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Title: High 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

Background

In March 2020, many cases of COVID-19 were reported in three socially deprived neighbourhoods of the city of Perpignan, in the south of France, where large sedentary gypsy communities live. A study to measure seroprevalence was conducted in July 2020 to assess the level of contamination in these neighbourhoods after the first wave of the pandemic, and to identify factors associated with seropositivity.

Methods

SCoPe is a cross-sectional survey conducted in selected persons aged six years old and over living in three neighbourhoods in Perpignan. Households were selected by systematic sampling and participants by random sampling. Collected blood samples were tested for SARS-CoV-2 IgG and IgM antibodies using the Elecsys® immunoassay to target the coronavirus's spike protein. Antibody seroprevalence was estimated from weighted data and associated factors were investigated using multivariate logistic regression.

Results

The seroprevalence of anti-SARS-CoV-2 antibodies was 35.4% (95% CI: 30.2-41.0). Over a fifth of seropositive individuals (21.7% ([14.1-31.8]) did not report any COVID-19 symptom. People aged 15-64 years old were at greater risk of seropositivity than those aged 65 years or over. Obesity prevalence was 40.7% (35.8-45.8) and obese people were more likely to be seropositive (aOR=2.0 [1.1-3.8]). The risk of being seropositive was higher in households with clinical COVID-19 cases (One case: aOR=2.5 [1.3-5.0]). In the neighbourhood with the highest measured seroprevalence, people living in a dwelling with 1-2 rooms had a higher risk of being seropositive than those living in a 4-room house (aOR=2.8 [1.2-6.3]). Working during the lockdown was associated with a lower risk of seropositivity (aOR=0.2 [0.03-1.0]).

Conclusion

Transmission prevalence of the SARS-COV-2 virus 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 by taking into account all social determinants of health, especially housing conditions.

Strengths and limitations of this study

- This seroprevalence study provides an analysis of inequalities in the risk of SARS-CoV-2 infection in a socially deprived population living in three neighbourhoods in a city in France.
- Participants were recruited with the involvement of field investigators from the population of the three neighbourhoods. They also participated to the individual questionnaire design.
- Data collection of socioeconomic information was restricted to the neighbourhoods of residence and housing for reasons of study acceptability.
- Behaviours and compliance with barrier measures were not studied in our analysis due to a change in behaviour in the population during the lockdown.

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]. Many health issues are involved, including inequalities in exposure to the SARS-CoV-2 virus, in the severity of the COVID-19 disease, and in access to healthcare[1 2]. These concerns are all the more important given that these health inequalities are often cumulative[3], leading to a marked risk of increased social deprivation in vulnerable populations[2 4]. Furthermore, lockdowns implemented in many countries have exacerbated pre-existing health inequalities.

During the ongoing epidemic, special attention has been given to the some 10,000 residents living in three of the poorest neighbourhoods (Haut-Vernet, Nouveau Logis and Saint-Jacques) in all of France. Located in the city of Perpignan (120,000 inhabitants, Occitania region), the employment rate is very low in these neighbourhoods, with only 25 to 30% of 15-64 year olds having work[5]. Sedentary gypsy communities make up a large part of the neighbourhoods' population and share commonalities in lifestyle and culture, with the roles of family and religion being especially important. In Europe, gypsy communities have lower education levels and higher unemployment rates than the general public. They often have poorer living conditions and commonly face social exclusion[6]. Furthermore, their health literacy level is low. Their perception of health is that no illness exists if there are no visible signs[7]. Moreover, they have a poorer health status than that of the general population and face greater barriers to accessing healthcare[8-10].

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-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[11]. 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 two 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 contamination 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

SCoPe is a cross-sectional seroprevalence survey of a sample of 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 (INSEE), 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. Depending on the household size, from one to four participants were then randomly recruited from households which agreed to participate (see: Supplemental materials - Survey procedure and logistics). Recruitment was carried out by teams of field investigators comprising members of the gypsy 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 and mentally able to move to one of the study's five purpose-built survey centres, and able to answer the survey questionnaire.

