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COVID-19 epidemic spread and green areas Italy and Spain between 2020 and 2021: An observational multi-country retrospective study

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ABSTRACT

Several studies have proposed that environmental factors influencing human wellbeing, such as chronic exposures to high levels of particulate matter, could indirectly or even directly affect also the severity of COVID-19 disease in case of infection by novel coronavirus SARS-COV2. This study has investigated the association between COVID-19 infections, hospitalizations or deaths and the extension of public green areas (km² per 100,000 based on OECD data of 2014), an indicator that has been chosen as independent endpoint variable to test the research hypothesis in 10 Italian and 8 Spanish Provinces with more than 500,000 inhabitants, including capitals (Rome and Madrid) and bigger cities (Bologna, Catania, Florence, Genoa, Milan, Naples, Palermo, Turin and Venice for Italy; Barcelona, Valencia, Seville, Zaragoza, Malaga, Las Palmas and Bilbao for Spain). Two different methodologies have been applied: a bottom-up approach was applied to Spanish institutional data concerning contagions/hospitalizations/deaths and the extent of public green areas for each responder to an official questionnaire in the frame of a nationwide survey (with detailed data granularity per province) containing specific georeferenced information; a top-down approach was used for Italy, starting from the official figures of contagions/hospitalizations/deaths of each province and linking them to the OECD statistics about the extension of public green areas in the different areas. Linear and generalized models were used for statistical analyses including also PM2.5 in a multivariate approach (with annual average concentrations from official air quality monitoring stations) and were able to adjust for the different number inhabitants living in each province, in order to take into account the difference in contagion dynamics related to the different density of population. The results obtained for Spain are consistent with those observed for Italy, as for both countries, it has clearly emerged a statistically significant association between COVID-19 clinical features (contagions, hospitalizations, and deaths) and the extension of public green areas, as well as the annual average concentrations of PM2.5 (with this latter variable loosing statistical significance in some province). Therefore, the extension of public green areas and air pollution seem to have a high correlation with COVID-19 severity.

1. Introduction

COVID-19 is an infectious disease caused by the SARS-CoV-2 coronavirus. Most people infected with the virus experience mild to moderate respiratory illness and recover without requiring special treatments (Rothan and Byrareddy, 2020). Current lifestyles, especially in cities, are characterized by heavy chronic stress and exposures to environmental hazards. These elements can influence the health status of local communities and they have been questioned to worsen the dynamics of contagion or clinical outcomes of COVID-19 pandemic (Bakadia et al., 2021). Several studies have shown that the population previously subjected to additional stressors, including chronic environmental pressures are more susceptible to severe forms of COVID-19 (World Food Program, 2020; Valderrama et al., 2020; Xianyu et al., 2018). Environmental stressors refer to environmental factors causing pressure on wellbeing status (Guski, 2001): such factors include...
available food, the presence of parasites or interactions with the environment that can affect the physical and mental health condition of the population in a certain area such as air quality.

Actually, such environmental stressors can represent a source of oxidative stress (Patel et al., 2018), that can be defined as an imbalance favoring the oxidative systems compared to the antioxidants, resulting in impaired functioning of certain enzymes, transduction of cellular signals and lowering of immune defense against pathogens, as well as altered cell cycle, cell differentiation, and regulation of capillary dilatation. Oxidative stress is involved as a trigger or associated with several disease complications and especially regarding SARS-COV2 syndrome (Cecchini and Cecchini, 2020). The exogenous and endogenous sources of oxidative stress could potentially favor the system oxidants versus antioxidants; thereby, the increased production of reactive oxygen species (ROS) during the oxidative stress could promote viral multiplication (Reshi et al., 2014). The COVID-19 exacerbation, hypothetically connected to effects of oxidative stress damages induced by exposure to environmental stressors, showcasing the promising way to be investigated further for sustainable control of the pandemic (Rothan and Byrareddy, 2020; Bakadia et al., 2021; World Food Program, 2020; Valderrama et al., 2020; Xianyu et al., 2018; Guski, 2001; Patel et al., 2018; Cecchini and Cecchini, 2020). In this study, we want to explore the potential benefits of green areas on the exposure to environmental stressors, exploring the possible association between the decrease in COVID-19 mortality or hospitalizations and the high availability of urban green areas (UGA) in cities and provinces with more than 500,000 inhabitants. Such relationship can let to better understand on how the different pre-existing environmental stressors and COVID-19-related stressors are further worsening the effects of the viral disease by inducing the generation of oxidative stress (Bakadia et al., 2021). Standing to EU COPERNICUS classification, urban green areas are defined as any area with vegetation within or partly embraced by urban fabric (Copernicus).

