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CORRELATIONAL ANALYSIS OF GEOGRAPHICAL AND SOCIOECONOMIC FACTORS ON COVID-19 SPREAD IN THE METROPOLITAN REGION OF CHILE

ANÁLISIS CORRELACIONAL DE FACTORES GEOGRÁFICOS Y SOCIOECONÓMICOS SOBRE LA PROPAGACIÓN DEL COVID-19 EN LA REGIÓN METROPOLITANA DE CHILE

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ABSTRACT

The COVID-19 disease is the major pandemic in the last decades, where the person-to-person transmission easily spreads the virus worldwide, where understanding the relationship between environmental and socio-economic variables in a spatial context is crucialto face future pandemics. Therefore, the aim of this study was to analyze in a global way the behavior of the COVID-19 outbreak in the Metropolitan Region of Chile during the months of March-June 2020. The Metropolitan Region was segmented by 52 communes, and epidemiological, demographic, socioeconomic variables and distribution of services were analyzed under this spatial division. Then, the number of contagions was correlated with days of lockdown, health risks, socioeconomic status, among others. The results show that there are areas in the Chilean Metropolitan Region that have a combination of factors that favor the spread of the SARS-CoV2 virus. Communes with a higher rate of overcrowding, lower educational level and higher rates of comorbidities were those with highest number of COVID-19 cases. Interestingly, these results show that since the beginning more cases were observed in the young adult population. These results provide a framework of variables related to the spreading of the virus and could contribute to decision making during pandemic in the Metropolitan Region of Chile.

Keywords: COVID-19, pandemic, geospatial distribution, Santiago

RESUMEN

La enfermedad COVID-19 es la mayor pandemia de las últimas décadas, donde la transmisión persona a persona hace que el virus se propague fácilmente a nivel mundial, donde comprender la relación entre las variables ambientales y socioeconómicas en un contexto espacial es crucial para enfrentar futuras pandemias. Por lo tanto, el objetivo de este estudio fue analizar de manera global el comportamiento del brote de COVID-19 en la Región Metropolitana de Chile durante los meses de marzo-junio de 2020. La Región Metropolitana fue segmentada en 52 comunas, y bajo esta división espacial se analizaron variables epidemiológicas, demográficas, socioeconómicas y de distribución de servicios. Luego, se correlacionó el número de contagios con días de aislamiento social, riesgos sanitarios, nivel socioeconómico, entre otros. Los resultados muestran que existen zonas en la Región Metropolitana de Chile que presentan una combinación de factores que favorecen la propagación del virus SARS-CoV2. Las comunas con mayor tasa de hacinamiento, menor nivel educacional y mayores tasas de comorbilidades fueron las que presentaron mayor número de casos de COVID-19. Curiosamente, estos resultados muestran que desde el inicio se observaron más casos en la población adulta joven. Estos resultados proporcionan un marco de variables relacionadas con la propagación del virus y podrían contribuir a la toma de decisiones durante la pandemia en la Región Metropolitana de Chile.

Palabras clave: COVID-19, pandemia, distribución geoespacial, Santiago.

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1 INTRODUCTION

Since early 2020 we are experiencing a global outbreak of the new type of coronavirus SARS-CoV-2, the causal agent of COVID-19. This outbreak originated in the city of Wuhan, China, quickly spread to other countries worldwide, been declared a pandemic on March. Afterward, Latin America became the epicenter of the pandemic during May 2020, including the metropolitan region of Chile.The Metropolitan Region is the second smallest region of all 16 first-order administrative divisions of Chile, and it is also the most inhabited with 8 million inhabitants. Since first case report in Chile, the government implemented different actions: borders were closed, partial lockdowns were decreed in places where contagions were increasing, until total lockdown of the Metropolitan Region. The region concentrated 81% of the contagions in 2020. The total confinement of the metropolitan region came into effect on Friday, May 15, 2020 (Ministerio de Salud, 2020), generating unprecedented changes in daily life of people and leading to an exceptional context to study the factors affecting the virus spreading.

The SARS-CoV-2 transmission occurs from a contagious human to another, through close contact. The incubation period ranged from 5.2 (Backer et al., 2020; Li et al., 2020) to 19 days (Bai et al., 2020), which finally generated a 14 days quarantine consensus (Jiang et al., 2020). To control outbreaks of COVID-19 in the community, rapid and accurate detection is crucial and performing diagnostic tests based on polymerase chain reaction (To et al., 2020). Patients affected by COVID-19 without vaccination could experience serious complications, including organ failure, septic shock and pulmonary oedema, and mortality reached 10% in some countries (Chen et al., 2020; Sohrabi et al., 2020). Lack of treatment and vaccination availability limit prevention of SARS-CoV-2 transmission, becoming a major challenge, where classical public health measures, including lockdown, quarantine, social distancing, and personal protective equipment remain as the most effective way to curb the pandemic. Lockdown surge as a key measure for controlling the spread of the virus in the community (Ibarra-Vega, 2020). This scenario allows to explore the geographical and socioeconomic factors that affect the spreading of the SARS-CoV-2 virus.

In this context, the need arises for geospatial tools. Geographic information systems (GIS) have been used to measure and explore geospatial relationships of health and health variables (Kirby et al., 2017). They provide a link between databases maps and visual impact of certain health variables, allowing the analysis of patients´ geospatialdistribution or conditions endangering health (Franch-Pardo et al., 2020). The geospatial disease mapping caneffectively reveal a geographic phenomenon and transfer the information to health managers,policy makers for effective planning. The study of a disease geospatial variables provides aframework to study the interaction of intrinsic characteristics of virus favoring spreading (Tao et al., 2021; Bulfone et al; 2021) with environmental, social, cultural, andbehavioral factors on people's health (Kirby et al., 2017; Madhu et al., 2016).