Participants were referred to the neighbourhood's survey centre, where physicians used a standardized questionnaire in French - specifically designed for SCoPE - to collect information on the following: socio-demographic characteristics, medical conditions associated with the risk of severe COVID-19[12], occurrence of symptoms suggestive of COVID-19 and healthcare seeking behaviour since

24 February 2020, characteristics of both the household and the housing the participant lived in during the first lockdown, knowledge of COVID-19 prevention measures, and behaviours during the first lockdown (see: Supplemental materials - Questionnaire). BMI was calculated by measuring height and weight and was categorised according to standard cut-off points for obesity (BMI≥30kg/m^2)[12]. Other quantitative variables (age, number of rooms, number of clinical COVID-19 cases) were categorised from the results of the univariate analysis. A blood sample was collected by venepuncture for each participant: 3.5 ml for those aged 18 years old and over, and 600µl for those aged 6-17 years old.

The study protocol was approved by a French ethics committee (*Comité de Protection des Personnes Sud Est II*, Lyon, 2020-A01828-31). All participants were informed about the processing of personal data and of their rights. All gave their prior oral consent to participate. For those under 18 years of age, a parent or legal guardian provided consent.

Patient and public involvement in research

The local mediators and the social workers involved in the design and the conduct of our study. 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 have 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 the week following the samples

Laboratory analysis

The samples were sent to the laboratory at Perpignan hospital at room temperature (18-25°C) after a maximum storage time of 12 hours at maximum temperature of 5°C.

Serological tests were performed using Elecsys Anti-SARS-CoV-2[13], an immunoassay for *in vitro* qualitative detection of immunoglobulin M (IgM) and immunoglobulin G (IgG) antibodies against the SARS-CoV-2 spike (S) protein in serum. Its sensitivity is 99.5% (97-100) at ≥ 14 days after PCR confirmation. Overall specificity is 99.8% (99.69-99.88)[13].

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 from 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 (i.e., the proportion of seropositive individuals) was estimated with a 95% confidence interval (CI). It was compared between neighbourhoods and according to individual characteristics using the adjusted Wald F test. The association between seropositivity and reported symptoms was investigated in univariate analysis. Factors associated with seropositivity were then analysed using a multivariate logistic regression which took into account the sampling design. Behaviours during the lockdown were excluded from this analysis, except for leaving home to go to work. A forward selection procedure was applied with age, sex and neighbourhood being forced into the model. Variables with a p-value <0.1 were retained in the multivariate model and interactions were tested. A p-value <0.05 was considered statistically significant. Data were analysed using Stata V14.2 software (StataCorp, College Station, TX, USA).

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 (i.e., study population): 312 from neighbourhood A (48.4%), 173 from neighbourhood B (70.0%) and 215 from neighbourhood C (60.4%).

Study population

After weighting, females 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: 35.8-45.8): 43.5% (38.9-48.3) in adults (BMI≥30kg/m^2) and 34.0% (22.2-48.2) in those aged 6-17 years old (BMI≥IOTF-30). Fifteen percent (13.0-17.3) of the study population reported having hypertension, 7.0% (5.5-8.8) heart disease, 9.4% (7.7-11.4) were being treated for diabetes, 5.5% (4.0-7.7) had asthma, while 4.9% (3.7-6.6) had (an)other chronic respiratory disease(s).

The majority of those in neighbourhood A were living in an apartment (71.5% [64.6-77.6]), while the majority of people in neighbourhoods B and C were living in a house (73.9% [62.8-82.6] and 83.9% [79.0-87.8], respectively). The number of people per room (except the living room) in each home was

greater than one for 75.3% (69.9-80.1) of people living in neighbourhood A, for 55.5% (46.9-63.7) in neighbourhood B and for 80.5% (75.8-84.6) in neighbourhood C.

Seroprevalence

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

Symptoms during the study period

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

There was a significant positive association between seropositivity and symptoms (Odds Ratio (OR)=8.1 [4.5-14.6], p<0.001). Ageusia/anosmia were the symptoms most strongly associated with seropositivity (OR=14.8 [7.9-27.7], p<0.001), with positive and negative predictive values of 81.3% [71.5-88.3] and 77.3% [71.4-82.4], respectively. All other symptoms were also significantly associated with seropositivity, except for rhinorrhea (Figure 3).