This class is assigned for urban greenery, which usually has recreational or ornamental character and is usually accessible for the public; it is applicable to parks inside settlements, with or without public access, ornamental gardens, mansions’ green grounds, botanical and zoological gardens situated inside settlements or in contact-peripheral zone of settlement, city squares with greenery, inner spaces of city blocks or any vegetated areas that can potentially be used for recreational purpose. Standing to “Urban green spaces and Health Report” edited by WHO in 2016 (Europe, 2016), urban green spaces, can promote mental and physical health, and reduce morbidity and mortality in urban residents by providing psychological relaxation and stress alleviation, stimulating social cohesion, supporting physical activity, and reducing exposure to air pollutants, noise and excessive heat. Several epidemiological studies evaluated the effects of urban green space on the health outcomes of study participants (Europe, 2016). However, the mechanisms underlying links between green space access and health are complex and interconnected and synergic. Hartig et al. (World Health Organization, 2016) suggested that there are four main interactive pathways through which nature or green space may contribute to health: improved air quality, enhanced physical activity, stress reduction and greater social cohesion. Regarding the current pandemic, all these co-benefits can alleviate the pressure of environmental stressor and finally determine a rebalancing of oxidative stress and a consequential reduction of the impact of COVID-19 (De Petris et al., 2021). Furthermore, Urban green spaces, as part of a wider environmental context, have the potential to in a preventive way that can be more efficient than just intervening on the consequences of illnesses (Hartig et al., 2014). This study has investigated the association between COVID-19 infections, hospitalizations or deaths and the extension of public green areas (km2 per 100,000 based on OECD data of 2014), an indicator that has been chosen as independent endpoint variable. The research hypothesis was tested in Italy and Spain, two Mediterranean countries with similar characteristics.

2. Materials and methods

For the proposed multicentric analysis, open datasets of confirmed cases, hospital admissions and deaths published by the Spanish Institute of Public Health (Istituto de Salud Carlos III, ISCIII) and by the Italian Civil Protection Department were used. For Italy, the number of COVID-19 infections from January 2020 to December 2021 were assessed with regard to the average per-capita availability of urban green areas per 100,000 inhabitants as resulting from the database of the Organization for Economic Cooperation and Development (OECD, 2014). For Spain, the number of infections from January 2020 to December 2021, were then merged at municipal level with the data of household expenditure of the INE (Istituto Nacional de Estadística), taking into account the degree of the area of residence, in a progressive manner from a value of higher urbanization (1) to a value of higher rural density (9). In addition, in order to evaluate the incidence of air pollution, data from PM2.5 monitoring stations at provincial level were used. The source of PM2.5 data for Italy was the National Program for Air Quality Assessment (Viias). The source of pollution data for Spain was the annual report edited by the Spanish Ministry of Ecological Transition. To assess the presence of a statistically significant association between a reduced severity in the burden of COVID-19 and the higher availability of urban green areas, we analyzed 11 Italian provinces (Rome, Milan, Naples, Turin, Palermo, Genoa, Florence, Bari, Bologna, Catania and Venice), and 8 Spanish provinces (Madrid, Barcelona, Valencia, Seville, Zaragoza, Malaga, Las Palmas, Bilbao). In addition, the average of value annual concentrations of PM 2.5 (category of particulate air pollutant that is 2.5 μm or smaller in size) was evaluated as a corrective factor to assess - on the primary analysis - how air pollution impacted the rates of infections, hospitalizations and death due to COVID-19.

