

# SEROPREVALENCE OF SARS-CoV-2 AND ASSESSMENT OF EPIDEMIOLOGIC DETERMINANTS IN PORTUGUESE MUNICIPAL WORKERS

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## Abstract

**Objectives:** To assess the seroprevalence of SARS-CoV-2 antibodies in municipal employees of Northern Portugal during the first pandemic wave (May–June 2020) and its association with potentially related risk factors for infection. **Material and Methods:** The authors assessed municipal employees of 2 cities in Northern Portugal, in whom serological tests to SARS-CoV-2 and an epidemiological survey were applied. The authors assessed the proportion of individuals presenting IgM and/or IgG antibodies to SARS-CoV-2, and evaluated the association between having positive serological test results, epidemiologic variables and clinical presentations. Reported symptoms were evaluated on their sensitivity, specificity, and predictive values. **Results:** The authors assessed 1696 employees, of whom 22.0% were firefighters, 10.4% were police officers, 10.3% were maintenance workers, and 8.1% were administrative assistants. The seroprevalence of SARS-CoV-2 infection was 2.9% (95% CI: 2.1–3.7%). Administrative assistants comprised the professional group with highest seroprevalence of SARS-CoV-2 (OR = 1.9 in the comparison with other occupational groups, 95% CI: 0.8–4.3,  $p = 0.126$ ). The seroprevalence of SARS-CoV-2 infection among those who were in direct contact with COVID-19 patients in their professional activity was 3.9%, compared to 2.7% among those who were not in direct contact with such patients (OR = 1.5, 95% CI: 0.8–2.8,  $p = 0.222$ ). The highest risk of infection was associated with the presence of a confirmed SARS-CoV-2 infection in the household (OR = 17.4, 95% CI: 8.3–36.8,  $p < 0.001$ ). Living with a healthcare professional was not associated with a higher risk of infection (OR = 1.0, 95% CI: 0.4–2.5,  $p = 0.934$ ). Anosmia/dysgeusia was the symptom with the highest positive predictive value (52.2%, 95% CI: 31.8–72.6,  $p < 0.001$ ) and specificity (99.3%, 95% CI: 98.9–99.7,  $p < 0.001$ ), while cough was the most prevalent symptom among SARS-CoV-2 seropositive participants (36%). **Conclusions:** The authors observed a SARS-CoV-2 seroprevalence of 2.9% among assessed municipal employees. Anosmia/dysgeusia was the COVID-19 symptom which displayed the highest positive predictive value and specificity. *Int J Occup Med Environ Health.* 2022;35(3)

## Key words:

SARS-CoV-2 infection, COVID-19 pandemic, COVID-19 virus, COVID-19 serodiagnosis, COVID-19 antibody testing, SARS-CoV-2 infection serological testing

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## INTRODUCTION

On March 11, 2020, COVID-19 was classified by the World Health Organization (WHO) as a pandemic. Since then, and as of August 2021, it has resulted in over 4 million deaths worldwide [1]. The clinical presentation of COVID-19 varies, with some patients being asymptomatic or pauci-symptomatic and others developing severe illness or death [2]. Its high transmissibility has forced several countries to adopt preventive measures such as social distancing, quarantine and the use of personal protective equipment (PPE) [3].

Controlling SARS-CoV-2 spread requires a fast and reliable tracking of the epidemiology of COVID-19. Such tracking may involve a strategy based on both large-scale molecular and serological testing. As molecular testing (by polymerase chain reaction [PCR] of samples collected by nasopharyngeal swabs) can detect active infection, its large-scale performance has been promoted by the WHO to better contain COVID-19 spread [4]. On the other hand, serological tests detect the presence of SARS-CoV-2 antibodies formed after contact with the virus. The duration and extent of the protection conferred by these antibodies are still not totally clear, precluding serological tests from being used in the diagnosis of COVID-19. However, since not all subjects infected with SARS-CoV-2 end up being diagnosed (as a large fraction are asymptomatic or pauci-symptomatic), serological tests play a key role in assessing the frequency of individuals who have been infected, as they reveal the existence of previous and, often, late active infection [5,6]. Such properties, along with their relatively low cost and possibilities of use on a large scale, render serological tests adequate for epidemiological contexts (particularly in early outbreaks), allowing to identify factors associated with higher chances of infection by SARS-CoV-2 [7]. Such data may be particularly helpful in professional contexts, helping to outline the best preventive practices, and to improve the safety of those who may face a higher risk of infection [8,9]. While several previ-

ous studies were conducted in hospital and industrial settings [10–12], other professional contexts have been less frequently assessed.

