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Relationship between Sociodemographic Characteristics of Portuguese Municipalities and Incidence of SARS-CoV-2 Infection

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Abstract

Background: So far, little is known of how the sociodemographic characteristics of populations affect the risk of SARS-CoV-2 infection. The regional sociodemographic heterogeneity of the Portuguese territory and the heterogeneity of CoVID-19 incidence along the country create an opportunity to uncover the relationship between these characteristics and CoVID-19 incidence.

Methods: We have gathered data on the sociodemographic characteristics and CoVID-19 incidence in the 278 municipalities of the Portuguese mainland territory and evaluated the relationships between them, in both univariate and multivariate analysis. The rank correlation Spearman´s coefficient was used to identify variables significantly associated with CoVID-19 incidence in univariate analysis. After exclusion of those highly correlated with each other, they were included in a stepwise multiple regression model to identify those independently associated with CoVID-19 incidence.

Results: The municipalities' sociodemographic characteristics independently associated with an increased risk of SARS-CoV-2 infection are the population density, the size of households, the number of employees per non-financial company, and the proximity to the great metropolitan areas. On the other hand, the percentage of primary sector employees is independently associated with a decreased risk of SARS-CoV-2 infection.

Conclusions: The study results, by allowing the identification of regional sociodemographic characteristics associated with higher risk of infection, might help health authorities to make a more rational allocation of available resources and to more effectively combat the pandemic.

Keywords: SARS-CoV-2 infection; Sociodemographic characteristics; Municipalities; Infection

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Introduction

So far, little is known of how the sociodemographic characteristics of populations affect the risk of SARS-CoV-2 infection.

Earlier studies, addressing this question, found a relationship between the incidence of CoVID-19 and some sociodemographic characteristics of the populations.

A study [1] has shown that, in addition to pathological conditions such as kidney failure, there is an association between SARS-CoV-2 infection and deprivation, population density and ethnicity. These results are confirmed by the study of Zhang and collaborators [2], who have shown that, in the United States, population density, proportion of elderly residents and poverty were associated with higher incidence of CoVID-19.

Sy and collaborators [3] have shown that, in New York City, the percentage of individuals in essential work and the use of subway are associated with a greater number of cases of CoVID-19. On the other hand, a study [4] conducted in the area of São Paulo, Brazil, showed that distance to large cities was negatively associated with time-to-introduction and incidence rates of CoVID-19. This study also showed a positive relationship between population density and the incidence of CoVID-19.

Portugal is geographically located in the southwest of the Iberian Peninsula (Europe) and its territory has a continental area and two Autonomous Island Regions (Azores and Madeira), located in the Atlantic Ocean. The country is divided in 308 municipalities or counties (30 in the Autonomous Regions and 278 in the mainland). In Portugal, the incidence of SARS-CoV-2 infection varies widely throughout the territory, with areas of high incidence while in others the number of cases is residual. The country's human geography is very heterogeneous, with heavily urbanised areas (located on the coast) and rural areas of low population density (in the interior regions).

In this setting, an opportunity is created to study the relationships between the demographic, social, working and business characteristics of the various municipalities of the country and the incidence of SARS-CoV-2 infection.

Objectives

We aimed to uncover the sociodemographic factors associated with the risk of SARS-CoV-2 infection in Portugal.

Methods

We analysed data regarding the 278 municipalities of the mainland. The municipalities of the Azores and Madeira archipelagos were not included in this study because of their island location thousands of kilometres away from the mainland. This feature significantly affects virus transmission chains and would create bias in the analysis.

Data collection

Portuguese Health authorities produce an official daily report on the CoVID-19 outbreak. Besides other indicators, this report includes the cumulative number of confirmed cases in each municipality. The official definition of confirmed case is a patient with laboratory confirmation of SARS-CoV-2 infection by nasopharynx swab PCR test, regardless of signs and symptoms.