2.1. Italy

The sample for the year 2020 consisted of 3432 timepoints recorded from 1st of January 2020 to 31st December 2020. The sample for the year 2021 was composed of 4015 time points recorded from 1st of January 2021 to 31st of December 2021. Each time point contained the observations concerning the number of infected cases, the number of hospital admissions and the total deaths due to COVID-19. As already mentioned, the selected provinces were Bologna, Catania, Florence, Genoa, Milan, Naples, Palermo, Rome, Turin and Venice. The endpoint variable taken into account for the analysis was the average per-capita availability (expressed in km2) of green urban areas per 100,000 for green areas in urban areas (OECD, 2014) per each province. Then, the variable of the incidence of green areas was then divided into 3 categories (Low, Medium, High presence of green areas) with a cut-off to the first quartile (Q1) and second quartile (Q2), as described below:

The derived variable is composed as follows:

- The number of COVID-19 infections, hospitalizations, and deaths is distributed as follows:

2.1.1. Spain

The sample consisted of 1472 household units, with a total population of 3680, registered by INE between the year 1998 to the year 2019. The selected provinces are Madrid, Barcelona, Valencia, Seville, Zaragoza, Malaga, Las Palmas and Bilbao. The statistical robustness of the sample was significantly demonstrated by INE (Spanish National Institute of Statistics). No households were registered in the province of Barcelona, which was therefore excluded from the analysis. The endpoint variable involved for the analysis is the type of residence in which the household unit is located. The original variable of residence type was so subdivided: 1 Urban luxury, 2 High Urban, 3 Urban, 4 Low Urban, 5 Rural industrialized, 6 Fishing Rural, 7 Agriculture Rural. The data were then grouped on the basis of high exposure to urbanization (1, 2) medium exposure to urbanization (3, 4, 5) and low exposure to urbanization (6, 7), thus resulting distributed as follows:
The average per-capita availability of green areas in Spain for the selected provinces, estimated in 2014 (OECD) was around 84.79 for 100,000 inhabitants, as described below:

The ISCIII database on the number of infections, hospitalizations and deaths due to COVID-19 from January 2020 to December 2021 for the selected provinces was merged to the household expenditure questionnaire (INE database).

The sample is distributed as follows (Table 8):

### 2.2. Data analysis

Descriptive data are presented for numeric variables in mean, standard deviation (SD), quartiles (Q1 and Q2). For categorical variables, data are presented in percent (%), 95% confidence interval (95% CI), cumulative absolute frequency, and cumulative relative frequency. Confidence intervals are presented calculated using the Clopper-Pearson method. Tests applied in this paper are examined at an alpha significance less than/equal to 0.05 (5%). Continuous variables are compared through the t-student (t-value) test statistic. The Multiple Linear Regression Analysis Method was applied to analyze the correlation between the COVID-19 indicators (contagion, hospital admissions and deaths) confirmed in each province and the green zone indicators. Based on the data from the selected observation variable, multiple linear regression models can be constructed as shown in the equation:

\[ y_i = \beta_0 + \beta_1 x_1 + \epsilon_i \]

The model has been developed in three different steps:

- The first step considers \( y \) as the dependent variable, representing the number of confirmed cases over time, measured in days. While the independent variables represent the parameter of green areas per capita per 100,000 inhabitants in the provinces, the level of PM2.5 per capita per 100,000 inhabitants in the provinces and the total population to ensure homogeneity of the population in the clusters.

- The second step considers \( y \) as the dependent variable, representing the number of confirmed hospital admissions over time, measured in days. While the independent variables represent the parameter of green areas per capita per 100,000 inhabitants in the provinces, the level of PM2.5 per capita per 100,000 inhabitants in the provinces and the total population to ensure homogeneity of the population in the clusters.

- The third step considers \( y \) as the dependent variable, which represents the number of confirmed deaths over time, measured in days. While the independent variables represent the parameter of green areas per capita per 100,000 inhabitants in the provinces, the level of PM10 per capita per 100,000 inhabitants in the provinces and the total population to ensure homogeneity of the population in the clusters.

\( \beta_i \) are the unknown parameters of the corresponding independent variables; \( \epsilon \) is called the error term. The above linear regression model can be used to predict daily virus trends and determine the correlation between each independent variable and the dependent variable.

