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RESEARCH ARTICLE

# Verifying the Theory of Climate Affecting Lethality of COVID-19 by an Analysis in Two Climatic Zones of Chile

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**Abstract:**

***Introduction:***

The study of seasonal influences on the COVID-19 pandemic can take advantage of the unique position of Chile and its different climatic profiles in the north-south extension. The purpose is to verify the influence of seasonal climate changes on the COVID-19 in the temperate and sub-arctic areas of Chile.

***Methods:***

We monitored the evolution of CFR in temperate *versus* sub-boreal regions, reporting from the John Hopkins University COVID-19 Center on the CFR in each province in midwinter, spring, and early summer.

***Results:***

CFR worsened from mid-winter to mid-spring in the temperate zone of Chile, while in the sub-boreal area the CFR improves in the same period, (Kruskal Wallis Test, p=0.004). In the temperate zone after the increase in late winter-early spring, CRF tends to stabilize; on the contrary in the sub-boreal zone, there is a more marked tendency to worsen the CFR at the same time (Kruskal Wallis Test, p=0.010). The temperate zone of Chile shows a CFR increasing until spring-like temperate Europe, unlike Europe CFR does not decrease in summer, but the mean minimum temperature in temperate Chile is lower in summer than in temperate Europe. In Patagonian, CFR remains stable or drops from winter to spring but increases in early summer.

***Conclusion:***

The temperate and sub-boreal zones of Chile have a markedly different CFR variation profile during the COVID-19 pandemic.

**Keywords:** COVID-19, Climate change, Chile, Sub-artic regions, CFR, Pandemic, Analysis.

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|---|---|---|---|

## 1. INTRODUCTION

Analyzing the role of the climate in the trend of the COVID-19 pandemic, and more in detail on the lethality of the virus, some relevant knots have to be faced [1] due the spread depends on multiple co-factors including (but not exhaustively) measures of social distancing [2, 3], pollution [4, 5], health

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systems and access to care [6 - 12], genetic variants of populations [13 - 15], the difference in phases of the pandemic in different countries [16]. However, some geographical areas are more suitable for an in-depth study due to the relative homogeneity of social and political rules and health systems which allow, at least partially, modulating the variables involved [17 - 20]. Using this perspective and methodology, a series of researches highlighted that in the midst of the first wave of the pandemic when Italy was the most affected nation in late winter-early spring 2020, within the Italian regions, the hottest provinces were those with which the COVID-19 pandemic showed the lowest Case Fatality Ratio (CFR) [21]. Later it was found that the tropical territories of three European states (Netherlands, France, and the United Kingdom) had lower CFRs than metropolitan areas of the same countries [22]. While the peri-equatorial countries were the most protected against the COVID-19 lethality (with the exception of Ecuador) [22]. Studying the CSF in the European region and within the European Union, it is hypothesized that while the central cold temperate areas had shown the highest levels of CFR, the sub-arctic (with the exception of Sweden) and Mediterranean areas were, at least in late spring, more protected [17].

The trend of lowering the CFR with the arrival of summer was seen in the opposite sign to the contemporary trend in Australia [23] and Chile (with the arrival of winter) [24]. However, the trend was not perfectly homogeneous in New Zealand (where in fact the pandemic had been stopped) and in Argentina [23, 24]. All these observations have led to hypothesize a greater risk in cold temperate areas and a situation of bimodal protection in colder and warmer areas with a maximum expression where a good health organizational response is added to the climatic protective factor (as in Singapore in the South or in Iceland to the north) [19]. The study of the influence of seasonal climate changes on the COVID-19 pandemic can take advantage of the unique position of Chile. This nation has in fact different climatic profiles in its long north-south extension. With a sub-arctic area in the south, a temperate area in the center, and, in the north, different climates from the tropical to the desert area of the Atacama, while in the East area the Andean areas have like Alpine Climate [25, 26]. In addition, the John Hopkins University COVID-19 Center [25] has provided specific CFRs for this country by province. Although climatic changes may also be revealed within the same provinces, however, the largest portion of the population is concentrated in cities. So, if we refer to the climate of the main cities of the provinces, the CFR reference can be approximately correct if reported for the whole province.

The purpose of this work is to verify the influence of seasonal climate changes on the COVID-19 in the Chilean provinces, in particular in the temperate and sub-arctic areas.

