Atmospheric particulate matter effects on Sars-Cov-2 infection and spreading dynamics: a spatio-temporal point process model.

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Introduction

The COVID-19 was caused by a novel coronavirus, named Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) Transmission rates and host's susceptibility to influenza and other viral diseases are influenced by several factors, such as demography, age, gender, socio-economic factors, education, and comorbidities. These elements can explain the differential distribution and transmission rates of SARS-CoV-2. It has been recently shown how environmental factors, including atmospheric particulate matter (PM), temperature, humidity and pollution may play an important role in SARS-CoV-2 differential distribution and transmission. The evidence for the association between air pollution and COVID-19 severity is getting stronger, suggesting that the potential chronic exposure to air pollution might increase the susceptibility to COVID-19; nevertheless, the potential association between PM10 exposure and SARS-CoV-2 spreading remains unclear. The infectious disease dynamics can be divided in endemic and epidemic components using individual-level surveillance data. In the epidemic component, infected cases are directly linked to the previously observed cases, whereas in the endemic component, new infected cases are independent, not directly attributable to the epidemic process, and then they do not generate secondary cases. The aim of this study is to assess the effect of residential exposure to atmospheric PM on SARS-CoV-2 infection and on the dynamics of disease spreading in Marche Region (Italy) from February to 31 May 2020 with a prediction model including both endemic and epidemic components

Materials and Methods

This study included all individuals with first positive SARS-CoV-2 nasal/oropharyngeal swab test from February up to May 2020 that were residents or domiciled in Marche Region, central Italy; other data collected were gender, age, domicile or residence address and employment. Tumours , diabetes, hypertension and chronic diseases of the respiratory were considered as comorbidities in this study. All residential addresses were geocoded and socio-economic deprivation index, measured at census block level, was attributed to each residence/domicile. Long-term exposure to outdoor fine PM air pollution of ≤10 μm diameter (PM_{10}) concentrations (μg/m^3), Temperature (°C) and Relative Humidity (%) were estimated at 10 km^2 grid cells of Marche Region; subjects were assigned to their respectively pollution and meteorological variables of grid cell containing their residential addresses. PM_{10} concentrations was estimated as average of daily concentrations on 2010-2019 years at 10 km^2 spatial grid, recorded at the 15 stations of Regional Air Quality Monitoring Networks located across Marche. Daily temperature and relative humidity from 113 monitoring stations were provided by the Regional Civil Protection Service for February-May 2020 period. The effect of temperature and humidity was evaluated at the previous 14 days (average lag 1–14) to account for the incubation period reported by WHO. The endemic component considered the grid cell population as population at risk of infection (offset). The epidemic component described the disease transmission from a primary case-patient to its secondary cases (direct person-to-person contact). Each primary case exerted its effect within an infectious period of 14 days and a spatial radius of 200 km, assuming a decay of the infection force as the spatial and temporal distance from it increased. Rate ratios (RR) and 95% Wald confidence intervals (CI) for endemic and epidemic factors were calculated. P-values<0.05 were considered statistically significant.

Results

Population summary statistics are reported in Table 1. Summary statistics of ambient air pollution and meteorological data at regional level were showed in Table 2. Parameter estimates, confidence intervals and p-values of regression model were presented in Table 3 for the epidemic component, including environmental and individual covariates and in Table 4 for the endemic component, where only spatio-temporal exogenous covariates were considered. 10-years PM10 exposure was associated with an increased risk of new endemic infectious (RR 1.14, 95% CI 1.04-1.24), as well as lockdown period (RR 2.29, 95% CI 1.96-2.66).

The severity of infection was associated with male gender and older age. Living in a nursing homes/long-term care facility, a long-term exposure to PM10 concentrations and the worsening of the socio-economic deprivation class increased the risk of secondary infection, whereas lockdown and high temperature reduced the transmission risk (RR 0.96, 95% CI 0.94-0.97). Temperature also reduced the risk of endemic infection (RR 0.88, 95% CI 0.87-0.89) (Tables 3-4). Regarding sensitivity analysis, no statistically significant effects for pre-existing disease were associated with the risk of transmitting Sars-Cov-2 infection and all effect estimated and their statistical inference were consistent with the main model that did not include PED.