The models are then compared between/inside countries taking into consideration R squared adjusted of to demonstrate the speed of the event at each step.

In addition, derived the green areas in three categories (high urbanization, medium urbanization and low urbanization) as reference

### Table 1

| Variable: Green Areas pro capita 100,000 | N | SD | Q1 | Q3 |
|----------------------------------------|---|----|----|----|
| Mean                                    | 209.65 | 268.02 | 22.11 | 366.64 |

### Table 2

| Derived categorized variable for Green Areas in Italy (2020). | N | Percentage | Cumulative N | Cumulative Percentage |
|-------------------------------------------------------------|---|------------|--------------|-----------------------|
| 1 (Low)                                                     | 936 | 27.27      | 936          | 27.27                 |
| 2 (Medium)                                                  | 1872 | 54.55      | 2808         | 81.82                 |
| 3 (High)                                                   | 624  | 18.18      | 3432         | 100                   |

### Table 3

| Derived categorized variable for Green Areas in Italy, 2021. | N | Percentage | Cumulative N | Cumulative Percentage |
|-------------------------------------------------------------|---|------------|--------------|-----------------------|
| 1 (Low)                                                     | 1095 | 27.27      | 1095         | 27.27                 |
| 2 (Medium)                                                  | 2190 | 54.55      | 3285         | 81.82                 |
| 3 (High)                                                   | 730  | 18.18      | 4015         | 100                   |

### Table 4

| COVID-19 demographic table (Contagions, Hospital Admissions, Deaths), Italy 2020 |
|-------------------------------------------------------------------------------|
| Variable: Contagions                                                        |
| Mean | SD | Q1 | Q3 |
| 127858.80 | 85335.55 | 62479.00 | 197897.00 |
| Variable: Hospital admissions                                               |
| Mean | Q1 | Q3 |
| 1037.29 | 243.00 | 1494.00 |
| Variable: Deaths                                                            |
| Mean | Q1 | Q3 |
| 1095 | 27.27 | 1095 |
| 1037.29 | 243.00 | 1494.00 |
| 1388.10 | 71.74 | 2466.48 |

### Table 5

| Derived categorized variable for Type of Residence in Spain (1998) to 2019. | N | Percentage | Cumulative N | Cumulative Percentage |
|--------------------------------------------------------------------------|---|------------|--------------|-----------------------|
| 1 (Low)                                                                  | 300 | 20.38      | 300          | 20.38                 |
| 2 (Medium)                                                               | 515 | 34.99      | 815          | 55.37                 |
| 3 (High)                                                                 | 657 | 44.63      | 1472         | 100.00                |

### Table 6

| Derived categorized variable for Green Areas per-capita per 100,000        |
|--------------------------------------------------------------------------|
| Mean | Median | SD | Q1 | Q3 |
| 84.79 | 46.59 | 77.141 | 23.18 | 171.53 |
The logistic model is implemented to identify the protective or risk value for the analysis. ORs are presented with their respective 95% confidence intervals.

The fitting of goodness model then are compared in terms of Akaike Information Criterion (AIC).

3. Results

In a preliminary analysis, we evaluated the difference in terms of available urban green areas in the selected provinces for Italy and Spain. The results showed a significant difference of the two areas, in line with the literature. In fact, in Spain there are about 7 million trees planted in a population of 47 million people, while in Italy there are 22 million trees planted in a population of 59 million people. The results are shown below:

The test was conducted with a two-tailed t-test and was highly statistically significant. Linear regression shows high significance for green areas and pollution with a negative trend for green areas and a positive trend for pollution. This shows that significant increases in covid incidence are lower for green areas. The models were corrected for populations between provinces. It can be seen that the corrections tend to balance the population weights between very dense and not so dense area. The results are shown below:

The trends are similar for Spain and Italy (see Table 14) (see Table 15). We can see that the R squared of the regressions in Spain are lower than those in Italy. This trend is justified because the exposure to urban green areas in Italy is higher than in Spain, as shown in the preliminary analysis. It can also be noted that the effect of covid mortality is higher in the year 2021 than in 2020. In 2020 Spain, the effect of pollution on Covid is found to be non-significant and very low higher in the year 2021 than in 2020. The logistic model is implemented to identify the protective or risk value for the analysis. ORs are presented with their respective 95% confidence intervals.