The data on CoVID-19 cases were extracted from the report of June 28, 2020 [5] and were referred to June 27, 2020. We obtained data on the estimates of the Portuguese population by municipality from the Instituto Nacional de Estatística- INE [6]. All the other sociodemographic data were obtained from the PORDATA platform [7], except the number of places in nursing homes of each municipality, which was obtained from a public government database [8]. The last available data were used.

Study variables

The incidence of SARS-CoV-2 infection for each municipality was calculated dividing the cumulative number of cases of that municipality since Mars 2, 2020 (the date of the first CoVID-19 case registered in Portugal) until June 27, 2020 by the number of residents in that municipality and is presented as number of cases per 10,000.

The other variables included in the study cover four dimensions (in square brackets is the year to which the data refer): a demographic dimension, a social dimension, a labour and entrepreneurial dimension, and a geographical dimension.

The demographic dimension includes the following variables: related to age (percentage of residents of the municipality aged up to 14, aged between 15 and 64, and over 64, and ageing index - number of residents aged 65 or more per 100 residents under 15) [2018], gender (percentage of female residents) [2019], and population density (residents/Km^2) [2019].

The social dimension includes the following variables: average household size of the municipality [2011], the number of dwellings per km^2[2018], the number of places in nursing homes per 10.000 residents[2015], the percentage of students of all educational degrees [2018], and the average purchasing power per capita of the municipality (indexed to its national value) [2017].

The labour and entrepreneurial dimension includes the following variables: number of non-financial companies/Km^2 [2018], dichotomised number of employees per company (above the median and equal or below the median) [2018], and the percentage of residents working in the primary, secondary, and tertiary sector [2011].

The geographical dimension is given by the distance in kilometres to the nearest great metropolitan area of the country (Lisbon or Porto).

Statistical analysis

The Mann-Whitney U test was used to compare independent numeric variables, the Chi-square test for proportions comparison, and the Spearman's coefficient of rank correlation (rho) was used to evaluate the relationships between study variables and the incidence of SARS-CoV-2 infection in univariate analysis. Multiple regression (stepwise, P to enter=0.05, P to remove=0.10) was used to detect the variables independently associated with CoVID-19 incidence. Variables that presented a statistically significant relationship with the incidence of SARS-CoV-2 infection in univariate analysis were included in the multiple regression models, except if a coefficient of rank correlation greater than 0.70 was found between them. Out of these, we selected the variable with the highest correlation coefficient in univariate analysis for inclusion in the multiple regression models. Numeric data are presented as median and interquartile range. Proportions are presented as percentages.

Ethics

This study only uses publicly available data. No data from individual patients or persons was analysed. For these reasons, it was exempted from submission to the Ethics Committee Board.

Results

Portugal is a small country with a total population of 10,286,263 and a total area of 92,090 square kilometres. Forty five percent of its population is concentrated in two large coastal metropolitan areas: Lisbon and Porto. The population density of the rest of the country is low, especially in the interior regions of the mainland (**Figure 1**).

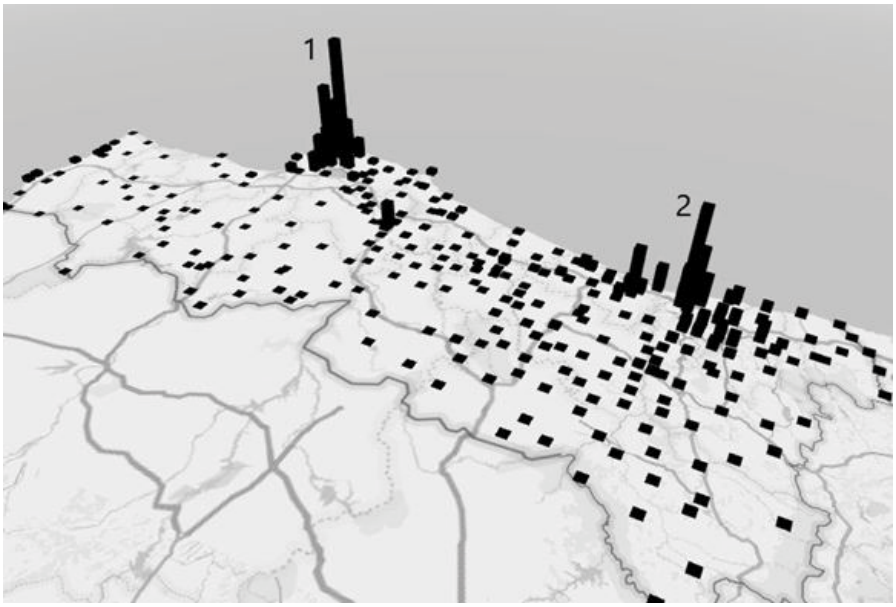
The cumulative number of SARS-CoV-2 infection confirmed cases between the beginning of the outbreak and June 27, 2020 was

