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Seroprevalence of anti-SARS-CoV-2 antibodies after the first wave of the COVID-19 pandemic in a vulnerable population in France: a cross-sectional study

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ABSTRACT

Objectives We aimed to assess the level of prior SARS-CoV-2 infection in socially deprived neighbourhoods after the first wave of the pandemic, and to identify factors associated with seropositivity.

Design A cross-sectional study.

Setting Three socially deprived neighbourhoods of the city of Perpignan, in the south of France, where large settled Roma communities live.

Participants People aged 6 years old or over, living in the study area. 700 people were included in the study using two-stage stratified sampling design.

Interventions The study included a questionnaire and SARS-CoV-2 antibody testing by the Roche Elecsys immunoassay between 29 June and 17 July 2020.

Primary and secondary outcome measures SARS-CoV-2 antibody seroprevalence was estimated from weighted data. Associated factors and reported symptoms were investigated using univariable and multivariable logistic regressions.

Results The seroprevalence of anti-SARS-CoV-2 antibodies was 35.4% (95% CI 30.2% to 41.0%). People aged 15–64 years old had increased odds of being seropositive than those aged 65 years or over. Obese people had higher odds of being seropositive (adjusted OR (aOR)=2.0, 95% CI 1.1 to 3.8). The odds of being seropositive were higher in households with clinical COVID-19 cases (one case: aOR=2.5, 95% CI 1.3 to 5.0; several cases: aOR=6.9, 95% CI 3.1 to 15.2). In the neighbourhood with the highest measured seroprevalence, people living in a dwelling with one to two rooms had higher odds of being seropositive than those living in a four-room house (aOR=2.8, 95% CI 1.2 to 6.3). Working during the lockdown was associated with lower odds of being seropositive (aOR=0.2, 95% CI 0.03 to 1.0).

Conclusion Transmission of SARS-COV-2 in this vulnerable population was very high during the COVID-19 pandemic's first wave. Our results highlight the need to strengthen and adapt preventive measures taking into account all social determinants of health, especially housing conditions.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ We examined prevalence of SARS-CoV-2 antibodies and associated environmental and behavioural factors in a socially deprived population which is difficult to access.

⇒ A strong collaboration with mediators from the study population for the questionnaire design and the recruitment allowed a better participation of the population in the survey.

⇒ Collection of socioeconomic information was restricted to neighbourhood of residence and housing for reasons of acceptability by the participants.

⇒ Preventive behaviours and compliance with barrier measures were not studied in our analysis due to probable changes in behaviour during the lockdown.

⇒ Men and children were under-represented in the study sample.

INTRODUCTION

With the emergence of COVID-19 and the resulting pandemic, questions about social inequalities in health during the current crisis have been raised.[1–4] Many health issues are involved, including inequalities in exposure to SARS-CoV-2, in the severity of the COVID-19 disease and in access to healthcare.[1 4–6] These concerns are all the more important given that these health inequalities are often cumulative,[7] leading to a marked risk of increased social deprivation in vulnerable populations.[3 5 8] Furthermore, lockdowns implemented in many countries have exacerbated pre-existing health inequalities.[1 5 9 10]

During the ongoing epidemic, special attention has been given to some 10 000 residents living in three of the poorest neighbourhoods (Haut-Vernet, Nouveau Logis and Saint-Jacques) in France. Located in the city of Perpignan (120 000 inhabitants, Occitania

region), the employment rate is very low in these neighbourhoods, with only 25%–30% of people aged 15–64 years old being employed.[11] Roma communities, calling themselves 'gitans' (gypsies), make up a large part of the population of the neighbourhoods where they have settled for several generations. They share commonalities in lifestyle and culture, with the roles of family and religion being especially important. In Europe, Roma communities have lower education levels and higher unemployment rates than the general public. They often have poorer living conditions and commonly face social exclusion.[12] Furthermore, their health literacy level is low and they have their own perception of health and sickness. Sickness must have visible and tangible consequences for them to recognise it and act accordingly.[13] Moreover, they have a poorer health status than that of the general population and face greater barriers to accessing healthcare.[14–16]