The model is presented in 3 steps:

- The first step considers y as the dependent variable, representing the province (see Table 1). While the independent variables represent the derived green area variable (Table 2, Table 3, Table 6), the level of PM2.5 per capita per 100,000 population in the provinces and the total cases (see Table 5) (see Table 4).
- The second step considers y as the dependent variable, representing the province. While the independent variables represent the derived green area variable (Table 2, Table 3, Table 6), the level of PM2.5 per capita per 100,000 population in the provinces and number of hospital admissions.
- The third step considers y as the dependent variable, representing the province. While the independent variables represent the derived green area variable (Table 2, Table 3, Table 6), the level of PM2.5 per capita per 100,000 population in the provinces and the number of deaths.

The logistic model is implemented to identify the protective or risk value for the analysis. ORs are presented with their respective 95% confidence intervals.

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protective against the spread of the SARS-COV2 virus. In Italy, the ORs are much more remarkable than in Spain. This is because in Spain (7 million trees in all the country per 47 million inhabitants) the availability of green areas for urban areas is lower than Italy (22 million trees per 59 million inhabitants), as demonstrated in the preliminary analysis by difference t-test on green area per-capita. Otherwise, the value of the OR indicates a risk in Spain for the value “Medium” vs. “High”. This is because morphologically the territory of Spain on green maps is more desertic than that of Italy. Therefore, the green areas on average are “higher” than the highly green areas which also have a lower greenery compared to the high Italian green areas, as shown in Table 7.

4. Discussion

This study has investigated the association between COVID-19 clinical outcomes and the extension of public green areas (with three different categories: high urban areas, medium urban and rural areas) in provinces with more than 500,000 inhabitants of two different Mediterranean countries (8 provinces in Spain and 10 in Italy) for years 2020 and 2021. Two different methodologies were applied: a bottom-up approach was applied to Spanish institutional data both concerning contagions/hospitalizations/deaths and the extent of public green areas for each responder to an official questionnaire in the frame of a nationwide survey (with detailed data granularity per province)
containing specific georeferenced information; a top-down approach was used for Italy, starting from the official numbers of contagions/hospitalizations/deaths of each province and linking them to the OECD statistics (year 2014) about the extension of public green areas in the different provinces. The linear and generalized models used for statistical analyses included also PM2.5 in a multivariate approach (with annual average concentrations from official air quality monitoring stations) and were able to adjust for the different number inhabitants living in each province, in order to take into account the difference in contagion dynamics related to the higher density of population. The results obtained for Spain are consistent with those observed for Italy, as for both countries, it has clearly emerged a statistically significant association between COVID-19 clinical features (contagions, hospitalizations, and deaths) and the extension of public green areas in the provinces, as well as the annual average concentrations of PM2.5 (with this latter variable losing somewhere statistical significance). Therefore, the

### Table 15
Logistic Multivariable models for Contagion, Hospitalized, Deaths - Italy, 2020.

| Endpoint | Categories | Without Adjusted for PM2.5 | With Adjusted for PM2.5 |
|----------|------------|---------------------------|------------------------|
|          | OR         | 95% CI p-value AIC        | OR         | 95% CI p-value AIC |
| contagions | Low vs Median | 0.17 (0.14, 0.20) <.0001 15752.10 | 0.13 (0.11, 0.15) <.0001 14957.23 |
|          | Low vs High  | 0.10 (0.08, 0.12)         | 0.12 (0.10, 0.14)      |
|          | Median vs High | 0.61 (0.53, 0.70)         | 0.92 (0.80, 1.07)      |
| hospitalized | Low vs Median | 0.18 (0.16, 0.22) <.0001 14249.77 | 0.13 (0.11, 0.15) <.0001 13751.33 |
|          | Low vs High  | 0.12 (0.10, 0.15)         | 0.13 (0.11, 0.16)      |
|          | Median vs High | 0.65 (0.56, 0.75)         | 1.04 (0.88, 1.22)      |
| deaths   | Low vs Median | 0.17 (0.15, 0.21) <.0001 14237.24 | 0.12 (0.10, 0.15) <.0001 13729.83 |
|          | Low vs High  | 0.11 (0.09, 0.14)         | 0.13 (0.11, 0.16)      |
|          | Median vs High | 0.65 (0.56, 0.76)         | 1.06 (0.91, 1.25)      |