During COVID pandemic, GIS have been valuablefor decision making and design of more effective measures (Ahasan & Hossain, 2021). Thus, the aim of this work was to correlate different variables, with contagion rate, geospatially distributed, during COVID-19 pandemic in the Metropolitan Region of Chile,during of March-June 2020.

2 MATERIALS AND METHODS

2.1 Study Area

The study area was focused on the Metropolitan Region, whose capital is Santiago city. It is bordered to the north and west by the Valparaíso Region, to the east by Argentina, and to the south by the O'Higgins Region. The Metropolitan Region represents only 2.0% of the national territory. Despite this, it concentrates just over 40% of the national population, with a population of 7,112,808 inhabitants (3,462,267 men and 3,650,541 women) according to the 2017 census (Bagherzadeh et al., 2018; Barrenechea et al., 2023; Naranjo et al., 2024). This study considers the political-administrative division of the metropolitan area, based on communes (**table S1**). The political-administrative division of the region is composed of provinces: Chacabuco, Cordillera, Maipo, Melipilla, Santiago and Talagante. And a total of 52 communes, with characteristics of field (rural) and urban (Santiago, Cordillera, Colina). As shown in table S1.

2.2 Geospatial variables

2.2.1 *Determination of contagions by SARS-CoV-2.*

SARS-CoV-2 contagious cases, in the period from 1 March to 1 June 2020, were obtained from the daily report published by the Ministry of Health of Chile. The specific location of cases by commune was obtained from the epidemiological report issued by Ministry of Health of Chile (Ministerio de Salud, 2020).

2.2.2 Determination co-morbidities prevalence and their associated risk.

Hypertension, diabetes, cardiovascular diseases, and their susceptibility conditions may be related to the pathogenesis of COVID-19 (Mueller-Wieland et al., 2022; Pathangey et al., 2021). Thus, data including pre-existing pathologies, from the 2017 cardiovascular health program (PSCV), were obtained from the Chilean Ministry of Health (Ministerio de Salud, 2017).

2.2.3 Age ranges.

Age ranges for this study were determined as follows: 0-39 years old; 40-69 years old and over 70 years old. These age ranges were chosen based on data previously published in the national health survey conducted in 2010, and studies published in 2012, which related the association between anthropometric parameters to define obesity, BMI, waist circumference and waist/height ratio, with the prevalence of arterial hypertension, dyslipidemia and diabetes, and with the risk of coronary heart disease in young and adult populations (Lanas Zanetti, 2017; Martinez et al., 2012).

2.2.4 Distribution of mass concentration centers.

Supermarkets and pharmacies are considered mass congregation centers. Location of these centers were obtained using the locations published in their web pages. This information was crossed with the one on the Chilean government's tax service page. In this case, large pharmacy chains as well as independent pharmacies were considered.

2.2.5 Socioeconomic status (SES).

The socioeconomic variables used were: Demographic, Educational Housing, and vulnerability. The demographic variable considered was: Population density. The educational variables considered were the following: People without higher education, People with higher education. The housing variables were: Number of overcrowded homes. Data were obtained from 2017 national census and were downloaded from the Instituto Nacional de Estadísticasplatform.

2.2.6 Lockdowns.

Length of lockdown per commune was considered, no matter these were dynamic (only part of a commune enters lockdown) or total (the entire commune under lockdown).

2.3 Variable correlation analysis

The analysis was performed estimating indexes or rates. The following variables were calculated: WIC: Percentages of communal contagions in relation to the total number of contagions in the Metropolitan Region, as of June 1, 2020. PIC: Percentage of contagions with respect to the total number of inhabitants of the commune, DQ: Days of lockdown, CRI: Index of communal rurality, calculated with 2017 census data, SPI: Social Priority Index, calculated with 2017 census data, PDEN: Population Density, AID: Average number of inhabitants per inhabited dwelling. PO: Population overcrowding Rate of overcrowded housing with respect to the total number of houses in the commune, SRI: supermarket rate per inhabitant, CRPR: Rate of inhabitants with cardiovascular risk in relation to the total of inhabitants over 45 years old in the commune. RID: Rate of inhabitants with diabetes in relation to the total number of inhabitants over 25 years old, in the commune. RphI: Rate of pharmacies in relation to the total number of people over 15 years old in the commune. EAR: Rate of people with higher education in relation to the total number of people with formal education. RPCC: Rate of primary public attention centers with respect to the total of inhabitants by commune. EWAR Rate of population without education. Education level determines at least in part the access to works that allow teleworking. In Chile, 20.6% of the employed work in activities where face-to-face work is mandatory, while 23% can apply teleworking.

In the next period, Rate of increase to 01-05-2020= 409 — 306 = 0,3366. This means that the increase of contagions in that period was 33.66% compared to 15-04-2020.

2.4 Biplot Analysis

The proximity between points was interpreted in terms of similarity in this case the communes were similar according to the characteristics (variables) that we included in the study. The angle between vectors is interpreted in terms of correlation between the variables and the projections of the communes to the vectors(variables) allow to obtain, in an approximate way, the values of the database. The length of the vector approximates the standard deviation of the variable, longer vectors represent greater variability. The projection of each vector with the commune was used to perform the calculation of the value of the variable with respect to that commune.