Healthcare seeking behaviours during the study period

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

Among seropositive participants, 7.9% (4.6-13.2) 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 univariate analysis (Table 1), people aged 65 years or over were less likely to be seropositive (p<0.001). No significant difference was observed between males and females regarding the likelihood of being seropositive. Obese people were more likely to be seropositive (OR=2.0 IC95%=[1.3-3.2], p=0.002). The presence of one (OR=3.0 [1.8-5.2], p<0.001) or more (OR=7.8 [4.0-15.2], p<0.001) clinical COVID-19 cases in the household was associated with a greater risk of seropositivity. People living in a

dwelling with three or fewer rooms (1-2 rooms: OR=2.1 [1.2-3.8], p=0.011; 3 rooms: OR=2.2 [1.3-3.9], p=0.005) were more likely to be 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 were less likely to be seropositive (OR=0.1 [0.02-0.5], p=0.006). Furthermore, people who reported leaving their home once a week or less for walks during the lockdown were less likely to be seropositive than people who went out every day or almost every day (OR=0.2 [0.1-0.7], p=0.012).

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

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

[1] Seroprevalence estimated from weighted data

[2] For those aged 18 years or older: BMI≥30kg/m^2; for those aged 6-17 years: BMI≥IOTF-30

[3] 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

[4] 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]).

In the multivariate 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 odds ratio (aOR)=2.5 [1.3-5.0], p=0.007; ≥ 2 persons: aOR=6.9 [3.1-15.2], p<0.001). People aged 15-19 years (aOR 9.1 [2.8-29.8], p<0.001) and 20-64 years (aOR=4.5 (2.0-10.1), p<0.001) had a higher risk of being seropositive than those aged 65 years or over. Females were more likely to be seropositive than males (aOR=1.8 [1.0-3.3], p=0.034). Seropositivity was significantly associated with obesity (aOR=2.0 [1.1-3.8], p=0.02) and other medical conditions (aOR=3.2 [1.6-6.3], p=0.001). There was a significant interaction between the neighbourhood and the number of rooms in the dwelling (p=0.004). People living in a one- or two-room dwelling in neighbourhood A were more likely to be seropositive than those living in a dwelling with four or more rooms (aOR=2.8 [1.2-6.3]). Working during lockdown remained independently associated with decreased seropositivity (aOR=0.2 [0.03-1.0], p=0.05).

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

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

Analysis performed on 655/700 sampled individuals.

[1] Model includes an interaction term: number of rooms*neighbourhood

DISCUSSION

Our findings from the SCoPe seroprevalence study in three socially deprived neighbourhoods with a large sedentary gypsy 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)[14 15].

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% [17-25])[16] (17% [14-20])[17]. The strong specificity of ageusia/anosmia symptoms has already been observed in other studies[18]. This specificity could be explored in greater depth in the context of 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 (Guillaume Sudérie, personal communication, 2020). In addition, females were more likely to be seropositive in the multivariate analysis. The associations between seropositivity and age and between seropositivity and sex differ between studies, although several have found a lower seroprevalence among older people, particularly in France[14 19]. 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 [1.30-1.65])[20]. Obesity has been associated with low socioeconomic status[21]. 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[22 23]. 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[24], 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[14 15]. 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. It might also be explained by a reduction in close indoor contacts with other household members, something highlighted in a seroprevalence study among socially deprived populations living in overcrowded residences in the Paris region[25].

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[14 25]. 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[14 15], 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 40m² [26]. Insalubrity was also very present in neighbourhood A, which is one of the priority areas in an ongoing national urban renewal programme [27]. Accordingly, ventilation problems, lack of outdoor space and overcrowding may explain the higher risk of contamination. In general, the community-based lifestyle of the gypsy 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 (Guillaume Sudérie, personal communication, 2020). 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, we also had difficulties reaching some of the selected households, despite flyers being placed in letterboxes and several visits. Finally, 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.