### Table 16
Logistic Multivariable models for Contagion, Hospitalized, Deaths – Italy, 2021.

| Endpoint | Categories | Without Adjusted for PM2.5 | With Adjusted for PM2.5 |
|----------|------------|---------------------------|------------------------|
|          | OR         | 95% CI p-value AIC        | OR         | 95% CI p-value AIC |
| contagions | Low vs Median | 0.18 (0.15, 0.21) <.0001 19275.10 | 0.07 (0.06, 0.08) <.0001 17294.50 |
|          | Low vs High  | 0.10 (0.08, 0.13)         | 0.04 (0.03, 0.05)      |
|          | Median vs High | 0.58 (0.51, 0.67)         | 0.65 (0.56, 0.74)      |
| hospitalized | Low vs Median | 0.18 (0.16, 0.22) 0.284 16757.90 | 0.12 (0.11, 0.15) <.0001 16906.00 |
|          | Low vs High  | 0.11 (0.09, 0.13)         | 0.12 (0.10, 0.15)      |
|          | Median vs High | 0.58 (0.51, 0.67)         | 0.97 (0.84, 1.13)      |
| deaths   | Low vs Median | 0.18 (0.16, 0.22) <.0001 16744.50 | 0.13 (0.11, 0.15) 0.191 16110.50 |
|          | Low vs High  | 0.11 (0.09, 0.13)         | 0.13 (0.11, 0.15)      |
|          | Median vs High | 0.59 (0.52, 0.68)         | 0.99 (0.86, 1.15)      |

### Table 17
Logistic Multivariable models for Contagion, Hospitalized, Deaths - Spain, 2020.

| Endpoint | Categories | Without Adjusted for PM2.5 | With Adjusted for PM2.5 |
|----------|------------|---------------------------|------------------------|
|          | OR         | 95% CI p-value AIC        | OR         | 95% CI p-value AIC |
| contagions | Low vs Median | 0.22 (0.11, 0.44) 0.04 1026.61 | 0.20 (0.10, 0.41) 0.04 860.40 |
|          | Low vs High  | 0.27 (0.14, 0.54)         | 0.29 (0.14, 0.59)      |
|          | Median vs High | 1.25 (0.80, 1.95)         | 1.44 (0.89, 2.22)      |
| hospitalized | Low vs Median | 0.24 (0.12, 0.48) <.0001 1016.23 | 0.22 (0.11, 0.45) 0.04 850.17 |
|          | Low vs High  | 0.29 (0.15, 0.59)         | 0.31 (0.15, 0.64)      |
|          | Median vs High | 1.23 (0.78, 1.93)         | 1.42 (0.88, 2.31)      |
| deaths   | Low vs Median | 0.22 (0.11, 0.44) 0.02 1025.36 | 0.20 (0.10, 0.42) 0.05 859.36 |
|          | Low vs High  | 0.27 (0.14, 0.55)         | 0.29 (0.14, 0.60)      |
|          | Median vs High | 1.25 (0.80, 1.95)         | 1.43 (0.89, 2.32)      |