3 RESULTS

3.1. Number of contagions in the metropolitan region

The number of contagions by COVID-19 remained relatively lowbetween March 1 and May 14 with a daily number of 500 contagions per day, later, increased to more than 3,000 from May 15 to June 1, distributed throughout the country,concentrating most of them in the Metropolitan Region of Santiago, specifically in theProvince of Santiago, as shown in **Figure. 1**. It is important to note that the metropolitan Region represents 80.97% of the total numberof contagions at the national level, which can be explained, in part, by the fact that it is theregion with the largest population. When reviewing the contagions by commune, a concentration in the communes that are part of the “Gran Santiago” (capital of the Metropolitan Region) was appreciated, being the communes of Puente Alto and Santiago, those with greater numbers (see **Figure 1**).

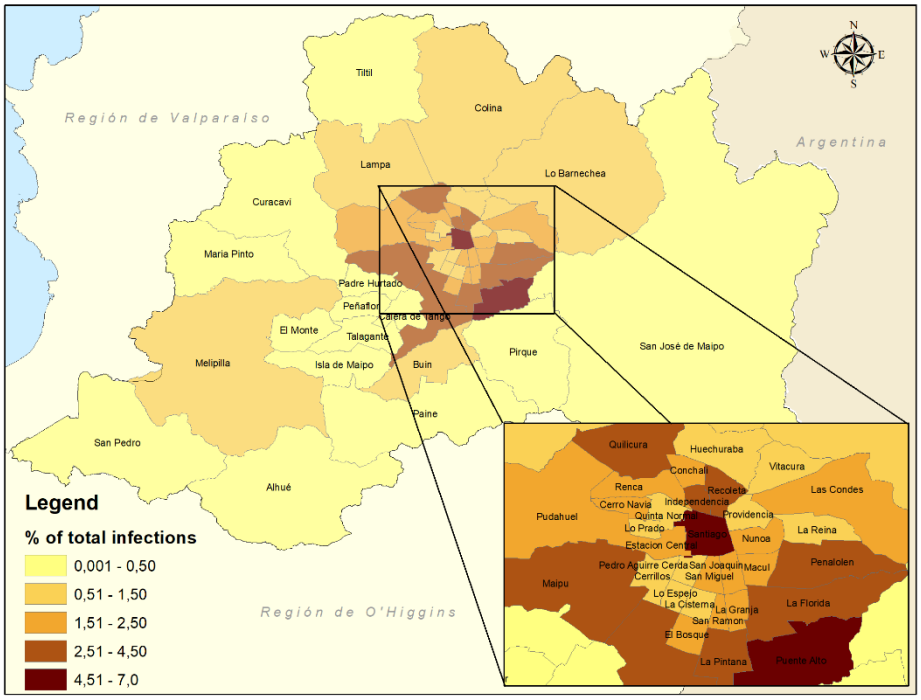

Figure. 1. Contagion rate distribution. Based on the data provided by the Ministry of Health of Chile and published in its web page https://www.minsal.cl/nuevo-coronavirus-2019-ncov/casos- confirmados-en-chile-covid-19/, then represented on the map, using the ArcGiS program. Yellow represents the lowest contagion rate. Brown represents the highest in relation to the total contagion rate of the Metropolitan Region

3.1.2 Geospatial analysis

The analysis of the variables wasfocused on the 10 communes of the region with the highest contagion

rate: Puente Alto, Santiago, La Florida, Peñalolén, Maipú, Recoleta, Quilicura, Independencia, San Bernardo and La Pintana. In descriptive terms, these communes are characterized for being those with the largest population not only at regional level, but also nationally, being Puente Alto and Santiago the communes with largest population of the country. The socioeconomic level of the same ones is in the middle, middle-low and low stratum (**table S2**).

3.1.3. *Age ranges.*

The population under 39 years old, has less probabilities of morbidity and/or death, but behaves as a vector, putting at risk the older population. Of the total number of contagions in the country, 52.4% correspond to under 39 years people. As it is observed in (**Fig. 2**), the communes with greater amount of population with ages between 0 and 39 years, are those that register greater contagions. It is identified that the communes with greater contagion are those that have 60% of population between 0-39 years. On the contrary, there is no direct relationship between the groups of 40-69 and older than 70 years. Older adult population was more vulnerable to severe infection caused by the virus, an early appeal was made to the age group over 60 years old to avoid leaving their homes (Davies et al., 2020).The communes of Puente Alto and Santiago are those with greater contagion rate and at the same time, those with largest population in the age range between 0 - 39 years (**Fig. 2**).

3.1.4. *Centers of mass congregation.*

The supermarkets, pharmacies and family health centers location analysis showed a close relationship between the number of mass congregation centers and the contagions in the Metropolitan Region (**Figure. S1**). Thus, the communes with the highest contagion rate are the ones with the highest number of supermarkets and pharmacies, but not the health centers.The communes of Santiago, Las Condes, Providencia, and Puente Alto stands out in the great number of pharmacies, registering a total of 253, 123, 108 and 84, respectively. In relation to the supermarkets, the communes of Maipú, Santiago and Puente Alto register the greater amount with a total of 38, 38 and 21 premises, respectively. Although the communes of Las Condes and Providencia are not considered to be among the most contagious communes, they do not have a high number of supermarkets, as is the case of the communes of Santiago and Puente Alto. The same is observed for free fairs, where the communes of Puente Alto and Maipú are those with highest amount. The data suggest that the greater the number of centers of mass concentration, the greater the number of contagious (**Figure S1**).