## 2. METHODS

We have considered the recent zonation of Chile into four major bioclimatic regions [21]. We specifically monitored the evolution of CFR in temperate *versus* sub-boreal regions (which are the most definable regions), we reported from the John Hopkins University COVID-19 Center [27] the CFR in each province in midwinter (22/8), spring (11/11), and early summer (20/12), then we compared using Kruskal Wallis test the differences in CFR from 22/8 to 11/11 and from 11/11 and 20/12 in the provinces of the two areas. To better understand if there could be a relationship between climatic evolution and the spread of the virus, we have reported in Table **1** the changes in the temperature of the two most significant cities of the two regions (Punta Arenas e Puerto Montt for the sub-boreal zone and Valparaiso and Santiago for the temperate one) in August, November, and December [28].

To verify a possible comparison with respect to what happened in Europe we have in the same figure shown two cities in the European Mediterranean area considered to have a low risk of the lethality of COVID-19 (Palermo and Athens), two cities of the European temperate area considered to be at high risk of lethality (Paris and London) and two European cities of the sub-artic area considered at low risk of lethality (Reykjavik and Oslo).

## 3. RESULTS

Table **2** shows a worsening of CFR from mid-winter to mid-spring (22/8 *vs* 11/11) in all provinces of the temperate zone of Chile, while in the whole sub-boreal area the CFR improves in the same period, the difference of the mean of differences is statistically significant (differences in Temperates *vs* Sub-Boreal provinces, Kruskal Wallis Test, H=8.077 [1N=12], p=0.004). In the temperate zone after the increase in late winter-early spring CRF tends to stabilize with variations from -1 to +6 considering the interval of time 11/11 *vs* 20/12; on the contrary in the sub-boreal zone there is a more marked tendency to worsen the CFR at the same time with differences from +6 to +40, the difference is statistically significant (differences in Temperates *vs* Sub-Boreal provinces, Kruskal Wallis Test, H=6.533 [1N=12] p=0.010), it should also be noted that the increase tends to be stronger in the colder southern provinces. In August the average maximums in Valparaiso and Santiago are slightly higher than those of the two reference cities of Mediterranean Europe (and also of the other European cities reported in reported in the Table **1**) in the same period of the year (February), but the mean minimums are closer to those of European cities with a cold temperate climate (Paris and London). In spring and early summer (November and December in the South, May and late June in the North) the climate of Valparaiso and Santiago is more similar to that of cold temperate Europe although drier. In winter, the minimum temperatures in Puerto Montt and Punta Arenas are less cold than in Scandinavia but colder than in Central Europe. However, the minimum temperatures in spring in the cities of the boreal zone remain colder than in Paris and London and similar to Reykjavik and Oslo. At the beginning of the summer, the change in climate in the boreal cities is not as sharp as in Iceland and Norway, especially in the minimum temperatures that rise by only 2 degrees, while in the Northern cities the change is more marked.

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**Table 1. Comparing climate trend in different climate zone cities of europe and chile.**

| City | August - max-min C° (rainfall) [*vs* February North] | November max-min C° (rainfall) [*vs* May - North] | December max-min C° (rainfall) [*vs* June North] |
|---|---|---|---|
| Valparaiso | 16; 8 (7) | 20-11 (0.1) | 21-12 (0) |
| Santiago | 16; 3 (5) | 25-8 (0) | 27-10 (0) |
| Palermo | 15; 9 (7) | 24-17 (2) | 28-21 (2) |
| Athens | 14; 7 (5) | 25-16 (2) | 29-20 (1) |
| Paris | 9; 3 (8) | 20-11 (9) | 24-14 (8) |
| London | 9; 5 (4) | 18-10 (8) | 21-13 (6) |
| Puerto Montt | 10; 3 (21) | 15-6 (12) | 18-8 (12) |
| Punta Arenas | 3, 0 (3) | 11-4 (2) | 13-6 (3) |
| Reykjavik | 3; -2 (13) | 10-4 (10) | 12-7 (9) |
| Oslo | 1; -5 (7) | 17-7 (8) | 21-11 (9) |