### Table 18
Logistic Multivariable models for Contagion, Hospitalized, Deaths - Spain, 2021.

| Endpoint | Categories | Without Adjusted for PM2.5 | With Adjusted for PM2.5 |
|----------|------------|---------------------------|------------------------|
|          | OR         | 95% CI p-value AIC        | OR         | 95% CI p-value AIC |
| contagions | Low vs Median | 0.78 (0.59, 1.04) <.0001 5282.52 | 0.67 (0.50, 0.91) <.0001 4366.90 |
|          | Low vs High  | 0.81 (0.62, 1.06)         | 0.70 (0.53, 0.94)      |
|          | Median vs High | 1.03 (0.84, 1.26)         | 1.05 (0.85, 1.30)      |
| hospitalized | Low vs Median | 0.78 (0.59, 1.03) <.0001 5275.66 | 0.66 (0.49, 0.90) <.0001 4358.78 |
|          | Low vs High  | 0.80 (0.61, 1.05)         | 0.70 (0.52, 0.93)      |
|          | Median vs High | 1.03 (0.84, 1.26)         | 1.05 (0.85, 1.30)      |
| deaths   | Low vs Median | 0.80 (0.61, 1.06) <.0001 5304.81 | 0.69 (0.51, 0.93) 0.191 4387.80 |
|          | Low vs High  | 0.82 (0.63, 1.08)         | 0.72 (0.54, 0.96)      |
|          | Median vs High | 1.03 (0.84, 1.26)         | 1.05 (0.84, 1.29)      |
extension of public green areas and air pollution seem to have a high correlation with SARS-CoV-2 activity. It should be noticed that there is a substantial difference between Spain and Italy concerning the extension of green areas belonging to the intermediate cut-off (medium urban areas) vs. those included in highest class (rural areas with lower urbanization rate). Actually, living in a medium urban area in Spain does not represent a protective factor towards COVID-19 severe clinical outcomes, because the extension of public green areas in medium urban and high urban areas in Spain does not significantly differ (due to the inclusion of desert zones with less dense vegetation in the “green” areas”). This study is based only on official data provided by the national and European agencies, with a high level of granularity. Our results are consistent with studies that show how the incidence of green spaces, especially forests, can influence the transmission of COVID-19 (Bin and Yi, 2021). These researches have proposed that the development of COVID-19 epidemic in urban spaces can be correlated and eventually predicted based on changes in temperature and deforestation. This association can potentially trigger indeed corresponding prevention and control measures that can be promptly adopted to protect public health. It has been suggested that it is necessary to grasp the influence of climate factors and that active measures can be taken to control COVID-19 outbreaks when virus activity is at a low level (Lin et al., 2020). Currently, the specific mechanism of the interaction between green environment and virus activity is unknown. But COVID-19 has been proved to produce less dramatic effects in green areas (Berdejo-Espinola et al., 2021). For these reasons, Governments should pay particular attention to the environment when formulating measures to prevent and control the epidemic situation, which can cause SARS-CoV-2 to have higher activity in presence of scarce green areas. All the countries should strengthen decisions in favor of environmental policies to protect air, water and land across Europe. The preventive and control measures related to COVID-19 epidemic should be strengthened when the activity of the virus is low, so as to suppress the trend of subsequent epidemic outbreaks or waves and achieve the purpose of epidemic prevention and control. At the same time, attention should be paid to the prevention and control of environmental factors such as increasing the urban green areas and reducing air pollution. Our results are also significantly worse for hospitalized and mortality in areas with lower availability of green spaces and highly polluted environments. So, it could be hypothesized that fewer green public areas and higher air pollution also lead to an increase in suspended solids in the atmosphere (as proposed by some authors) which provides ideal conditions for attachment, replication and increase in suspended solids in the atmosphere (as proposed by some authors).

5. Conclusions

The results of our study show that huge extension of public green areas in province is significantly associated with less severe COVID-19 clinical outcomes in terms of contagions, hospitalizations, and especially deaths. The adjusted additional effect of air pollution (namely PM2.5 annual average concentrations) was shown to turn in similar results, with lower levels of PM2.5 further reducing the burden of negative clinical outcomes. In line with the resolutions adopted at COP-26, protective public health measures in the view of pandemic preparedness should include a strong governmental commitment if reforestation and air pollution reduction.

CRediT authorship contribution statement

Andrea Falco: Writing,Statistician. Prisco Piscitelli: Writing, Project administration. Domenico Vito: Writing, Study Design. Federico Pacella: Validation. Cristina Franco: Quality Check. Manuela Pulimen: Investigation. Paolo Ambrosino: Supervision. Javier Arias: Supervision. Alessandro Miani: Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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