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[29]. 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[22 24]. All future vaccination strategies should be designed to ensure that they are acceptable to this vulnerable population[30].

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[31]. 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.

CONTRIBUTORS

AB: responsible for data analysis, data interpretation, manuscript writing and submission and participated in study design, protocol writing, data collection (coordination) and training of field investigators ; CD: responsible for study design, online questionnaire and participated in protocol writing, data collection (coordination), data analysis, data manuscript writing ; ML: responsible for protocol writing and participated in study design, data collection (coordination), training of field investigators, data interpretation and manuscript writing ; VS: participated in data collection (coordination), training of field investigators, data interpretation and manuscript writing ; HN and YLS: participated in data analysis and manuscript revision ; DD: participated in data collection (coordination) and manuscript revision ; LC and MM: participated in data collection (serology) and manuscript revision ; PG: responsible for serological analysis ; DM: responsible for organising data collection and ethics committee approval and participated in study design, protocol writing, data collection, data interpretation, manuscript writing and submission ; HA: initiated the study, responsible for organising data collection and participated in ethics committee approval, data interpretation and manuscript writing.

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COMPETING INTERESTS

None declared

DATA AVAILABILITY

Data may be obtained from a third party and are not publicly available: Anonymised data are available for researchers from the corresponding author, Damien Mouly, on reasonable request.

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FIGURES

Figure 1 - Map of the city of Perpignan and the three neighbourhoods studied

Figure 2 – Flow chart of participants

Figure 3 - Association between seropositivity and reporting symptoms

* Analysis performed on all sampled individuals (n=700) using simple logistic regressions.

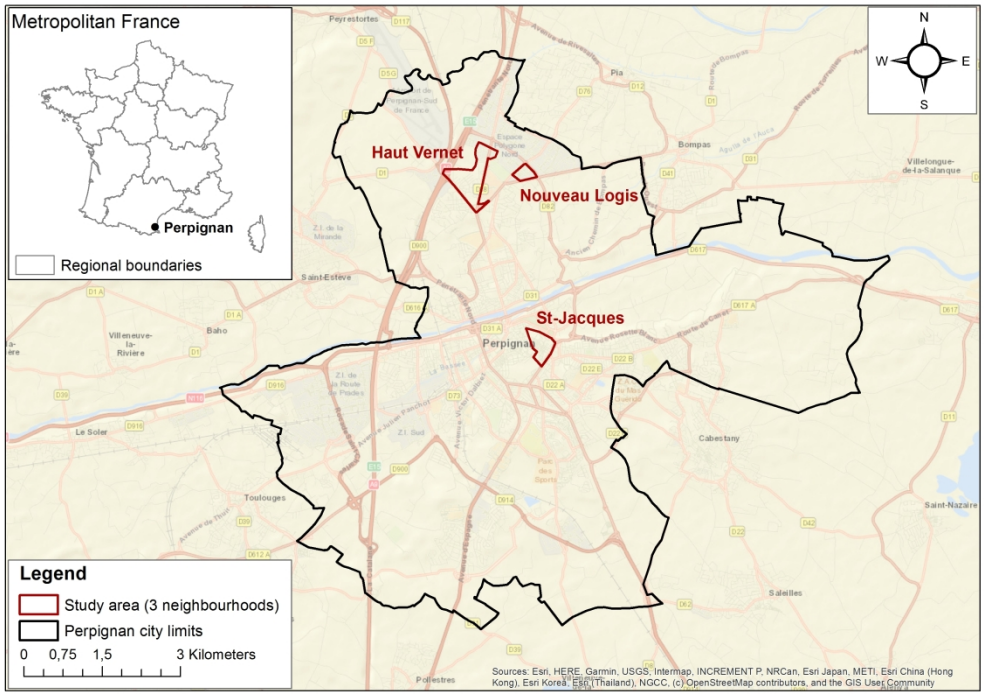

Figure 1 - Map of the city of Perpignan and the three neighbourhoods studied

297x209mm (300 x 300 DPI)