Supermarkets and pharmacies were considered areas of more agglomeration and its contribution to the communes that registered the highest contagion rate was evaluated. Additionally, pharmacies were included given the relevance they acquire in cases of health emergencies. We also found a positive relationship between the communes with the highest number of Supermarkets, and the contagion rate. What may be revealing is the lack of precautionary measures at the time of attending these places, such as not keeping the necessary physical distance or the time it takes people to do their shopping and stay in these places, which were recommended but not mandatory, would favor the spread of the disease.

3.1.5 *Overcrowding.*

According to the Ministry of Housing and Urban Development, overcrowding is defined as housing with between 4.5 and 5.5 inhabitants per room. This variable is important when analyzing the distribution of the contagion, since one of the main causes of the SARS-CoV-2 spreading is physical contact between people. If there is no adequate social distancing, the probability of contagion increases.

The most overcrowded communes are those with lower incomes (**Figure. 3**), where the collective housing known as "*cités*", accommodate a lot of families in a reduced space14. The communes of Santiago and Puente Alto are those with the highest levels of overcrowding, coinciding with the highest numbers of contagions, followed by the communes of San Bernardo and Maipú. Furthermore, the commune of Puente Alto, is at the edge of a rural zone, with many irregular houses and concentrating high number of people in reduced spaces.

On the other hand, the commune of Santiago has presented a substantial increase in the construction of housing buildings of reduced space, which have been leased to families of medium socioeconomic level, where usually live more than one family.

3.2 Educational Level

According to 2017 Census, all communes (except for the commune of Santiago) register more than 70% of their population without superior education (In this case, the population that has completed its school education, basic and secondary, and is able to access higher education is considered). It is observed that the communes of La Pintana and San Bernardo are those with greater amount of population without superior education, with 89.8% and 85.5% respectively, being the first the only one in analysis presenting a low socioeconomic stratum (Figure S2).

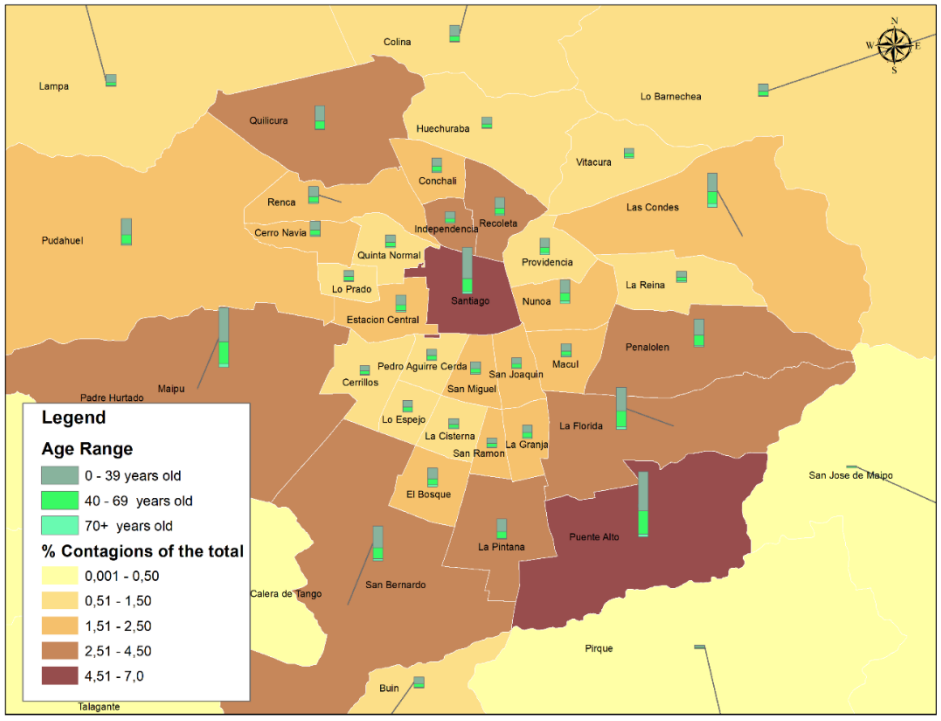

Figure. 2. Contagion rate in relation to the age range of the population. This figure illustrates relationship between age groups and contagion rate by commune in relation to the regional total. As it can be seen, the communes with the highest contagion rate without those that present a greater number of populations at the young age group, which could imply a latent risk for the older groups, given that young people do not adapt easily to social distancing. To build this map, the data on infections published by the Ministry of Health of Chile through the epidemiological reports available on the website of the ministry and were crossed with the data available in the INE for the age groups living in each commune according to the last census of 2017.

In the case of the commune of Santiago, although it is the one that registers greater contagion, the 59% of its population is without superior education, which could be interpreted as a factor that favors the decrease of contagion, however, it is a civic center, so the floating population, possibly associated to long distances to their works in an overcrowded public transportation, combined with the other variables described above, elevates therisk of contagion of its population. Moreover, as expected, the percentage of informal work increases as the educational level decreases. ILO data, show that during the six-year period 2014-2019 the type of employment that grew most strongly in Chile was self-employment (on average, at 3.8% per year), while salaried employment grew by less than half (1.6%). This has direct implications for the composition of employment. This was the situation in Chile at the beginning of the pandemic (Kremerman, 2021; Maurizio et al., 2021). It would then be explained that the communes with thehighest percentage of contagion are the ones with the highest amount of uneducatedpopulation, since it is inferred that this population works in jobs, which cannot be done byteleworking, forcing them to move to their workplaces.