Therefore, in this study, the authors aimed to assess the seroprevalence of SARS-CoV-2 antibodies in municipal employees of 2 different cities in Portugal and to identify the main epidemiological variables associated with past SARS-CoV-2 infection. In addition, and based on serological data, the authors aimed to assess the discriminative capacity of the main signs and symptoms of COVID-19.

## MATERIAL AND METHODS

### Setting and participants

Serological tests and an epidemiological survey to municipal employees of 2 cities in Northern Portugal (Porto and Matosinhos) were applied. These 2 cities have a combined population of over 400 000 inhabitants, having >4900 municipal employees [13]. In Portugal, municipal employees are responsible for a wide range of functions and include, among others, firefighters, municipal police officers, maintenance workers, administrative assistants, managers, engineers, and others. The authors assessed those employees tested May 15–June 19, 2020, with all municipal employees being eligible for inclusion. Participants' verbal informed consent was required to participate in the study, with no eligible employees refusing to participate in the study. All responses were provided anonymously.

### Serological tests

The authors applied serological tests to participants to assess both the presence/absence of IgM and IgG to SARS-CoV-2 (COVID-19 IgG/IgM Rapid Test Cassettes; SureScreen Diagnostics Co., Ltd., Derby, UK). The applied serological tests display a sensitivity of 96.6% and a specificity of 99.7% [14,15]. A participant was considered to have a positive serological test result in case of positivity for either IgM or IgG.

### Epidemiological survey

The applied epidemiological survey included demographic and general clinical questions (e.g., questions on the area of residence and on comorbidities), as well as questions on the type of work, mask-wearing habits, history of COVID-19-compatible symptoms, possible COVID-19 risk factors, and history of previous COVID-19 tests (and respective results). COVID-19-compatible symptoms comprised cough, fever, dyspnea, anosmia/dysgeusia (these 4 are herein referred as “COVID-19 main symptoms”), and other symptoms considered relevant to the participants and researchers. The questionnaire was applied by an interviewer, who registered the answers given by the participants. Participants answered the questionnaire before undergoing serological testing to ensure that researchers applying the questionnaire did not know the serological results of respondents.

All stages of the study were based on the Declaration of Helsinki principles for research with humans.

### Statistical analysis

Categorical variables were described using absolute and relative frequencies, while continuous variables were described using means and standard deviations. The association between having a positive serological test result and demographic, epidemiologic and clinical independent variables was assessed using univariable logistic regression models. Exponentials of regression coefficients were interpreted as odds ratio (OR). Multivariable logistic regression models were not considered due to the reduced effective sample size (i.e., low number of participants with positive serological tests).

To assess the discriminative properties of the different COVID-19-compatible symptoms, the sensitivity, specificity and predictive values of each symptom were calculated using the serological results as the gold-standard. In addition, to assess the performance of serological tests, for those participants who reported having performed

a previous molecular PCR test, the authors assessed the frequency of positive PCR test results among patients in whom SARS-CoV-2 antibodies were and were not detected.

No prior calculation of the sample size was performed due to insufficient reliable data at the time. The number of participants included in the study represents the total amount of municipal workers tested and surveyed during the considered time.

The authors considered statistically significant associations those with p-value <0.05. All statistical analyses were performed using software R (v. 4.0.0).

### RESULTS

From the 4994 existing municipal workers, a total of 1696 participants completed the epidemiological survey. The mean  $\pm$  standard deviation ( $M\pm SD$ ) age of the sample was  $46.1\pm 11.0$  years old, with a predominance of males ( $N = 1256$ , 74.1%). In terms of occupational groups, 22.0% of participants were firefighters, 10.4% were police officers, 10.3% were maintenance workers, and 8.1% were administrative assistants. The remaining municipal staff varied, and included – among others – social assistants, managers and politicians, engineers, drivers and technical personnel. Each assessed participant completed the whole survey, so that there was no missing data.