The first wave of the COVID-19 pandemic hit France at the beginning of 2020, leading to a national lockdown between 17 March and 11 May 2020. After the first positive case in Perpignan was detected using RT(reverse transcriptase)-PCR on 11 March 2020, the epidemic progressed rapidly in the city. On 20 March 2020, there were 47 confirmed cases in all the Pyrénées-Orientales 'department' (administrative area larger than a district but smaller than a region) (475 000 inhabitants) where Perpignan is located. On the same day, the intensive care unit in Perpignan hospital reported 19 people hospitalised and 5 deaths. An analysis by the hospital's infectious and tropical diseases unit of all those diagnosed positive indicated that most of the patients were living in the three neighbourhoods described above. In order to control the situation, a curfew was implemented throughout the city beginning 21 March 2020 and accommodation facilities were offered to facilitate isolating positive cases and persons the latter had been in contact with. Outpatient medical centres were rapidly opened in the city's most affected neighbourhoods to provide care to clinical cases and to prevent the spread of the virus in less impacted neighbourhoods. Specific surveillance based on data from these centres was also set up to monitor the evolution of the epidemic.[17] The mobilisation of various health and local actors ensured the swift dissemination of specific prevention information to the population throughout the first wave. On 1 May 2020, the epidemic had largely dissipated and 2 months after the lockdown, viral circulation was close to zero in Perpignan.

In this context, we conducted a seroprevalence study of anti-SARS-CoV-2 antibodies in Perpignan (SCoPe) in the three neighbourhoods described above to estimate the level of prior infection during the first epidemic wave. In addition, we analysed environmental and behavioural factors in order to identify factors associated with increased viral circulation.

METHODS
Study design and participants
Seroprevalence of COVID-19 in Perpignan (SCoPe) is a cross-sectional seroprevalence survey of a sample of
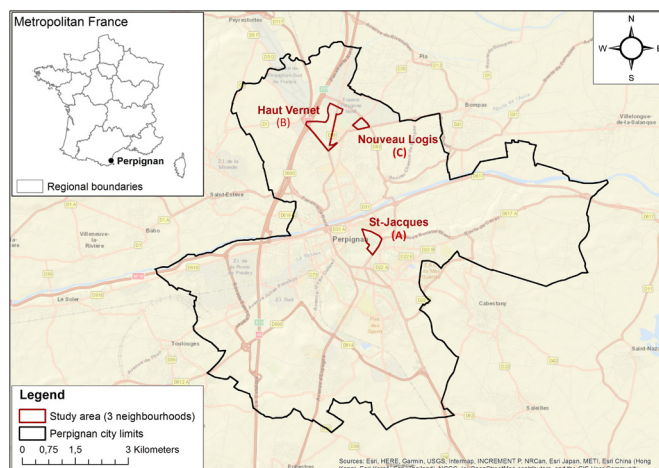
Figure 1 Map of the city of Perpignan and the three neighbourhoods studied.

the population living in three neighbourhoods (Saint-Jacques (neighbourhood A), Haut-Vernet (neighbourhood B) and Nouveau Logis (neighbourhood C)) in the city of Perpignan (figure 1). It was conducted between 29 June and 17 July 2020.

The limits of neighbourhoods A and B were demarcated using data from the French National Institute of Statistics and Economic Studies, and neighbourhood C from city data (priority neighbourhood for social actions).

As sampling frames were unavailable for inhabitants or dwellings, we chose a two-stage random sampling process (households, inhabitants) stratified by neighbourhood. The field investigators criss-crossed each neighbourhood to select households for potential participation by systematic sampling from a predefined route and sampling interval generated by the research team. In a second step, we randomly selected at least one person in each household using the next-birthday method.[18] The number of selected persons was predetermined according to the number of eligible persons in the household: one if one to two, two if three to four persons, three if five to six persons, and four if seven or over persons (see online supplemental materials—Survey procedure and logistics). Recruitment was carried out by teams of field investigators comprising members of the Roma community and local social workers.

Individuals were eligible if they were 6 years old or over, had resided in the study area between 1 January 2020 and the survey date, were physically able to move to one of the study's five purpose-built survey centres and were able to answer the survey questionnaire.