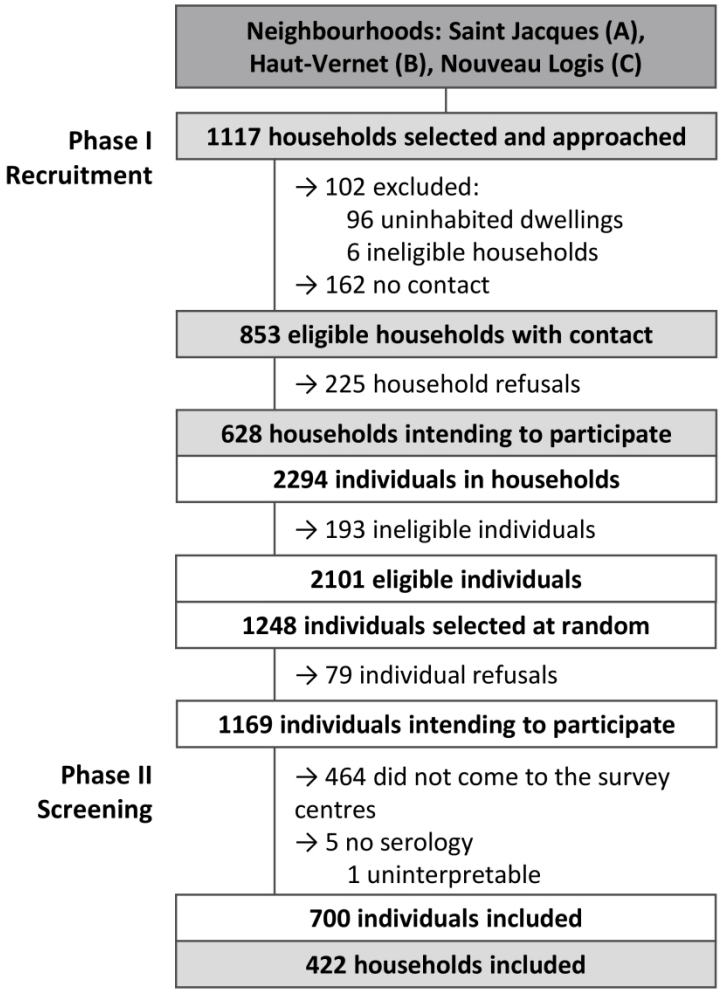

Figure 2 – Flow chart of participants

209x297mm (300 x 300 DPI)

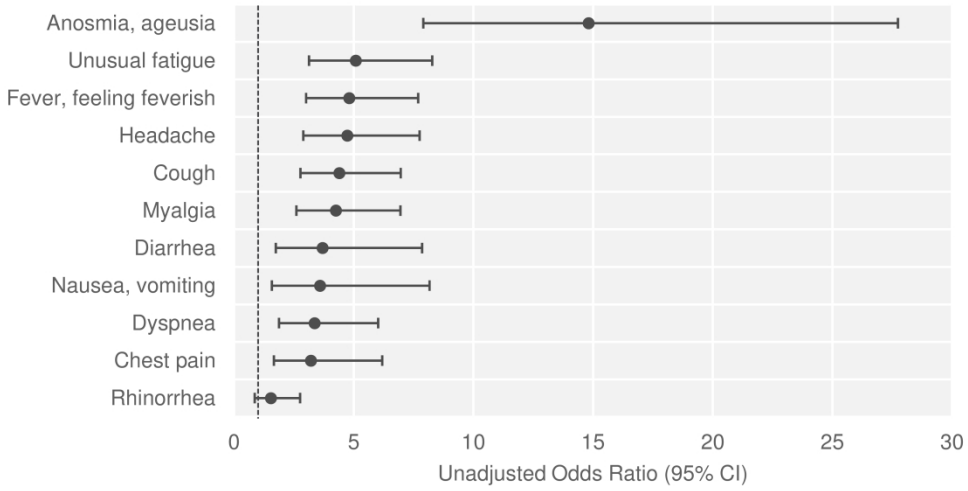

Figure 3 - Association between seropositivity and reporting symptoms
* Analysis performed on all sampled individuals (n=700) using simple logistic regressions.