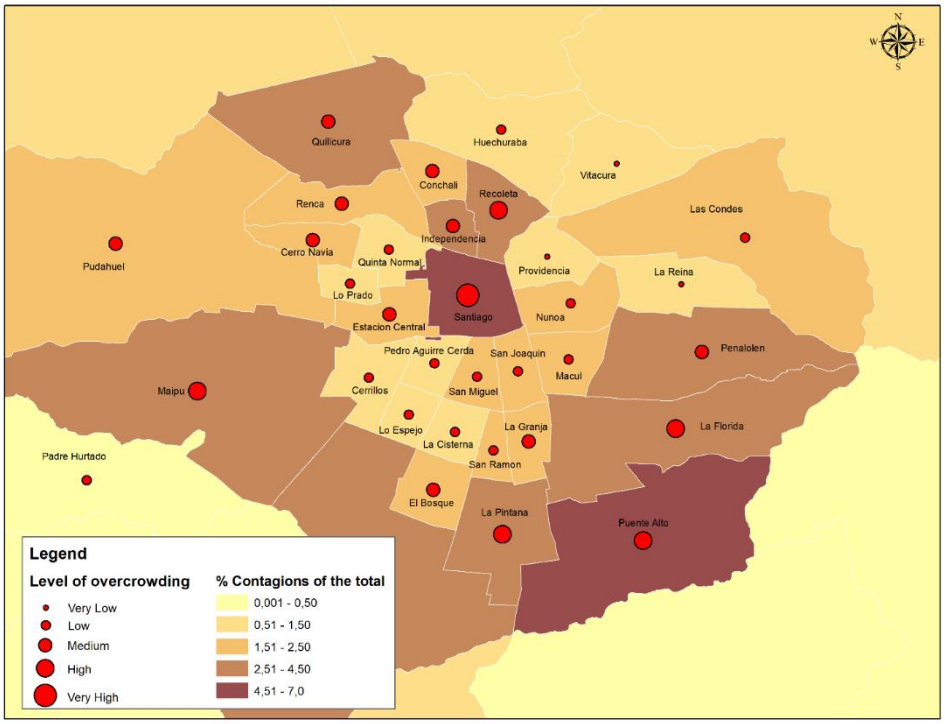

Figure. 3. Relationship between the level of overcrowding and the contagion rate. Communes that showed high/extremely high overcrowding were also those with high number of SARS-CoV-2 infections.

3.3 Co-morbidity

The communes of Puente Alto, La Florida and Maipú are those with the highest number ofpeople with cardiovascular risk. The first one with more than 38,000 people. Meanwhile,hypertension and diabetes, showed the highest prevalence in Puente Alto, with 60,184people with hypertension and 29,540 people with diabetes. This would be associated to thelower socioeconomic status and educational level in this commune. Thus, families are facedwith the challenge of low-cost food, positioning junk food and low nutrition value as thefirst option, bringing health consequences, **Figure 4**. Consequently, the communes with thehighest contagion are those registering the highest number of people with cardiovascularrisk diseases and diabetes.

3.4 Lockdown

The communes of Independencia and Santiago are those with the longest lockdown, with89 and 79 days, respectively, followed by Puente Alto and San Bernardo with 64 and 57days. However, all these communes are among those with the highest number of contagionsin the Metropolitan Region, which indicates that the lockdowns are not a preventivemeasure, but rather a reactive one, decreeing it in those communes that increase their cases.For a lockdown to be effective, it must be decreed prior to the increase in cases of contagions to protect the unaffected population (**Figure. S3**).

Finally, the effect of lockdowns on the contagion rate showed that the longest lockdown, the greater the number of contagions observed, which could show how reactive this measureis and that it should be taken at the beginning of the appearance of the first cases, and nothave made partial lockdown, a measure that was also adopted in other Latin Americancities such as Rio de Janeiro (Dantas et al., 2020). But on the other hand, it may also be revealing a littleadherence to this measure in the communes under study.