Participants were referred to the neighbourhood's survey centre, where physicians used a standardised questionnaire in French—specifically designed for SCoPe—to collect information on the following: sociodemographic characteristics, medical conditions associated with the risk of severe COVID-19,[19] occurrence of symptoms suggestive of COVID-19 and healthcare-seeking behaviour since 24 February 2020, characteristics of both the household and the housing the participants lived

in during the first lockdown, knowledge of COVID-19 prevention measures and behaviours during the first lockdown (see online supplemental materials—Questionnaire). Members of the Roma community were not identified in the questionnaire because of the prohibition of collection of ethnic statistics in France. BMI (Body mass index) was calculated by measuring height and weight and was categorised according to standard cut-off points for obesity (BMI $\geq 30 \, \text{kg/m}^2$).[19] Other quantitative variables (age, number of rooms, number of clinical COVID-19 cases) were categorised from the results of the univariable analysis. A blood sample was collected by venepuncture for each participant: 3.5 mL for those aged 18 years old and over, and 600 µl for those aged 6–17 years old.
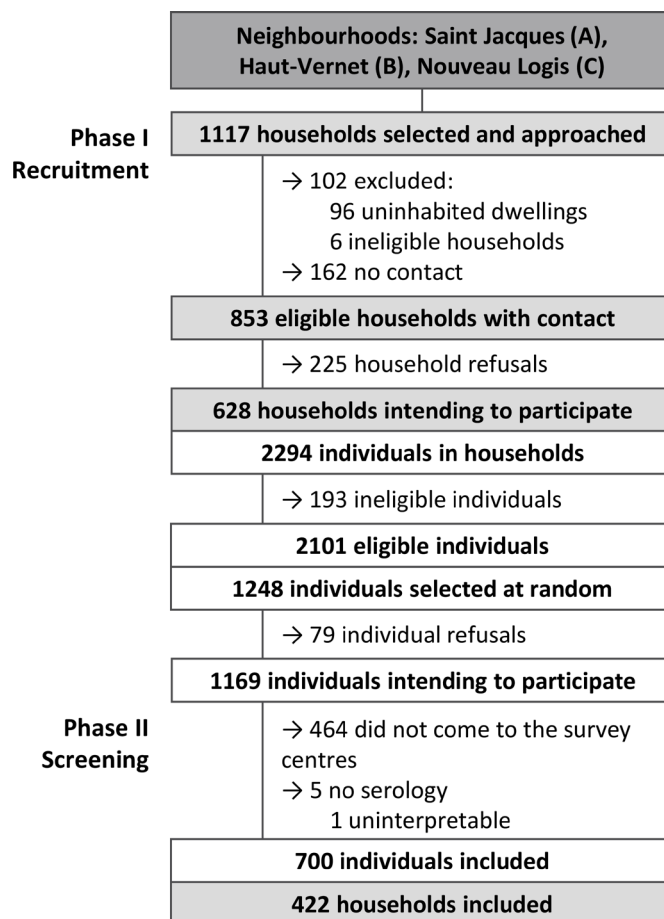
Laboratory analysis

Samples were stored locally for a maximum of 12 hours at less than 5° before being transferred to the laboratory at Perpignan Hospital.

Serological tests were performed using EIecsys Anti-SARS-CoV-2,[20] an immunoassay for in vitro qualitative detection of IgM and IgG antibodies against the SARS-CoV-2 spike protein in serum. Its sensitivity is 99.5% (95% CI 97% to 100%) at ≥ 14 days after PCR confirmation. Overall specificity is 99.8% (95% CI 99.69% to 99.88%).[20]

Statistical analysis

SCoPe's estimations take into account the sampling design components (stages, sampling weights, stratification). Data were weighted by the inverse of the probability of selection (sampling weight) and adjusted for the age and sex in each neighbourhood using data of selected persons who declined to participate in the study, and from post-stratification using data from the most recent population census (2017).

A person was defined seropositive if anti-SARS-CoV-2 antibodies (IgM or IgG) were detected by the immunoassay. Seroprevalence (ie, the proportion of seropositive individuals) was estimated with a 95% CI. Association of seroprevalence with the neighbourhood, other individual characteristics and reported symptoms were preliminarily tested by univariable analysis with Rao-Scott χ^2 test. Factors associated with seropositivity were then analysed using a multivariable logistic regression taking into account the sampling design. We reported ORs (unadjusted and adjusted) and adjusted Wald F test for significance for each variable. Behaviours during the lockdown were excluded from the multivariable analysis, except for leaving home to go to work. Age, sex and neighbourhood were always retained into the multivariable model. For the other variables, a forward selection procedure was applied and variables with a p value of <0.1 were retained. Interactions were tested. A p value of <0.05 was considered statistically significant. Data were analysed using Stata V.14.2 software (StataCorp, College Station, Texas, USA).

Figure 2 Flow chart of participants.