41,646. The median of the number of cases per municipality was 19 (4-78). The median of the incidence in all municipalities was 11.75 per 10,000 residents (5.98-28.76).

Table 1 shows the sociodemographic characteristics of municipalities with a SARS-CoV-2 incidence above and below (or equal) the median and the statistical significance for their differences.

As shown in **Table 2**, population and dwellings densities, average households sizes, indicators of higher levels of industrialisation (percentage of residents working in the secondary sector, non-financial companies per square Km, number of employees per non-financial company above median) and of higher social status (percentage of residents who are students of all teaching degrees, and higher purchasing power per capita) of municipalities were found to be positively associated with higher incidence of SARS-CoV-2 infection in the municipalities; while older age, the number of places in nursing homes per 10.000 residents, and indicators of rurality (percentage of residents working in the primary sector) were associated with lower incidence of SARS-CoV-2 infection in the municipalities.

The distance to the nearest great metropole (Lisbon or Porto) was negatively associated with SARS-CoV-2 infection incidence.



1: Lisbon metropolitan area; 2: Porto metropolitan area

Figure 1 Relative population densities of the mainland municipalities (black columns).

Table 1 Differences in the study variables between municipalities with a CoVID-19 incidence higher or lower than or equal to the median.

Variable	Incidence> median	Incidence ≤ median	P
Residents/Km^2	137.6 (64.0-438.4)	32.8 (13.2-67.7)	<0.0001
Age<15 years (%)	12.9 (11.1-14.3)	11.1 (9.9-12.4)	<0.0001
Age≥15<65 years (%)	64.5 (61.9-66.9)	61.6 (59.4-63.9)	<0.0001
Age≥65 years (%)	22.3 (21.2-23.3)	27.3 (23.3-30.3)	<0.0001
Ageing index	173.0 (136.3-224.5)	252.0 (192.0-294.0)	<0.0001
Female gender (%)	52.0 (51.6-52.5)	52.0 (51.4-52.5)	0.41
Persons/household (n)	2.6 (2.5-2.8)	2.5 (2.4-2.6)	<0.0001
Dwellings/Km^2	78.7 (40.0-220.7)	25.6 (12.4-48.3)	<0.0001
Places in NH/10.000	92.7 (58.5-159.6)	214.5 (129.7-320.8)	<0.0001
Students (%)	14.8 (12.7-17.0)	12.5 (10.3-15.5)	<0.0001
Purchasing power1 (per capita)	82.1 (70.7-92.6)	72.7 (65.2-83.3)	0.0001
Companies2/Km^2	16.5 (6.9-47.1)	4.1 (1.9-8.2)	<0.0001
Employees/company2>median	63.30%	36.00%	<0.0001
Primary sector (%)	1.43 (0.56-2.80)	3.08 (1.64-5.48)	<0.0001
Secondary sector (%)	10.91 (8.28-15.91)	9.15 (7.15-11.84)	0.0001
Tertiary sector (%)	25.67 (21.96-30.64)	25.45 (22.32-28.60)	0.27
Distance3 (Km)	80.2 (42.8-139.8)	163 (130.0-207.8)	<0.0001

NH: Nursing Homes; 1: Purchasing power indexed to the national value taken as 100 units; 2: Non-financial companies; 3: Distance to the nearest great metropolitan centre (Lisbon or Porto).