Table 1. Socio-demographic characteristics of Sars-Cov-2 Positive Subjects (N = 6,638).
Note: DI, Deprivation Index. NH/LTCF, Nursing Homes and Long-Term Care Facilities.

Covariate	Category	n (%)
Gender	Female	3,511 (52.9%)
	Male	3,127 (47.1%)
Age	0-44	1,309 (19.7%)
	45-64	2,292 (34.5%)
	65-79	1,405 (21.2%)
	80+	1,632 (24.6%)
DI	1 (Least deprived)	1,228 (18.5%)
	2	1,450 (21.8%)
	3	1,436 (21.6%)
	4	1,255 (18.9%)
	5 (Most deprived)	1,269 (19.1%)
Employment	Other	5,407 (81.5%)
	Healthcare	1,231 (18.5%)
Residence	Home	6,169 (92.9%)
	NH/LTCF	469 (7.1%)

Table 2. Descriptive statistics of long-term PM_{10} exposure and daily meteorological covariates based on grid cells estimates at regional level.

Covariate	Mean (Interquartile Range)
PM10 (ug/m3)	24.0 (17.5, 30.1)
Average Temperature (°C)	12.6 (9.3, 16.4)
Relative Humidity (%)	68.4 (57.7, 79.1)

Table 3. Rate Ratio, 95% Confidence Interval and P-value from Epidemic component of Two-component Spatio-Temporal Point Process Model.
Note: Rate Ratio per 10 μg/m^3 increment in PM_{10}. RR, Rate Ratio. CI, Confidence Interval. DI, Deprivation Index. NH/LTCF, Nursing Homes and Long-Term Care Facilities.

Covariates	RR (95% CI)	P-value
PM_{10} (μg/m^3)	1.15 (1.08, 1.22)	<0.0001
Temperature (°C - Lag 1-14)	0.96 (0.94, 0.97)	<0.0001
Relative Humidity (% - Lag 1-14)	1.00 (1.00, 1.01)	0.0543
Lockdown		
No	Reference	
Yes	0.47 (0.43, 0.52)	<0.0001
Gender		
Female	Reference	
Male	1.16 (1.06, 1.26)	0.0007
Age		
0-44	Reference	
45-64	1.25 (1.10, 1.42)	0.0005
65-79	1.48 (1.30, 1.70)	<0.0001
80+	1.69 (1.48, 1.93)	<0.0001
DI	1.05 (1.03, 1.08)	0.0001
Employment		
Other	Reference	
Healthcare	1.03 (0.92, 1.16)	0.6272
Home		
Residence	Reference	
NH/LTCF	1.2 (1.04, 1.38)	0.0112

Table 4. Rate Ratio, 95% Confidence Interval and P-value from Endemic component of Two-component Spatio-Temporal Point Process Regression Model.
Note: Rate Ratio per 10 μg/m^3 increment in PM_{10}. RR, Rate Ratio. CI, Confidence Interval.

Covariates	RR (95% CI)	P-value
PM_{10} (μg/m^3)	1.14 (1.04, 1.24)	0.0035
Temperature (°C - Lag 1-14)	0.88 (0.87, 0.89)	<0.0001
Relative Humidity (% - Lag 1-14)	1.02 (1.02, 1.03)	<0.0001
Lockdown		
No	Reference	
Yes	2.29 (1.96, 2.66)	<0.0001
Day of week		
Weekdays/Saturday	Reference	
Sunday	0.45 (0.38, 0.54)	<0.0001

Conclusions

Results showed an increment of RR for exposure to increased levels of PM_{10} both in endemic and epidemic components. Targeted interventions are necessary to improve air quality in most polluted areas, where deprived populations are more likely to live, to minimize the burden of endemic and epidemic COVID-19 disease and to reduce unequal distribution of health risk.

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