The flow chart contains the following:

Neighbourhoods: Saint Jacques (A), Haut-Vernet (B), Nouveau Logis (C)

Phase I Recruitment

1117 households selected and approached
→ 102 excluded:
   96 uninhabited dwellings
   6 ineligible households
→ 162 no contact

853 eligible households with contact
→ 225 household refusals

628 households intending to participate
2294 individuals in households
→ 193 ineligible individuals

2101 eligible individuals
1248 individuals selected at random
→ 79 individual refusals

1169 individuals intending to participate

Phase II Screening
→ 464 did not come to the survey centres
→ 5 no serology
   1 uninterpretable

700 individuals included
422 households included

Patient and public involvement

The questionnaire was designed in collaboration with local mediators in order to ensure that it would be acceptable to the study population and that they could understand it. Then, they implemented the selection phase of participants and provided them information about the survey. Participants received their individual results of antibodies anti-SARS-CoV-2 analysis in the week following the samples.

RESULTS

Of the total 1117 households initially selected for the study, 853 were visited and invited to participate (figure 2). Of the latter, 628 (73.6%) households with 2101 eligible individuals agreed to partake in the random participant selection stage. The rate of those agreeing to partake in this stage varied between all three neighbourhoods: 78.7% in neighbourhood A, 48.7% in neighbourhood B and 98.9% in neighbourhood C. Among the 1248 individuals subsequently selected at random from the 2101 who were eligible, 700 (56.1%) went to the survey centres and were included in the analysis (ie, study population): 312 from neighbourhood A (48.4%), 173 from neighbourhood B (70.0%) and 215 from neighbourhood C (60.4%).

A total of 287 men (41.0%) and 413 women (59.0%) participated in the study. Among all participants, 117

(16.7%) were aged between 6 and 19 years, 468 (66.9%) between 20 and 64 years, and 115 (16.4%) were aged 65 years or over. After weighting data, men and children were under-represented. Therefore, post-stratification adjustment was applied.

Study population

After post-stratification, women accounted for 50.4% of the study population. One-third (34.3%) of the population was aged between 6 and 19 years old, 53.7% between 20 and 64 years old, while 12.0% were 65 years old or over.

Obesity prevalence was 40.7% (95% CI 35.8% to 45.8%): 43.5% (95% CI 38.9% to 48.3%) in adults (BMI $\geq 30 \, kg/m^2$) and 34.0% (95% CI 22.2% to 48.2%) in those aged 6–17 years old (International Obesity Task Force (IOTF); BMI≥IOTF-30 cut-off points). Fifteen per cent (95% CI 13.0% to 17.3%) of the study population reported having hypertension, 7.0% (95% CI 5.5% to 8.8%) heart disease, 9.4% (95% CI 7.7% to 11.4%) were being treated for diabetes, 5.5% (95% CI 4.0% to 7.7%) had asthma, while 4.9% (95% CI 3.7% to 6.6%) had (an) other chronic respiratory disease(s).

The majority of those in neighbourhood A were living in an apartment (71.5%, 95% CI 64.6% to 77.6%), while the majority of people in neighbourhoods B and C were living in a house (73.9%, 95% CI 62.8% to 82.6%, and 83.9%, 95% CI 79.0% to 87.8%, respectively). The number of people per room (except the living room) in each home was greater than one for 75.3% (95% CI 69.9% to 80.1%) of people living in neighbourhood A, for 55.5% (95% CI 46.9% to 63.7%) in neighbourhood B and for 80.5% (95% CI 75.8% to 84.6%) in neighbourhood C. Detailed characteristics by neighbourhood are described in online supplemental table 1.

Seroprevalence

Overall seroprevalence was estimated at 35.4% (95% CI 30.2% to 41.0%) for all three neighbourhoods. It was significantly higher in neighbourhood A (46.7%, 95% CI 39.0% to 54.7%) than in neighbourhoods B and C (13.9%, 95% CI 8.2% to 22.6%, and 17.1%, 95% CI 13.0% to 22.2%, respectively).

Symptoms during the study period

Among seropositive people, 21.7% (95% CI 14.1% to 31.8%) reported no symptoms suggestive of COVID-19 during the study period (from 24 February 2020 to the survey date). One in seven (14.6%, 95% CI 9.5% to 21.9%) of those who reported no symptoms were tested seropositive. Seropositive people mostly reported unusual fatigue (58.9%, 95% CI 48.9% to 68.2%), a headache (51.7%, 95% CI 42.4% to 60.9%), ageusia/anosmia (49.8%, 95% CI 40.2% to 59.4%), a fever or a feeling of having a fever (49.1%, 95% CI 40.6% to 57.6%), a cough (46.4%, 95% CI 37.5% to 55.5%) and myalgia (45.7%, 95% CI 37.4% to 54.3%).