**Table 2. Differences in Temperates *vs* Sub-Boreal provinces.**

| | Case Fatality Ratio% (22/8) | Case Fatality Ratio% (11/11) | Case Fatality Ratio% (20/12) |
|---|---|---|---|
| **Temperate** | | | |
| Coquimbo CI | 1.25 | 2.02 +77 | 2,08 +6 |
| Valparaiso CI | 3.01 | 3.52 +51 | 3,52 0 |
| Santiago CI | 3.07 | 3.36 +29 | 3.39 +3 |
| O'Higgins (Rancagua) | 2.49 | 2.68 +19 | 2.74 +6 |
| Maule (Talca) | 2.17 | 2.26 +9 | 2.29 +3 |
| Nuble (Chillan) | 1.81 | 2.05 +24 | 1.99 +6 |
| Biobio Conception | 1.13 | 1.67 +54 | 1.66 -1 |
| **Sub Boreal** | | | |
| Araucania | 1.82 | 1.24 (-58) | 1.30 +6 |
| Los Rios | 1.46 | 0.89 (-57) | 0.97 +8 |
| Los Lagos | 1.03 | 0.86 (-17) | 1.02 +16 |
| Aysen | 1.01 | 0.70 (-31) | 1.10 +40 |
| Magallanes | 1.26 | 1.21 (-5) | 1.39 +18 |

22/8 *vs* 11/11 - Temperates *vs* Sub-Boreal Kruskall Wallis Test, H=8.077 (1N=12) p=0.004.
11/11 *vs* 20/12 - Temperates *vs* Sub-Boreal Kruskall Wallis Test, H=6.533 (1N=12) p=0.010.

## 4. DISCUSSION

The research highlights a clear difference in the COVID-19 spread in the two climatic zones of Chile. These differences suggest a role, at least as a co-factor to the characteristics of the climate as a determinant of the profile of the pandemic. However, it is difficult on the basis of qualitative analyzes comparing the trend in Europe to establish similarities that can clarify the true role of climate factors. The increase in CRF in late winter and early spring was similar in the Chilean and European temperate areas. It is hard to hypothesize that this trend is only due to weather because this is already heating up. Even if the abandonment of a "protective" cold climate without having yet reached a sufficient hot may be a co-factor, in fact in Europe the protected areas have been in the South (Mediterranean climate) and North (sub-climate climate) arctic) while the risk was stronger in the central temperate area. However, the same trend is also evident in Mediterranean Europe so the hypothesis of the risk window between a colder and a warmer protective one cannot fully explain this increase in CFR from winter to spring. Once the CFR has risen in the early part of spring, in temperate Chile, unlike in Europe, does not go down. It should be noted that temperatures in Valparaiso and Santiago de Chile in early summer, especially the minimum ones, are much lower than in temperate Europe and similar to those of Paris and London in the middle of spring (when in these cities the CFR was higher). Temperatures in Punta Arenas and Perto Montt, although not as high as in Norway and Iceland, remain higher than in continental Europe even in spring (while the CFR, on the other hand, decreases in opposition to temperate Chile). When the paradoxical increase of CFR in the summer arrives in Patagonia, it can be seen that the temperatures in Patagonian cities have become in the same range as in those of central Europe in the middle of winter (*i.e.*, with a high CFR risk). The weather influence on the pandemic may depend on higher risk related to could climate on concomitant respiratory diseases that can influence the evolution of COVID-19 infection [29 - 31] or of the influence of the sun on vitamin D which may have a relationship with resistance to the virus [32, 33]. But it could also depend on mediators indirectly influenced by the climate such as the easier social distancing due to the cold [34] or the lower level of pollution in the city with a colder climate causing strong wing (similarly in Scandinavia and Iceland and Patagonia) [35]. However, as far as regards this late point, it is difficult to affirm that there are today, especially in the south, areas with a low level of pollution, in particular in Patagonian, pollution risks have been highlighted, even relating to substances suspected of facilitating the spread of the pandemic [36 - 38].