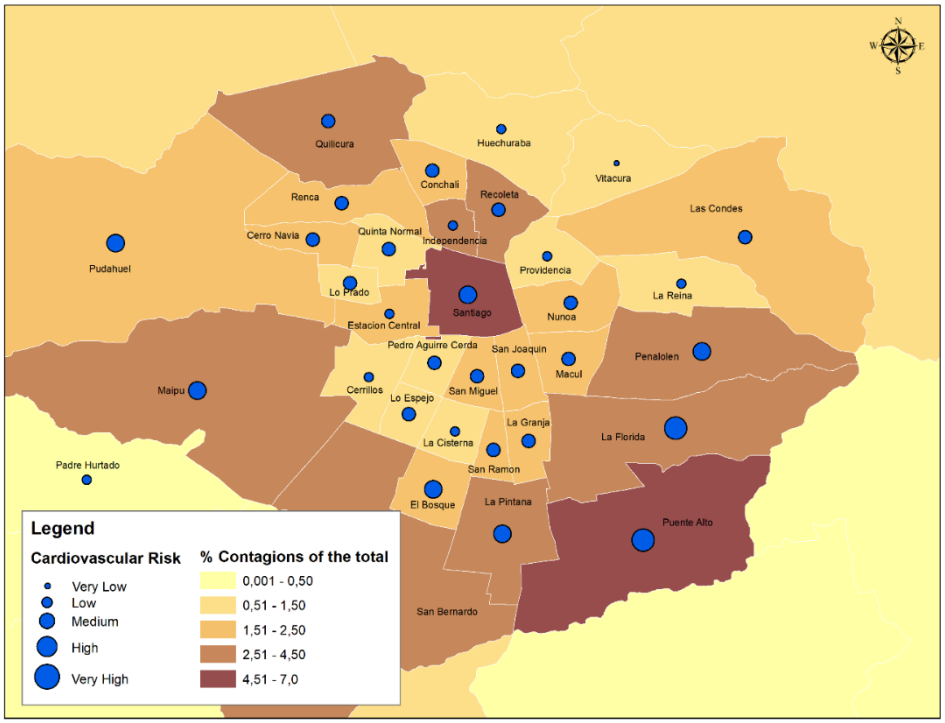

Figure. 4. Ratio of population at risk of cardiovascular disease and contagion rate by municipality in relation to the regional total. The communes of Puente Alto and La Florida have the highest number of people at risk of cardiovascular disease, which can be attributed to the socioeconomic level and number of people living in these communes. Low-nutrient food is generally of lower cost and therefore facilitates the economic feeding of a family. This poor diet leads to the development of cardiovascular disease, hypertension, and diabetes. Source: Authors' elaboration.

3.5 Correlation Matrix

When analyzing the Metropolitan Region as a whole, the variable number of days underlockdown shows a positive correlation of 0.67 with the contagion rate in the region,indicating that the measure taken by the State to control the pandemic is not effective. Lockdowns were accompanied by a series of permits that allowed an increase in people traveling though the city 43. Thiscorrelation would indicate that the communes with the greatest number of days inconfinement have the highest contagion rate. This could be interpreted because of the lateimplementation of lockdowns and its reactive effect, i.e., the decision to lockdown acommune is not made with the aim of protecting the population from contagion, but rather,not to spread the virus to nearby communes.

On the other hand, the index variables of rurality and population density presentcorrelations of 0.56, possibly associated to the fact that rural communities in Chile havelower levels of sanitation (Alves et al., 2021; Silva et al., 2020; Silva et al., 2021). Furthermore, population density presents a correlation of 0.48, adirect relationship: the greater the number of people per square kilometer, the greater thecontagion probability, as shown in **Figure. 5**.

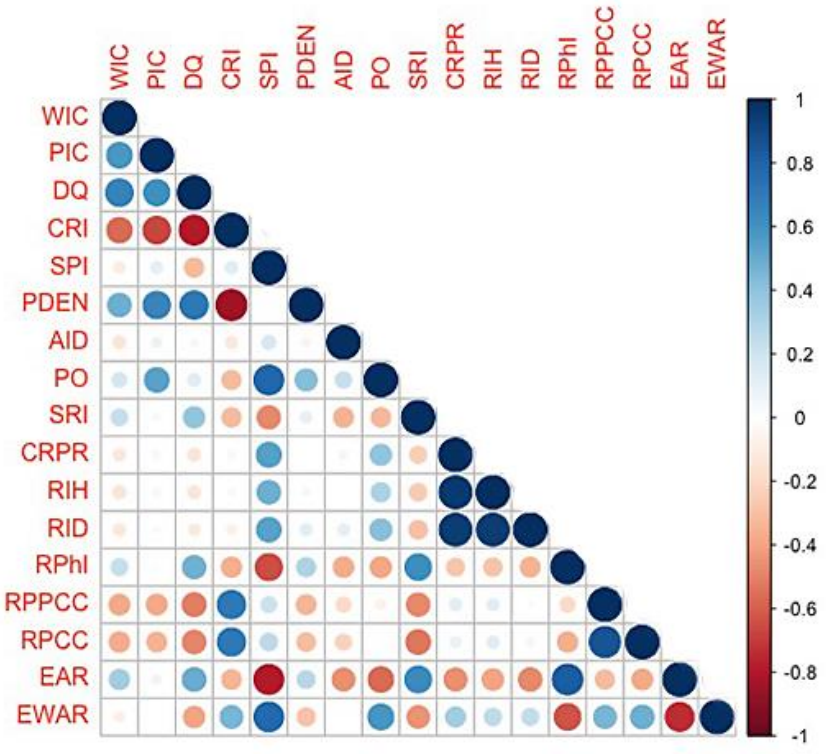

Figure. 5. Correlation matrix. It can be observed that there are significant correlations between the variable percentage of contagion in the region (% CONTG_REGI) and percentage of contagion in the commune (0.58), which is evident given that the Metropolitan Region has the highest percentage of contagion rate, so it is logical to find communes with a high percentage of contagion rate.

Less significant are the number (rate) of public health centers available per commune forpublic health beneficiaries (-0.38) and the number (rate) of health centers available for allinhabitants of the commune (-0.36).

When the variable “contagion rate per commune” is analyzed, it also appears to be significantly correlated with the same variables as above, adding the percentage of overcrowded homes to the total number of homes in the commune, it reaches a correlation value of 0.53. This variable is important because of the sanitary measure of social isolation that has been recommended by the health authority, which, under conditions of overcrowding, is difficult to comply with.
Despite the above, the correlation between population density and the contagion rate at the regional level is significantly higher than the overcrowding and the same variable. This difference may be since compliance with isolation measures in the region was not observed by the entire population in the same way, with much less adherence in the communes with the largest populations, such as Puente Alto and Santiago. The movement of people in the streets and in centers of mass concentration (explained above) may have influenced the greater numbers of contagion.