There was a significant positive association between seropositivity and symptoms (OR=8.1, 95% CI 4.5 to 14.6,
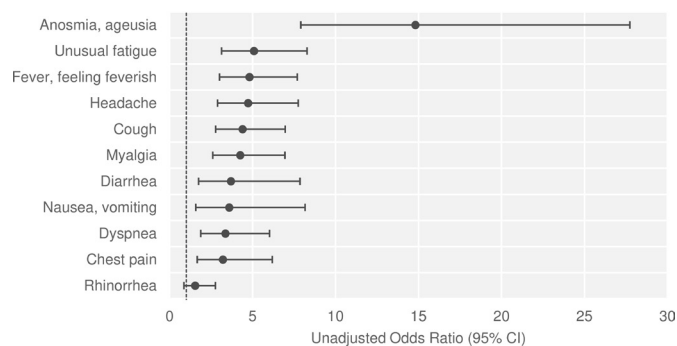
Figure 3 Association between seropositivity and reporting symptoms. Analysis performed on all sampled individuals (n=700) using simple logistic regressions.

p<0.001). Ageusia/anosmia were the symptoms most strongly associated with seropositivity (OR=14.8, 95% CI 7.9 to 27.7, p<0.001), with positive and negative predictive values of 81.3% (95% CI 71.5% to 88.3%) and 77.3% (95% CI 71.4% to 82.4%), respectively. All other symptoms were also significantly associated with seropositivity, except for rhinorrhoea (figure 3).

Healthcare-seeking behaviours during the study period

During the study period, 15.8% (95% CI 11.3% to 21.6%) of symptomatic people consulted a COVID-19 centre when symptoms occurred and 9.6% (95% CI 6.6% to 13.6%) had an RT-PCR test (positive PCR=29.0%). Specifically, 41.8% of seropositive participants tested with RT-PCR had a positive result.

Among seropositive participants, 7.9% (95% CI 4.6% to 13.2%) had been hospitalised during the study period, almost all having had medical conditions associated with severe COVID-19 (89.3%).

Factors associated with seropositivity

In the univariable analysis (table 1), people aged 65 years or over had lower odds of being seropositive (p<0.001). No significant difference was observed between males and females regarding the odds of being seropositive. Obese people had higher odds of being seropositive (OR=2.0, 95% CI 1.3 to 3.2). The presence of one (OR=3.0, 95% CI 1.8 to 5.2) or more (OR=7.8, 95% CI 4.0 to 15.2) clinical COVID-19 cases in the household was associated with increased odds of being seropositive. People living in a dwelling with three or fewer rooms (one to two rooms: OR=2.1, 95% CI 1.2 to 3.8; three rooms: OR=2.2, 95% CI 1.3 to 3.9) had higher odds of being seropositive. The proportion of seropositive people increased with the number of people per room in the dwelling (p=0.001). People who worked during the lockdown had reduced odds of being seropositive (OR=0.1, 95% CI 0.02 to 0.5). Furthermore, people who reported leaving their home once a week or less for walks during the lockdown had lower odds of being seropositive than people who went out every day or almost every day (OR=0.2, 95% CI 0.1 to 0.7).