A total of 50 participants (2.9%, 95% confidence interval [CI]: 2.1–3.7%) had a positive serological test. IgG were detected in 43 (2.5%) participants, while IgM were detected in 27 (1.6%) participants, with 20 participants having both detected IgM and IgG antibodies.

Twelve participants with positive serological test (24.0%) reported another case of confirmed infection in the respective household, compared to 29 participants with negative serological test (1.8%) (OR = 17.4, 95% CI: 8.3–36.8,  $p < 0.001$ ) (Table 1). Accordingly, having a possible risk exposure/contact strongly associated with having a positive serological test, with such association being particu-

**Table 1.** Characteristics of the assessed participants and results of univariable regression models comparing patients with positive serological tests vs. those with negative results – data from 1696 municipal employees of 2 cities in Northern Portugal, assessed May 15–June 19, 2020

Variable	Participants (N = 1696)		OR (95% CI)	p
	total	with positive serological test (N = 50)		
Age [years] (M±SD)	46.1±11.0	45.2±11.9	1.0 (1.0–1.0)	0.568
Gender [n (%)]				
males	1256 (74.1)	29 (58.0)	0.5 (0.3–0.8)	<b>0.007</b>
females	440 (25.9)	21 (42.0)		
Cohabitation with a healthcare professional [n (%)]	199 (11.7)	6 (12.0)	1.0 (0.4–2.5)	0.934
Occupation [n (%)]				
firefighter	373 (22.0)	10 (20.0)	0.9 (0.4–1.8)	0.727
police officer	177 (10.4)	6 (12.0)	1.2 (0.5–2.8)	0.716
administrative assistant	137 (8.1)	7 (14.0)	1.9 (0.8–4.3)	0.126
maintenance worker	174 (10.3)	5 (10.0)	1.0 (0.4–2.5)	0.949
Direct contact with COVID-19+ patients in professional activity [n (%)]	355 (21.0)	14 (28.0)	1.5 (0.8–2.8)	0.222
Use of mask in professional activity [n (%)]	1633 (96.3)	49 (98.0)	1.9 (0.3–13.9)	0.533
since March or before	990 (58.4)	27 (54.0)	1.7 (0.2–12.8)	0.601
since April	249 (14.7)	9 (18.0)	2.3 (0.3–18.4)	0.437 <sup>a</sup>
since May	394 (23.2)	13 (26.0)	2.1 (0.3–16.2)	0.484 <sup>a</sup>
Confirmed COVID-19 case in the household [n (%)]	41 (2.4)	12 (24.0)	17.4 (8.3–36.8)	<b>&lt;0.001</b>
Possible risk exposure/contact [n (%)]	150 (8.8)	25 (16.7)	12.2 (6.8–21.8)	<b>&lt;0.001</b>
at work	70 (4.1)	8 (11.4)	4.9 (2.2–10.8)	<b>&lt;0.001</b>
in national or international travels	10 (0.6)	1 (10.0)	3.7 (0.7–19.9)	0.218
with a family member	49 (2.9)	11 (22.4)	12.0 (5.7–25.1)	<b>&lt;0.001</b>

<sup>a</sup> Reference group consisting of those patients who did not wear a mask in their professional activity. Bolded are p-values <0.05.

larly strong when concerning a family member (OR = 12.0, 95% CI: 5.7–25.1,  $p < 0.001$ ).

Living with a healthcare professional was not associated with increased odds of having a positive serological test (OR = 1.0, 95% CI: 0.4–2.5,  $p = 0.934$ ). Participants having direct contact with COVID-19 positive or suspected patients in their professional activities displayed higher seroprevalence of SARS-CoV-2 infection compared to those without direct contact (3.9% vs. 2.7%;

OR = 1.5, 95% CI: 0.8–2.8,  $p = 0.222$ ). The occupational group associated with the highest risk was that of administrative assistant (OR = 1.9, 95% CI: 0.8–4.3,  $p = 0.126$ ). Separate results for patients in whom IgG and IgM antibodies were detected are displayed in Table 2.