We found no association between the percentage of females in the municipalities and the municipalities SARS-CoV-2 infection incidence.

The following variables presented a rank correlation coefficient (rho) between them greater than 0.97 in univariate analysis: residents/Km^2, dwellings/km^2, companies/Km^2. Only residents/Km^2 was included in multivariate analysis. The percentage of students and purchasing power presented a high value for rho too: 0.73. Percentage of students was selected for inclusion in multivariate analysis. The same happened (rho=0.73) between the number of places in nursing homes per 10,000 residents and the aging index. Only the first one was included in multivariate analysis.

Table 2 Rank correlation coefficient (Spearman's rho) between the study variables and CoVID-19 incidence (per 10.000 residents) in mainland Portuguese municipalities.

Variable	rho	P
Residents/Km^2	0.54	<0.0001
Age<15 years (%)	0.35	<0.0001
Age≥15<65 years (%)	0.37	<0.0001
Age≥65 years (%)	-0.41	<0.0001
Ageing index	-0.4	<0.0001
Female gender (%)	0.09	0.14
Persons/household	0.36	<0.0001
Dwellings/Km^2	0.52	<0.0001
Places in NH/10.000	-0.49	<0.0001
Students (%)	0.33	<0.0001
Purchasing power1 (per capita)	0.28	<0.0001
Companies2/Km^2	0.53	<0.0001
Employees/company2>median	0.31	<0.0001
Primary sector (%)	-0.45	<0.0001
Secondary sector (%)	0.21	0.0004
Tertiary sector (%)	0.1	0.09
Distance3 (Km)	-0.55	<0.0001

NH: Nursing Homes; 1: Purchasing power indexed to the national value taken as 100 units; 2: Non-financial companies; 3: Distance to the nearest great metropolitan centre (Lisbon or Porto).

Table 3 presents the regression coefficients of variables independently associated with SARS-CoV-2 infection incidence. As shown, population density, bigger households, and municipalities with bigger companies (number of employees above the median) are independent predictors of higher SARS-CoV-2 infection incidence. On the contrary, the percentage of people working in the primary sector, an indicator of rurality, and the distance to the nearest great metropolitan area are independently and strongly associated with lower incidences.

The coefficient of determination (R^2), a measure of the goodness of fit of the regression model, was 0.64. The analysis of variance yielded a F-test of 96.2 (P<0.0001), revealing that the multiple correlation coefficient of 0.80 was statistically significant.

Figure 2, by showing the relationship between the observed incidence of SARS-CoV-2 infection in each municipality and the

Table 3 Outputs of the stepwise multiple regression (P to enter=0.05, P to remove=0.10) with CoVID-19 incidence per 10,000 inhabitants as dependent variable and the population density in number of inhabitants per square kilometre as weighting variable.

Independent variable	Regression coefficient	t statistic	P
Residents/km^2 (n)	0.006	10.72	<0.0001
Persons/household	23.895	4.31	<0.0001
Employees/company>median1	5.532	2.38	<0.02
Primary sector (%)	-2.164	-2.47	0.01
Distance2 in Km	-0.13	-6.27	<0.0001

Excluded variables: Places in nursing homes/10.000 residents, Students (%).
1: Number of employees per non-financial company above the median; 2: Distance to the nearest great metropolitan centre (Lisbon or Porto).

Figure 2 Observed incidence (black) and predicted values (grey) for each municipality in the Portuguese mainland territory. The black columns marked with an asterisk are recent isolated outbreaks in nursing homes or, in a specific case, a cluster in a small village in the earlier phase of the Portuguese outbreak, which caused exceptional increases in the incidence of SARS-CoV-2 infection in the respective municipalities.

correspondent multiple regression predicted value, provides a visual estimate of the relationship between this set of indicators and the incidence of SARS-CoV-2 infection in the mainland.

