	
Andalusia EU	18,059	1,443	
Estremadura+ EU	3,664	522	
Ceuta y Melilla EU	348	2	
The Canaries EU	3,167	164	
The Balearics EU	3,780	225	
Greece EU	6,177	216	
Cyprus EU	1,291	20	
Malta EU	1,190	9	
Croatia EU	5,870	170	
Gibraltar	203	0	
Israel	88,151	639	
Lebanon	7,413	89	
Turkey	240,392	5,891	
Albania	6,817	208	
Tunisia	1,780	52	
Algeria	36,699	1,333	
Morocco	36,694	556	
Vatican City	12	0	
Monaco	141	4	
Total (only) EU	288,167	22,570	7.80%
Total	706,469	31,342	4.43%

Table 1 c. Case Fatality Ratio in the European and Peri-European Regions with cold weather.

Region /Country	Total Cases	Global Deaths on 13 August 2020	Case Fatality Ratio
Austria EU	22,439	724	
Finland EU	7,642	333	
Estonia EU	2,164	63	
Latvia EU	1,303	32	
Lithuania EU	2,309	81	

Region /Country	Total Cases	Global Deaths on 13 August 2020	Case Fatality Ratio
Sweden EU	83,455	5,774	
Switzerland	37,169	1,991	
Liechtenstein	90	1	
Moldavia	28,697	863	
Ukraine	86,504	1,999	
Belarus	69,102	595	
Russia	900,745	15,531	
Norway	9,783	256	
Iceland	1972	10	
Faroe Islands	339	0	
Greenland	14	0	
Total only EU	119,312	7,007	5.87%
Total	1,253,727	28,253	2.25%
Total without Russia	352,982	12.722	3.6%

Table 2 compares these differences and measures the Association between High Case Fatality Ratio and Humid Temperate Weather in the enlarged European Zone. Living in Humid Temperate Weather regions or countries is strongly associated with a risk of High Case Fatality Ratio for COVID-19, with regard to both inhabitants of the warmest Mediterranean zones (OR=0.42, IC 95% 0.41-0.43) or those living in a cold climate zone (OR=0.33, IC-95% 0.33-0.35 and OR =0.20, IC 95% 0.20-0.21 when Russia is excluded).

Table 2. Association between high case fatality ratio and humid temperate weather in the enlarged European Zone.

Weather Zone	Cumulative cases	Survivors	Global deaths	X2;p	Ro, CI 95%
Humid Temperate Weather	1,548,885	1,395,102	153,783	==	==
Mediterranean Weather	706,469	675,127	31,342	19,423.8 p<0.00001	0.42; 0.41-0.43
Cold Weather	352,982	340,260	12722	14394.07 p<0.00001	0.33 0.33-0.35
Cold Weather with Russia	1,253,727	1,225,474	28,253	60204.7 p<0.00001	0.20 0.20-0.21

Table 3 compares the same differences and measures the Association between High Case Fatality Ratio and Humid Temperate Weather in the European Union. Living in Humid Temperate Weather regions or countries is confirmed as being associated with the risk of a High Case Fatality Ratio for Covid-19, with respect to both inhabitants of the warmest Mediterranean zones (OR=0.85, IC 95% 0.84-0.87) or those living in cold climate zone (OR=0.63, IC 95% 0.61-0.65).

Table 3. Association between high case fatality ratio and humid temperate weather in the European Union.

Weather Zone	Weather Zone	Cumulative cases	Survivors	Global deaths	X2;p
Humid Temperate Weather	1,161,767	1,057,022	104,742	===	===
Mediterranean Weather	288,167	265,297	22,570	387.83	0.85 0.84-0.87
Cold Weather	119,312	112,305	7,007	1342.36 p<0.00001	0.63 0.61-0.65

3.1. Discussion.

Ours is the first work that has found a humid temperate climate associated with a higher Case Fatality Ratio with respect to the coldest and warmest temperate climates. This was found both in the enlarged European area and by restricting the number of states/regions considered in the European Union alone. The first evaluation has the advantage of comparing a multiplicity

of different conditions in terms of culture and other possible confounding factors (pollution, greater exposure to travelers, state of health, variables related to the quality of the health system in detecting and transmitting data) [16]; the second evaluation concerns a small number of states with more homogeneous conditions [17]. The fact that both evaluations' results are in agreement, therefore, reinforces the validity of the result. To our knowledge, there are no systematic studies in the literature on possible protection from the risk of mortality associated with cold climates in the Covid pandemic [18,19,20]. Some studies had found a possible protective effect related to heat; in fact, the equatorial countries showed a lower mortality rate out of the total of infected people than the remaining regions and territories located in non-temperate areas of three European nations (France, The Netherlands, and the United Kingdom) had a lower rate of lethality than metropolitan areas in the same nations, in partial independence of age distribution [8, 14]. Moreover, the provinces of 4 Italian regions with the highest temperature in March presented a lower mortality rate from COVID than the other provinces in the same 4 regions [9].

Furthermore, a negative linear relationship was found in Brazil between temperatures and the number of confirmed cases with a curve that flattened at a threshold of 25.8 ° C [2, 13, 21]. However, our data only concern the risk of mortality amongst cases and not the risk of disease. Furthermore, in Brazil, there was no data relating to a cold climate. Let's carefully analyze the data in our study. We find that although a humid temperate climate is associated with a high Case Fatality Ratio, other factors are undoubtedly significant. This emerges from the analysis of the states/regions that are strongly discordant from the weather-related trend. Among the nations with a humid temperate climate, for example, the high Case Fatality Ratio of the United Kingdom stands out (14.80 vs 9.92%). Among the cold climate states, there is the case of Sweden (6.9 vs 2.25%). Both nations implemented very limited and delayed lockdown measures.

A similar trend is not observed in Belarus, another country with limited lockdown. However, the data may not be comparable in this case [10]. Some areas with a high metropolitan density show higher CFR trends, for example, the Madrid area. This is possible in relation to greater exposure to the infection, given the greater difficulty of social distancing. Although this trend can be found in several areas with high urban density, it is not always present (for example, in Luxembourg) because probably other factors also come into play. It can also be noted that temperate regions close to the endemic explosion (such as Liguria) still have very high CFRs. This multiplicity of factors at play also highlights this study's limits; in fact, the current state of knowledge makes it impossible to balance the various potential confounding factors. Another limitation derives from the fact that a country provides the data on the pandemic or at the most by Region, while obviously, the climate does not respond to these limitations. For example, Catalonia has been placed among the humid temperate climates because most of its territory, but not all, have this type of climate. However, the same Region reports an intermediate Case Fatality Ratio (6.9%) compared to those of the two climatic areas even in the European Union, and location in one or the other does not change the results. These considerations cannot be made for France's southern Region (with a Mediterranean climate) for which no data are available. Suppose our hypothesis has confirmed the interruption of the lockdown in Southern Europe. In that case, it could be followed, with the return of the cold by very problematic autumn [11, 12]. It should also be noted that the second wave in Europe at the end of the summer was characterized by the interest above all of the young people due to the lack of respect for distances in discos and entertainment venues. Therefore, the spread of

the epidemic to weaker bands could coincide with the increase in cold weather, and two risk elements would add up [1, 15, 22].

4. Conclusions

The study found that a humid temperate climate is associated with a higher Case Fatality Ratio concerning the coldest and warmest temperate climates in Europe. Although this does not appear to be the only determinant of the pandemic, it is an element that must be taken into serious consideration for the planning of response strategies.

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Conflicts of Interest

The authors declare no conflict of interest.

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