While most participants (96.3%) reported using a mask in their professional activities, no significant association was observed between the month in which mask use was adopted in the workplace and occurrence of a posi-

**Table 2.** Results from table 1 discriminating participants with positive IgG and IgM results – data from 1696 municipal employees of 2 cities in Northern Portugal, assessed May 15–June 19, 2020

Variable	Participants (N = 1696)						
	total	with IgG (N = 43)	OR (95% CI)	p	with IgM (N = 27)	OR (95% CI)	p
Age [years] (M±SD)	46.1±11.0	45.5±12.0	1.0 (1.0–1.0)	0.702	42.0±12.1	1.0 (0.9–1.0)	0.057
Males [n (%)]	1256 (74.1)	25 (58.1)	0.5 (0.2–0.8)	0.013	15 (55.6)	0.4 (0.2–0.9)	0.024
Cohabitation with a healthcare professional [n (%)]	199 (11.7)	6 (14.3)	1.2 (0.5–3.0)	0.632	4 (14.8)	1.4 (0.5–4.0)	0.583
Occupation [n (%)]							
firefighter	373 (22.0)	8 (19.5)	0.8 (0.4–1.8)	0.588	8 (29.6)	1.5 (0.6–3.4)	0.352
police officer	177 (10.4)	5 (11.6)	1.1 (0.4–2.9)	0.795	2 (7.4)	0.7 (0.2–2.9)	0.615
administrative assistant	137 (8.1)	7 (16.2)	2.3 (1.0–5.2)	0.053	2 (7.4)	0.9 (0.2–4.0)	0.924
maintenance worker	174 (10.3)	5 (11.6)	1.1 (0.4–3.0)	0.774	1 (3.7)	0.3 (0.1–2.5)	0.285
Direct contact with COVID-19+ patients in professional activity [n (%)]	355 (21.0)	11 (25.6)	1.3 (0.7–2.6)	0.450	9 (33.3)	1.9 (0.8–4.3)	0.119
Use of mask in professional activity [n (%)]	1633 (96.3)	42 (97.7)	1.6 (0.2–11.9)	0.637	27 (100)	–	–
Confirmed COVID-19 case in the household [n (%)]	41 (2.4)	11 (25.6)	18.9 (8.7–41.3)	<0.001	7 (25.9)	19.3 (7.6–49.3)	<0.001
Possible risk exposure/contact [n (%)]	150 (8.8)	23 (53.5)	13.8 (7.4–25.8)	<0.001	19 (70.4)	28.4 (12.2–66.3)	<0.001

tive serological test. Nevertheless, significant differences were observed when comparing professional classes on the time of mask use adoption – only 33% administrative assistants reported wearing a mask in their professional activities since March, compared to 60% in every other professional group (OR = 0.3, 95% CI: 0.2–0.5,  $p < 0.001$ ); on the other hand, 79% of ambulance vehicle operators, firefighters and police officers reported wearing a mask since March, comparing to 52% employees of the remaining groups (OR = 1.8, 95% CI: 1.5–2.3,  $p < 0.001$ ). When answering the survey, 141 (8.3%) participants reported having had at least 1 COVID-19 main symptom in the previous 2 months. Of the 50 participants with a positive serological test, 48% (N = 24) reported having at least 1 symptom, compared to 7% of those with negative serological tests ( $p < 0.001$ ) (Table 3). Anosmia/dysgeusia was the symptom with the highest positive predictive value (PPV) – 52.2% of participants with anosmia/dysgeusia had a positive serological test (95% CI: 31.8–72.6) (Table 3). For the remaining symptoms, the PPV ranged between 17.1% (cough) and 23.1% (other symptoms). Most participants with no symptoms had a negative serology to COVID-19, with negative predictive values (NPV) being over 97% for all assessed symptoms. The sensitivity of the inquired symptoms varied from 12.0% (dyspnea) to 36.0% (cough), while their specificities ranged from 94.7% (cough) to 99.3% (anosmia/dysgeusia). When asked about a previous test for SARS-CoV-2, 140 (8.3%) participants claimed to have undergone a previous PCR test, with 16 (11.4%) of them having positive results (Table 4). Of those with a positive PCR result, 15 (94%) had a positive serological test result (vs. 8 participants – 6% among those with negative PCR results).