Table 1 Factors associated with SARS-CoV-2 seropositivity: univariable analysis

	Total number	Seroprevalence % (95% CI)*	Unadjusted OR (95% CI)†	P value
Overall	**700**	**35.4 (30.2 to 41.0)**	–	–
Sex				0.119
Male	287	31.5 (24.2 to 40.0)	1 (ref)	
Female	413	39.2 (33.1 to 45.6)	1.4 (0.92 to 2.1)	0.119
Age (years)				<0.001
6–14	60	33.9 (20.0 to 51.3)	3.0 (1.2 to 7.4)	0.019
15–19	57	50.4 (35.5 to 65.2)	5.9 (2.6 to 13.3)	<0.001
20–64	468	36.1 (30.9 to 41.8)	3.3 (1.8 to 6.0)	<0.001
≥65	115	14.7 (8.9 to 23.2)	1 (ref)	
Obesity‡				0.002
No	368	28.7 (22.4 to 35.8)	1 (ref)	
Yes	315	44.9 (36.6 to 53.4)	2.0 (1.3 to 3.2)	0.002
Other medical conditions§				0.744
No	401	36.4 (29.7 to 43.5)	1 (ref)	
Yes: one	161	34.0 (25.7 to 43.4)	0.90 (0.56 to 1.5)	0.67
Yes: several	116	39.4 (29.3 to 50.6)	1.1 (0.66 to 2.0)	0.633
Clinical COVID-19 cases in the household¶				<0.001
No	437	18.6 (14.3 to 23.7)	1 (ref)	
1 person	159	40.9 (30.7 to 51.9)	3.0 (1.8 to 5.2)	<0.001
>1 person	104	64.0 (49.5 to 76.2)	7.8 (4.0 to 15.2)	<0.001
Number of rooms				0.006
1–2 rooms	141	43.0 (32.4 to 54.2)	2.1 (1.2 to 3.8)	0.011
3 rooms	185	43.9 (34.3 to 54.1)	2.2 (1.3 to 3.9)	0.005
≥4 rooms	366	26.2 (19.6 to 34.0)	1 (ref)	
Number of people per room (except living room)**				0.001
>1 person	435	40.0 (33.5 to 46.9)	4.0 (2.0 to 8.2)	<0.001
1 person	129	27.6 (19.1 to 38.2)	2.3 (1.1 to 5.0)	0.037
<1 person	128	14.3 (7.9 to 24.6)	1 (ref)	
At least one child in the household				0.116
No	306	29.6 (23.0 to 30.9)	1 (ref)	
Yes	387	37.9 (37.2 to 45.6)	1.5 (0.9 to 2.3)	0.116
Went out for work during the lockdown				0.006
No	670	36.5 (31.1 to 42.2)	1 (ref)	
Yes	30	5.4 (1.1 to 22.2)	0.10 (0.02 to 0.51)	0.006
Went out for a walk during the lockdown				0.001
Never	559	37.5 (32.0 to 43.4)	1.2 (0.53 to 2.8)	0.644
Sometimes (≤1 time a week)	51	9.7 (4.2 to 20.8)	0.22 (0.07 to 0.71)	0.012
Almost every day	87	33.0 (18.0 to 52.5)	1 (ref)	

*Seroprevalence estimated from weighted data.
†Unadjusted OR with corresponding 95% CIs and p values from univariable logistic regressions.
‡For those aged 18 years or older: BMI ≥30 kg/m²; for those aged 6–17 years: BMI (body mass index) ≥IOTF ((International Obesity Task Force) -30 cut-off points.
§Other medical conditions including: asthma, other respiratory diseases, hypertension, heart disease, treated diabetes, treated cancer (excluding hormone therapy), HIV and immunodeficiency, chronic liver disease, chronic kidney disease, neuromuscular diseases.
¶Clinical COVID-19 cases in the household: number of people, except the respondent, with clinical signs of COVID-19 (cough, fever), a positive RT-PCR test or who consulted for suspected COVID-19 since 24 February 2020.
**Living rooms were excluded, except for single people, in order to measure the potential for isolation in the dwellings. Indicator calculated: ([number of people]/number of rooms−1]).
IOTF, International Obesity Task Force.

Table 2 Factors associated with SARS-CoV-2 seropositivity: multivariable analysis

	Adjusted OR (95% CI)*	P value
Sex		0.034
Male	1 (ref)	
Female	1.8 (1.0 to 3.3)	0.034
Age (years)		<0.001
6–14	1.8 (0.53 to 6.1)	0.344
15–19	9.1 (2.8 to 29.8)	<0.001
20–64	4.5 (2.0 to 10.1)	<0.001
≥65	1 (ref)	
Obesity†		0.024
No	1 (ref)	
Yes	2.0 (1.1 to 3.8)	0.024
Other medical conditions‡		0.004
No	1 (ref)	
Yes: one	1.1 (0.57 to 2.0)	0.863
Yes: several	3.2 (1.6 to 6.3)	0.001
Clinical COVID-19 cases in the household§		<0.001
No	1 (ref)	
1 person	2.5 (1.3 to 5.0)	0.007
>1 person	6.9 (3.1 to 15.2)	<0.001
Went out for work during the lockdown		0.048
No	1 (ref)	
Yes	0.18 (0.03 to 1.0)	0.048
Number of rooms by neighbourhood¶		0.007
Neighbourhood A		
1–2	2.8 (1.2 to 6.3)	0.016
3	2.2 (1.0 to 5.0)	0.064
≥4	1 (ref)	
Neighbourhood B		
1–2	1.5 (0.3 to 6.4)	0.594
3	0.23 (0.04 to 1.2)	0.075
≥4	1 (ref)	
Neighbourhood C		
1–2	0.58 (0.22 to 1.5)	0.262
3	2.3 (0.91 to 5.9)	0.078
≥4	1 (ref)	