3.6 Relationship between communes and variables

The Biplot graph represents the communes and variables on the same coordinate axis. The main objective of this type of graph is to describe a rectangular matrix using a graphic representation in low dimension, which allows to visualize the interrelations between individuals and variables, as well as the relations between both sets (Cárdenas et al., 2007). This technique allows us to establish the relationship that exists between certain analyzed variables and the units considered, in this case, the communes.

The proximity between points is interpreted in terms of similarity, in this case, the communes are similar according to the characteristics (variables) that were included in the study. The angle between

vectors is interpreted in terms of correlation between the variables (lesser angle plus positive correlation, angle 90º have no correlation, angle 180º perfect negative correlation), the projections from the communes to the vectors(variables) allow to obtain, in an approximate way, the values of the database.

Groups of communes with similar characteristics can be identified, which are grouped to certain types of variables. With a good fit of 61.8%, in the upper left of the Biplot graph (see **Figure 6**) is a first group of communes in which are San Ramón, La Granja, La Pintana and Lo Prado, which can identify a direct correlation of variables associated with the contagion rate of its population: RID, CRPR, PO and SPI.As described above the variables, cardiovascular diseases, diabetes, and hypertension are often associated with poor dietary conditions, related to the socioeconomic level of the population.In this case all the communes in this group present a high Social Priority Index, that is, they are low-income communes, where overcrowding is also an important variable, since it is common to find two or more households in one house.

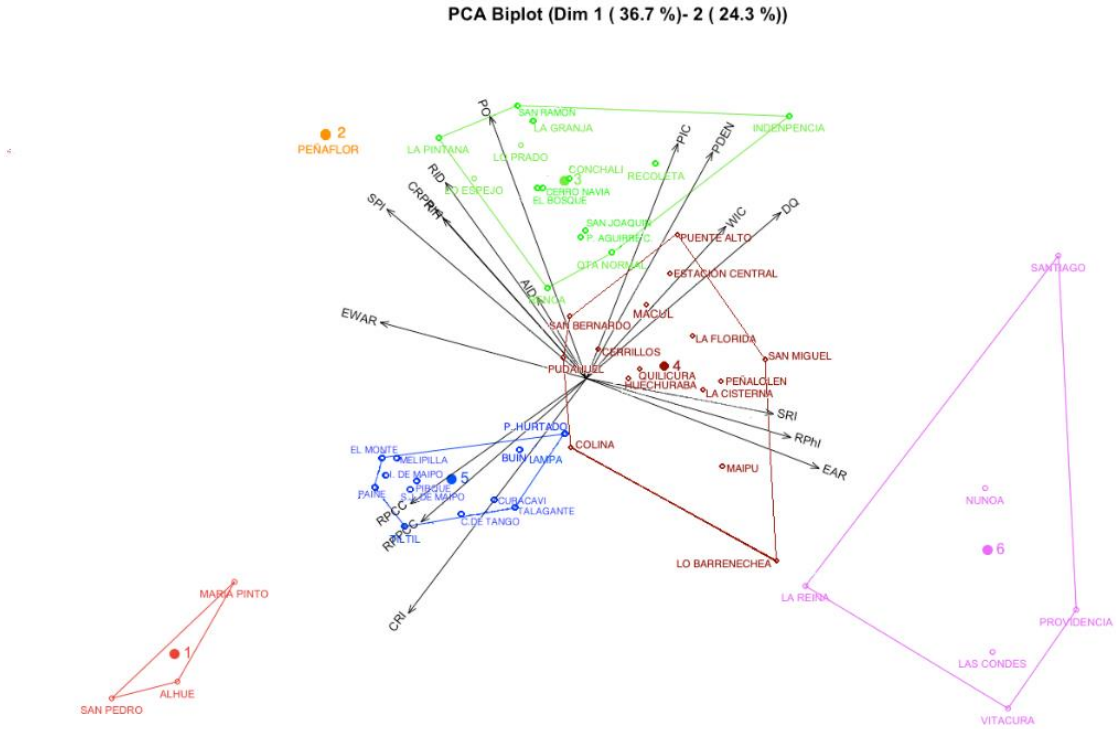

Figure. 6. Biplot graph. It is appreciated the relationship between the variables analyzed and the amount of communal contagion rate.

With a lower representation of the same variables, but not less important are the communes of Lo Espejo, Conchalí, El Bosque, San Joaquín and Pedro Aguirre Cerda, communes with similar socioeconomic characteristics to the previous group.

Another important observation that can be derived from the graphical information refers to the relationship between the contagion rate and the variables RPCC and CRI. The higher rate of rurality in these communities may influence public health centers to become focal points of contagion rate because of the large number of patients they serve. Since there are no private clinics, the population must turn to public health centers, which become centers of mass concentration and focal points of contagion.

The opposite occurs in communes with a higher socioeconomic level where the variables best correlated with EAR, SRI, RPhI, where the number of supermarkets and pharmacies per inhabitant is higher than the community average in the Metropolitan Region. As explained above, these

places are considered mass concentration centers, so the greatestrisk of contagion is associated with the population's attendance at these places. Such is thecase of the communes of La Reina, Las Condes, Vitacura and Providencia.