Social distances have been called into question above all for the increase in the spread of the virus but it could be less related to increasing lethality. This aspect, together with the climate and socio-economic factors, has been considered one of the causes of the specificity of spread in Africa and in other tropical areas where an extensive epidemic is almost everywhere matched by a very low lethality [39, 40]. As for Vitamin D, although it was shown an association between low levels with severe outcomes of COVID-19 [32], the causality remains uncertain as several determinants in worsening outcome in COVID-19 infection are the same that causes lower serum vitamin D levels [31] (*i.e*., the falls of vitamin D are shown during several inflammation processes thus is not clear if the low vitamin D is the cause of poor outcomes of COVID-19 or vice versa [30]). The hypothesis that the increases of the CFR in relation to the changes of seasons probably remain the most interesting to explore.

The prolongation of the worsening of the CFR in late spring in temperate areas of Chile and Europe is one of the most interesting aspects to be clarified in relation to the hypothesis of the link between climate on the pandemic. It should be noted that the trend is revealed, with few exceptions, in states that have adopted very different prevention measures and policies, including the rules on social distancing. At the current state of knowledge, it seems to emerge that the heat can have a protective role but only if the minimum temperatures exceed 10 ° C, as occurs in the temperate/cold or Mediterranean European areas in summer and as does not happen in the Chilean temperate zones. However, it cannot be ruled out that humidity can also play a role as the rainfall profile is very different and Chile is much drier in summer. The hypothesis that allergy or airborne pollen season, more frequent in spring, may play a role in prolonging the risk caused by increased cold in winter seems less sustainable. Although an association has been shown between some cases of severe allergic asthma and severe forms of COVID-19 pneumonia [41, 42], allergic diseases have been reported with reduced rates in COVID-19, and allergy-associated eosinophilia was not recognized as a factor linked with negative outcomes [42]. Even the hypothetical association between the allele variant HLA-DRB1*08:01 (shown in patients with Covid with worst outcome [13, 43]) with allergic rhinitis [44, 45] does not seem so strong and specific as to lead evidence in favor of a role of allergic rhinitis as a mediator in the prolongation of the risk in springs in both hemispheres.

## CONCLUSION

The temperate and sub-boreal zones of Chile have a markedly different CFR variation profile during the COVID-19 pandemic. Temperate zones show an increase of CFR until spring-like temperate Europe which, however, unlike Europe, does not decrease during the summer. This can be caused by a colder climate in the summer (at least relative to the minimum temperatures) of temperate Chile than in Europe with a temperate (both temperate/cold and Mediterranean) climate. In Patagonian areas, the CFR remains stable or drops from winter to spring but increases in early summer. This may be due to the fact that we pass from a sub-Antarctic climate to a climate similar to the temperate one in winter which highlighted the climatic belt associated with the highest level of CSF.

### What is already known on this topic?

- The influence of seasonal climate changes on the COVID-19 pandemic can take advantage of the unique position of Chile.
- Chile has different climatic profiles in its long north-south extension. With a sub-arctic area in the south, a temperate area in the center, and, in the north, different climates from the tropical to the desert area of the Atacama, while in the East area the Andean areas have like Alpine Climate.

### What does this study add?

- To verify the influence of seasonal climate changes on the COVID-19 in the temperate and sub-arctic areas of Chile.
- Monitoring the evolution of CFR in temperate *versus* sub-boreal regions, reporting from the John Hopkins University COVID-19 Center on the CFR in each province in midwinter, spring, and early summer.
- The temperate and sub-boreal zones of Chile have a markedly different CFR variation profile during the COVID-19 pandemic.

## AUTHORS' CONTRIBUTIONS

CIAG, FR, GK, DF, MGC, SDG, AR, LZ, AM, GO: Conceptualization, Methodology, Software;

MGC, CIAG, AS, GC, RL, MC, SD, FR,GK, DF, FM, SDG, AR, LZ, LM, GT, AM, GO, LC, MVB: Data curation, Writing, Original draft preparation;

MGC, AS, MC, SD, FM, AR, LM, GT, GO, LC, MVB: Visualization, Investigation;

MGC, GC, RL, LZ, GT, AM, GO, LC: Formal analysis;

MGC: Supervision;

MGC, GK, GO: Writing, Reviewing and Editing.

## ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

## HUMAN AND ANIMAL RIGHTS

No animals/humans were used for studies that are the basis of this research.

## CONSENT FOR PUBLICATION

Not applicable.

## AVAILABILITY OF DATA AND MATERIALS

Not applicable.

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## CONFLICT OF INTEREST

The authors declare no conflicts of interest, financial or otherwise.

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Declared none.

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