*Adjusted OR with corresponding 95% CIs and p values from multivariable logistic regression. Analysis performed on 655 of 700 sampled individuals.
†For those aged 18 years or older: BMI ≥30 kg/m²; for those aged 6–17 years: BMI (body mass index) ≥IOTF (International Obesity Task Force) -30 cut-off points.
‡Other medical conditions including: asthma, other respiratory diseases, hypertension, heart disease, treated diabetes, treated cancer (excluding hormone therapy), HIV and immunodeficiency, chronic liver disease, chronic kidney disease, neuromuscular diseases.
§Clinical COVID-19 cases in the household: number of people, except the respondent, with clinical signs of COVID-19 (cough, fever), a positive RT-PCR test or who were consulted for suspected COVID-19 since 24 February 2020.
¶Model includes an interaction term: number of rooms×neighbourhood.
IOTF, International Obesity Task Force.

In the multivariable analysis (table 2), the association between seropositivity and the presence of clinical cases in the household remained strong after adjusting for other factors (one person: adjusted OR (aOR)=2.5, 95% CI 1.3 to 5.0; ≥2 persons: aOR=6.9, 95% CI 3.1 to 15.2). People aged 15–19 years (aOR 9.1, 95% CI 2.8 to 29.8) and 20–64 years (aOR=4.5, 95% CI 2.0 to 10.1) had higher odds of being seropositive than those aged 65 years or over. Females had increased odds of being seropositive than males (aOR=1.8, 95% CI 1.0 to 3.3). Seropositivity was significantly associated with obesity (aOR=2.0, 95% CI 1.1 to 3.8) and other medical conditions (aOR=3.2, 95% CI 1.6 to 6.3). There was a significant interaction between the neighbourhood and the number of rooms in the dwelling (p=0.004). People living in a one-room or two-room dwelling in neighbourhood A had higher odds of being seropositive than those living in a dwelling with four or more rooms (aOR=2.8, 95% CI 1.2 to 6.3). Working during lockdown remained associated with decreased odds of being seropositive (aOR=0.2, 95% CI 0.03 to 1.0).

DISCUSSION

Our findings from the SCoPe seroprevalence study in three socially deprived neighbourhoods with a large settled Roma community in Perpignan indicate that more than one in three (35.4%) people developed antibodies against SARS-CoV-2 during the first months of the COVID-19 epidemic. In comparison, estimates for the general population in May 2020 indicated an antibody prevalence of 1.9% in the Occitania region (where Perpignan is situated) and less than 5% in France and Spain (Perpignan is located very close to the Spanish border).[21 22]

Although the proportion of asymptomatic SARS-CoV-2 infections varies greatly from one study to another, the proportion we found (21.7%) was comparable with the results of two meta-analyses (20%, 95% CI 17% to 25%)[23] (17%, 95% CI 14% to 20%).[24] The specificity of ageusia/anosmia symptoms was found to be very high, although this could not be confirmed by a temporal analysis which was not possible in this cross-sectional study. Such a high specificity has already been observed in numerous other studies.[25] It would be useful for developing a strategy for early diagnosis of COVID-19 and self-isolation.

Lower seroprevalence was reported among study participants aged 65 years and over. This may partially be explained by a result from a qualitative study simultaneously conducted with SCoPe which found that this older population went outdoors less frequently and had fewer social contacts during the first wave of the epidemic thanks to the very protective stance adopted by the local community.[26] In addition, females were more likely to be seropositive in the multivariable analysis. The associations between seropositivity and age and between seropositivity and sex respectively differ between studies, although several have found a lower seroprevalence among older people, particularly in France.[21 26 27] The fact that few

seroprevalence studies have been conducted to date in a similar context (high level of infection, socially deprived neighbourhood) could explain these differences.

Our results showed that obese people had higher seroprevalence of SARS-CoV-2 antibodies independently from other factors. This is consistent with the findings of a meta-analysis of 20 published studies on the subject (OR=1.46, 95% CI 1.30 to 1.65).[28] Obesity has been associated with low socioeconomic status.[29] The association we found between obesity and seropositivity may be explained by potential confounders linked to unfavourable socioeconomic conditions. SCoPe did not comprehensively measure these conditions for reasons of study acceptability. Metabolic and immune dysfunction and inflammatory mechanisms may be implicated in the clinical aggravation of COVID-19 in obese people.[30–32] These mechanisms might also be involved in increasing the risk of infection, although this association is less well established. Prolonged viral shedding in obese people, something already seen for influenza,[33] may also occur for SARS-CoV-2 and could play a role in the spread of the virus in families where obesity is prevalent.