In "Lockdown" variable, it can be observed that there is a moderate but significantcorrelation (0.60) between days under lockdown and the contagion rate. That is, thecommunes with more days under lockdown present the highest levels of SARS-CoV-2contagion rate (**Figure S4**), suggesting that the decision to start a lockdown occurs lately.

The implementation of lockdowns carried out early on proved to be effective for thecommunes in the eastern sector. In the case of the commune of Las Condes, its contagionrate increased by 47.12% as of April 14 compared to April 1. The same communeregistered a decrease in the increase of contagion rate on May 1, reaching only 33.66%compared to May 15. In other words, this commune lowered its contagion rate in thesecond half of April, considering that it was in total lockdown until May 16. In thefollowing period, this commune ceased lockdown and the rate of increase was 135% withrespect to the previous period. The same pattern was observed for Providencia, LoBarnechea and Vitacura.

4 DISCUSSION

Despite vaccines development and the initiation of vaccination in some countries, thepandemic control was far from being achieved, so understanding the environmental as well asgeospatial variables that influence the virus spreading was crucial during the pandemic, and for future pandemics. In thiseffort, different publications have shown the possible influence of environmental factors (Conticini et al., 2020; Zhu et al 2020), as well as sociodemographic and economic factors (Mena et al., 2021; Sarmadi et al., 2020). Most articlesand research focus on being able to determine areas of vulnerability to the pandemic, without considering the geospatial distribution of the disease. In this sense, this type of work becomes relevant when proposing a new way of analyzing the pandemic, not seeking to establish models of propagation, but rather, establishing geospatial correlations between the behavior of the disease and the territorial reality of the place where those contagions live.

It should be noted that The Metropolitan Region of Santiago de Chile, where this study was conducted, had 262,056 infected and 7,909 deaths, in August 2020, which puts them in first place in terms of mortality and incidence of the disease in the region (Díaz-Narváez et al., 2020).

We observed that the highest contagion rate was found in those communes with a younger population. This could be explained to low adherence to care recommendations and restrictions, since initially it was pointed out that only the older population was susceptible to the disease, information that changed over time. Another explanation may be related to the fact that this is the working population and therefore they continued moving and exposing themselves to attend their workplaces, thus increasing the chances of contagion.

Added to the little knowledge of the real risk of contagion that existed for the younger population at the time of this study. Subsequently, the relationship between overcrowding and the contagion rate was analyzed, finding that the highest rates were found in those communes where there is greater overcrowding. This requires a separate mention since these Metropolitan Region areas correspond to those with lowest income population, the most irregular constructions and more than one family group sharing that construction. So, these housing conditions have a combination of factors that promote virus spreading, known as the intra-domestic contagion. This correlates with the evidence found where the contagion rate is higher in those communes with a lower level of education, which coincide with higher values of overcrowding, another finding that coincides with previously published works (Rocklöv&Sjödin, 2020; Wu et al., 2020). Furthermore, they pointed out that a higher incidence rate is observed in states that reflect a greater socioeconomic difference, which may impact access and availability of diagnostic services and healthcare provisions, which may also occur in the areas studied in the Metropolitan Region (Mena et al., 2021; Sarmadi et al., 2021).

Those communes with a greater number of people with diabetes and hypertension are the ones that present a greater contagion rate and coincide with the communes with greater overcrowding, low income, and lower educational level. In previous works, it has been demonstrated the positive

correlation that exists between the severity of the disease and the pre-existence of comorbidities (Yang et al., 2020; Zhu et al., 2020).

Having said that, it is complex to compare the different realities that have occurred in South America, considering that the countries that make up the region do not have similar demographics and, furthermore, the date of confirmation of case zero by COVID-19 is not the same for all (Berenguer et al., 2020). Mexico City registers 49.2% of its population under this condition, results obtained by the collaborative study: EVALÚA, with Chile being among the fifteen countries with the lowest percentage of low-income overcrowded households (11.04%). Although overcrowding is an important variable when analyzing the distribution of contagions, as reaffirmed in this study, there is a more significant relationship with population density. For this reason, the concentration of people living together in small spaces cannot be established as a major cause of spread, but rather, the concentration of people in a territory, since the interaction of these generates personal relationships that increase contagion.

In terms of the number of contagions per million in the countries of the region, Chile and Ecuador showed the highest values, meanwhile, Brazil is the country with the highest number of deaths (Carvalho et al., 2021; de Souza et al., 2020). In Colombia and Peru, the highest contagion rate was observed inthe city of Bogotá and the Central Lima, respectively, the cities with highest populationdensity (Benítez et al., 2020; Florez& Singh, 2020; Rodriguez-Villamizaret al., 2021).

Finally, data shown and discussed here confirm the limited information available on thegeospatial of virus spreading, which is unbelievably valuable for decision makers.

5. CONCLUSIONS

The results obtained in this research suggest that i) The population density andovercrowding showed a high correlation with contagion rate in Santiago. ii) Lockdownimplementation should be taken earlier, for a significative reduction of new cases ofCOVID-19; iii) The socioeconomic level of the population does not influence the diseasespreading, but it can influence the severity of the disease; and finally, iv) GIS providevisual information, easy to observe and understand, allowing to identify combination ofgeospatial variables that possibly contribute to the spread of the virus in Santiago.Together, these data provide a description of variables related to the spreading of theSARS-CoV-2 virus, contributing to identify those most relevant for the decision-makingduring pandemic in the Chilean Metropolitan Region.

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