## DISCUSSION

In this study, 1696 municipal employees were evaluated, with 2.9% of them having positive results for the presence of either IgM or IgG antibodies for SARS-CoV-2. The fre-

quency of symptoms largely varied, with almost half of participants with a positive serological test reporting at least 1 COVID-19 symptom in the previous 2 months. Anosmia/dysgeusia were the symptoms associated with the highest PPV (52%).

The professional class with the highest seroprevalence (even though such difference was not statistically significant) was not one involved indirect contact with COVID-19 patients, but rather that of administrative assistants. This is surprising if we take into account that working in direct contact with COVID-19 patients associated – even if not significantly – with higher chances of having a positive serological test. However, this might be explained by a later and less strict use of PPE among the latter, by the fact that their jobs often involve staying for long periods in small and often inadequately ventilated spaces [16,17], as well as by being inexperienced with the use of PPE. By contrast, professionals with a higher exposure risk [18], such as ambulance vehicle operators, firefighters and police officers, had no significant increase in the presence of SARS-CoV-2 antibodies, likely explained by having more extensive use of PPE from early on. This hypothesis is further indirectly supported by the absence of significant association between living with a healthcare professional and having positive serological results – there seems to have been more widespread adoption of preventive behaviors among healthcare professionals, due to a greater perception of risk and vulnerability to infection (although it is possible that not all assessed healthcare professionals were involved in care for COVID-19 patients) [19,20]. Evidence on the seroprevalence of SARS-CoV-2 infection among Portuguese healthcare professionals within the first pandemic wave is scarce. While, by the end of May 2020, 3.2% healthcare professionals had been diagnosed with COVID-19 [21,22], the true extent of SARS-CoV-2 infection among this occupational group is not known (so that it is not possible to precisely compare with the general

**Table 3.** Frequency, sensitivity, specificity and predictive values of COVID-19 main symptoms – data from 1696 municipal employees of 2 cities in Northern Portugal, assessed May 15–June 19, 2020

Symptom	Participants (N = 1696)		Predictive value				Sensitivity [%]	95% CI	Specificity [%]	95% CI
	total [n]	with positive serological test (N = 50) [n (%)]	positive [%]	95% CI	negative [%]	95% CI				
At least one COVID-19 main symptom <sup>a</sup> (in the previous 2 months)			17.0	10.8–23.2	98.3	97.7–99.0	48.0	34.2–61.8	92.9	91.7–94.1
no	1555	26 (1.7)								
yes	141	24 (17.0) <sup>b</sup>								
Cough			17.1	9.9–24.4	98.0	97.3–98.7	36.0	22.7–49.3	94.7	93.6–95.8
no	1591	32 (2.0)								
yes	105	18 (17.1) <sup>b</sup>								
Fever			21.3	11.0–31.6	97.7	97.0–98.5	26.0	13.8–38.2	97.1	96.3–97.9
no	1635	37 (2.3)								
yes	61	13 (21.3) <sup>b</sup>								
Dyspnea			18.8	5.2–32.3	97.3	96.6–98.1	12.0	3.0–21.0	98.4	97.8–99.0
no	1664	44 (2.6)								
yes	32	6 (18.8) <sup>b</sup>								
Anosmia or dysgeusia			52.2	31.8–72.6	97.7	97.0–98.4	24.0	12.2–35.8	99.3	98.9–99.7
no	1673	38 (2.3)								
yes	23	12 (52.2) <sup>b</sup>								
Other			23.1	0.2–46.0	97.2	96.4–98.0	6.0	0–12.6	99.4	99.0–99.8
no	1683	47 (2.8)								
yes	13	3 (23.1) <sup>b</sup>								

<sup>a</sup> Dyspnea, fever, cough and/or anosmia/dysgeusia.

<sup>b</sup> Statistically significant difference in the frequency of the symptom among patients with positive serological tests and those with negative serological symptoms ( $p < 0.001$ ).

population, in whom a seroprevalence of 2.9% was observed [23]).