Discussion

Our data, regarding the sociodemographic characteristics of each Portuguese municipality and its CoVID-19 incidence, show that the main factors of CoVID-19 incidence are associated with opportunities of social contact between people. In fact, municipalities with higher population density, higher levels of industrialisation, bigger companies, bigger households, younger people, higher percentage of students, and more proximity to the great urban metropoles showed higher incidences of CoVID-19.

Despite the lockdown implemented in the country in earlier stages of the outbreak, the opportunities for social contact inside the municipality (related to population density, work obligations, school, and family life) and outside the municipality (ease of access to large urban centres) seem to be the main determinants of CoVID-19 incidence.

Our main results are in line with the results of previous studies [1-4]. However, unlike other studies [2,9], we found an inverse relationship between the aging of the populations and the incidence of CoVID-19 in univariate analysis. Simultaneously, a negative correlation between the number of places in nursing homes per 10.000 residents and CoVID-19 incidence was found too. The Portuguese health authorities have been particularly actives in monitoring SARS-CoV-2 incidence in nursing homes and promptly implementing the adequate sanitary measures, which might explain this relationship by breaking the viral transmission chains [10,11]. Additionally, this association might be due to the fact that the municipalities that are less populous, more ruralised, and more distant from the larger urban centres are those that have the highest proportion of elderly people and the lowest incidence of CoVID-19. For the same type of reasons, and unlike other studies [12], which have shown an association between poverty and CoVID-19 incidence, in our study the average index of purchasing power per capita was associated with higher incidences of CoVID-19. We don´t have data to study, in each municipality specifically, the association between these variables (we only have the averages for each municipality). Thus, what our results show is not an association between wealth and CoVID-19 incidence, but rather that municipalities with higher purchasing power have higher incidences, due to the reasons mentioned above.

The Portuguese schools have been shut down in the earlier phase of the outbreak and remained closed until now. This, probably, has reduced the impact of the percentage of students in municipalities in the CoVID-19 incidence.

In summary, our results suggest that some regional sociodemographic characteristics are independently associated with an increased risk of SARS-CoV-2 spread. These are the population density, the size of households, the number of employees per company (a surrogate indicator of company dimension), and the proximity to the great metropolitan areas.

On the other hand, the percentage of primary sector employees (a surrogate indicator of ruralisation) is independently associated with a decreased risk of SARS-CoV-2 spread.

Study limitations

This study uses the sociodemographic indicators of each municipality. Therefore, its results cannot be interpreted as if they were yielded by analysing a sample of the Portuguese population. Here the population under study consists of the Portuguese municipalities and the sample consists of the municipalities of the Portuguese mainland. The interpretation of the results should consider this methodology.

Some of our data are not contemporary of the SARS-CoV-2 outbreak. By using the last available data, we tried to minimise the impact of this discrepancy on the study results. However, some bias cannot be excluded.

As shown in **Figure 2**, during the study period some circumscribed clusters of CoVID-19 have occurred in a number of municipalities. This characteristic was not taken into account in the analysis. However, the goodness-of-fit of the multiple regression models is fairly high.

Study implications

The CoVID-19 pandemic is growing every day [12,13]. On a global scale, this growth is far from under control. It is increasingly important that the available resources are properly allocated. Our results reinforce the importance of social isolation in pandemic control [14,15], and, by allowing the identification of regional sociodemographic characteristics associated with higher risk of infection, might help health authorities to make a more rational allocation of available resources and to more effectively combat the pandemic.

Conclusion

The study results, by allowing the identification of regional sociodemographic characteristics associated with higher risk of infection, might help health authorities to make a more rational allocation of available resources and to more effectively combat the pandemic.

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