Our study also confirms findings elsewhere that the risk of transmission is greater when a clinical case is present in the same household.[21 22] Working outside the home during the first lockdown was associated with a lower risk of seropositivity. This result may reflect a higher socioeconomic status of people who worked. Other hypotheses (compliance with barriers measures, healthy worker effect, etc) could be formulated to explain this result, but cannot be further explored without additional data.

In our study, seroprevalence was higher for people living in crowded housing, and after adjusting for other factors, small dwelling size was a significant associated factor, but only in neighbourhood A. This result was also found in other French studies.[21 34] In addition, living conditions—not analysed in our study—may also explain the higher seroprevalence in this particular neighbourhood. Population density, a factor associated with higher seroprevalence elsewhere,[21 22] was higher in neighbourhood A than in both other neighbourhoods. The majority of accommodation in neighbourhood A comprises flats, and almost one-quarter of all dwellings are less than 40 m².[35] Insalubrity was also very present in neighbourhood A, which is one of the priority areas in an ongoing national urban renewal programme.[36] Accordingly, ventilation problems, lack of outdoor space and overcrowding may explain the higher risk of contamination. In general, the community-based lifestyle of the Roma population may also have increased the risk of contact with a clinical COVID-19 case.

Overall, we achieved a 56% participation rate in this difficult-to-reach population thanks to local mediators and contacts, whose collaboration was essential. Furthermore, despite the unavailability of sampling frames, the study was designed and implemented very quickly after the first wave ended, thanks to careful training and supervision of the interviewers throughout the field survey.

This speed of implementation was necessary given the uncertainties surrounding the duration of SARS-CoV-2 IgG antibodies after infection.

Our study has several limitations. First, it was conducted 4 months after the first wave ended, leading to possible recall bias in the reporting of symptoms. The assessment of behaviours during lockdown was very complex because of the fact that their evolution was not measured during the course of the first wave. It is important to underline that a qualitative study observed a shift in the three neighbourhoods' awareness of the dangers of COVID-19 following the first deaths, particularly that of a young woman.[26] The same study observed a substantial improvement in compliance with prevention measures during the lockdown. This is why the association between these behaviours and seropositivity (except for going out to work) was not studied in our analysis. Second, the systematic sampling method used to select households made it difficult to estimate the total number of individuals to approach. Third, although we consider the participation rate to be acceptable in this field study setting, it was suboptimal and with lower participation of children and men. However, we accounted for this bias by using post-stratification. We also had difficulties reaching some of the selected households, despite flyers being placed in letterboxes and several visits. Furthermore, selection bias may have occurred. More specifically, people with a history of COVID-19-type symptoms may have been more willing to participate in the study than people with no such history. It is also possible that people who had been tested positive before the study were less willing to participate. Incomplete data on reasons for non-response prevented us from further exploring this issue. Finally, a more in-depth analysis at the household level would be relevant in view of intrahousehold infections. However, our study design did not allow for this type of analysis.

The high estimated seroprevalence after the first wave of SARS-CoV-2 infection in the three socially deprived neighbourhoods in the present study confirms the very high vulnerability to COVID-19 of populations living in socially deprived conditions, and underlines the need for more sophisticated surveillance and specific disease prevention measures.[37] Additional observations using a sociological approach should provide an accurate assessment of the ability of this population to improve their level of health literacy and to assimilate protective measures. Although underlying mechanisms remain unclear, our results support previous findings that obese individuals are at higher risk of SARS-CoV-2 infection, and confirm the importance of conducting preventive interventions in this population. This is especially relevant as future vaccines might be less effective for these people.[30 33] All vaccination strategies should be designed to ensure that they are acceptable to this vulnerable population.[38]

The long-term protection of vulnerable populations such as that in the present study who are particularly exposed to health and environmental crises must be improved by strengthening specific prevention and health

promotion programmes and reducing social inequalities in health.[39] In this context, policies against substandard housing have a key role in improving living conditions. Finally, health strategies can only be successful by ensuring long-term partnerships with organisations and stakeholders capable of rapid mobilisation in the event of a crisis.

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