More than half (52%) of participants with a positive serological test did not report having had any of COVID-19 main symptoms and, of those reporting previous symptoms, only 17% had a positive serological test. Among symptomatic patients, anosmia/ageusia presented the highest specificity and PPV, pointing to its

importance when COVID-19 is suspected. Other studies [24,25] reported a PPV of 32% and 73%, and a specificity of 65% and 81%, respectively, for olfactory dysfunction. The characteristics of anosmia/dysgeusia make it an important symptom that, when present, can strongly suggest COVID-19 infection, being particularly relevant in young [24] and female patients [26]. While the exact mechanism causing lack of smell and taste is still un-

**Table 4.** Results of serological tests for SARS-CoV-2 in patients who had undergone a molecular (polymerase chain reaction – PCR) test for SARS-CoV-2 – data from 1696 municipal employees of 2 cities in Northern Portugal, assessed May 15–June 19, 2020

PCR test result	Serological tests (N = 140)				
	total [n (%)]	positive (N = 23)		negative (N = 117)	
		n (%)	95% CI	n (%)	95% CI
Positive	16 (11.4)	15 (93.8)	82.0–100	1 (6.3)	0–18.1
Negative	124 (88.6)	8 (6.5)	2.1–10.8	116 (93.5)	89.2–97.9

clear [27] (albeit it is known that SARS-CoV-2 entry factors are highly expressed in nasal epithelial cells [28], which are thought to have an important role in infection), anosmia/ageusia appears to be more common than initially stated [29] and it helps differentiating COVID-19 from other common respiratory viral infections (such as influenza). Given that this symptom can be accurate and easy to understand, the general public should be aware of its value, particularly in contexts where rapid molecular testing is not easily available [30]. Further studies should be carried out to better characterize this symptom among COVID-19 patients.

Having a confirmed COVID-19 case in the household was strongly and significantly associated with having a positive serological test, pointing to the high likelihood of infection transmission to coresidents, who might further spread their infection, even if asymptomatic [31].

This study has important limitations worth noting. Firstly, the authors identified a small number of participants with positive serological test results, affecting the estimates' precision (possibly precluding some relevant associations to be detected as statistically significant), and limiting the possibility of adjusting for confounders by means of multivariable methods. In addition, there may have been a selection bias, as employees who had died from COVID-19 or who had active disease when this study was being performed were not included. Nevertheless, the impact of such limitation in the results is

probably small – by the time this study was performed, <900 individuals had died from COVID-19 in Northern Portugal (most of whom were not of working-age), and the incidence of the disease was particularly low.

Another potential selection bias concerns the fact that municipal employees are not representative of the general population (i.e., they are people in active age, and as a result they do not include children and the elderly), so that their results cannot be generalized to all adults living in the assessed region. In fact, workers tend to be healthier than those who do not work (healthy worker effect) and may also have different exposures. Nevertheless, the authors' aim was to assess the seroprevalence of SARS-CoV-2 infection in municipal workers, and not in the general population.

On the other hand, despite having been actively questioned for the symptoms included in this study, they were self-reported and memory bias can be present – those who knew they had had a past SARS-CoV-2 infection may recall better any symptoms they may have had when compared to the remaining participants. Other possible variables, such as the level of education of the participants and their free time activities were not studied and could have had a significant impact on the results and in the assessment of their risk of exposure to SARS-CoV-2. The duration and strength of protection that antibodies confer are still in debate, with current evidence suggesting that antibodies may confer substantial protection against reinfection in the 3–6 months after infection [32–34]. However,



as this study was conducted at the end of the first wave of the pandemic (May/June), there was a low chance of seroreversion (i.e., loss of antibodies by those who were seropositive) in the participants.

The study has also important strengths. While previous studies assessed the discriminative properties of COVID-19-related symptoms, they were mostly carried out in a hospital context [35–37], leaving out many patients with mild presentations (contrary to what was observed in this study). In addition, the authors assessed the seroprevalence of SARS-CoV-2 infection in a professional context, assessing a diverse range of non-healthcare workers.

## CONCLUSIONS

In conclusion, 2.9% of tested municipal employees displayed positive serological tests. The study portrays how different professional groups were impacted in the first wave of the pandemic in this region, in a phase where large-scale PCR testing was still not available and preventive measures (such as lockdown and the recommendation of mask usage for the population) were still in early adoption. In this context, the existence of a COVID-19 confirmed case in a participant's household was the variable found to have the strongest association with COVID-19 seropositivity, while the reported symptom with the highest PPV and specificity was found to be that of anosmia/ageusia.

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