SUPPLEMENTAL MATERIALS

Survey procedure and logistics

All the interviewers were initially trained in the study method and the use of the survey tools (online questionnaire, household forms, logbooks). They were supervised throughout the survey. In total, the study mobilised almost 80 people.

Local mediators and social workers implemented the selection phase (households and inhabitants) and provided potential participants with information about the survey. For this purpose, they had a map of each neighbourhood describing the starting point and a specific route to be followed. These starting points were defined randomly from a grid of neighbourhood maps as follows: randomly drawing a grid cell and, after assigning a number to each building, randomly choosing one building on that grid cell to be the starting point. The starting direction was also randomly chosen. In neighbourhood A, every 2 out of 5 households were selected, while in neighbourhood B, every 2 out of 3 were selected. In neighbourhood C, all households were selected. These sampling intervals were determined according to the size of the targeted sample, the estimated non-response rate, the number of dwellings in the neighbourhood, and the average number of people per household in the population census. The sampling intervals were then adjusted to take into account field observations during the first days of the survey. The a priori targeted sample size was 1,000 participants, equally distributed among the three neighbourhoods, for an expected prevalence of 10%, a margin of error of 2.5 percentage points and a design effect of 2.

In each selected household, between one and four participants were randomly selected in proportion to the size of the household. The selected inhabitants received information notes and a ticket indicating their name and surname and the fact that they had been selected for participation. They were then invited to visit one of the five centres specifically set up for the survey (2 each in neighbourhoods A and B, 1 in neighbourhood C), and to bring their ticket with them to facilitate their identification and inclusion. All the initially selected households and their inhabitants were monitored using logbooks and forms to record household data. To increase the participation rate, three visits were made at different days and times. When no one was at home, a letter with a phone number was put in the letterbox. People who agreed to participate but who did not visit a survey centre were called back by phone.

In the survey centres, doctors and nurses from the infectious and tropical diseases unit (SMIT) of Perpignan hospital checked the identity of participants, administered a face-to-face questionnaire and took blood samples. Answers to the questionnaire items were entered in real-time online on a secure

Voozanoo™ platform. Children under 18 years had to be accompanied by a parent or legal representative, and participants who did not speak French very well could - if they wished - be accompanied by a family member or friend who did. The weight and height of the participants were measured at the time of the questionnaire. A doctor gave individual results to those tested in July/August 2020.

Questionnaire

French version / *English translation*

Date d'enquête :/ *Survey date:* …./…./2020
Centre de prélèvement : ☐ St Jacques
Test centre ☐ Haut-Vernet
☐ Nouveau logis

Acceptez-vous de participer à cette étude c'est-à-dire de répondre à ce questionnaire et de réaliser un prélèvement de sang ? / *Do you agree to participate in this study, that is to say, to answer this questionnaire and to have a blood sample taken?*

☐ oui / *yes* ☐ non / *no*

Si non, le participant refuse → stopper l'entretien
If no, the participant refuses → end the interview

Age :/ *Age:* …..

Sexe :/ *Sex:* ☐ Homme/Garçon / *Male* ☐ Femme/Fille / *Female*

Poids (en kg) :/ *Weight:* ……

Taille (en cm) :/ *Height:* …….

Antécédents médicaux :/ *Medical history:*

☐ Aucun	☐ *None*
☐ grossesse en cours	☐ *Current pregnancy*
☐ Asthme /	☐ *Asthma*
☐ Autres maladies respiratoires (bronchite chronique…)	☐ *Other respiratory diseases*
☐ Hypertension	☐ *Hypertension*
☐ maladie cardiaque (angine de poitrine, infarctus)	☐ *Heart disease*
☐ diabète traité	☐ *Treated diabetes*
☐ Cancer en cours de traitement (sauf hormonothérapie)	☐ *Being treated for cancer (excluding hormone therapy)*
☐ VIH et autres troubles de l'immunité	☐ *HIV and other immune disorders*
☐ maladies chroniques du foie	☐ *Chronic liver disease*
☐ maladies rénales chroniques	☐ *Chronic kidney disease*
☐ autre ALD, précisez : ……	☐ *Other chronic disease: ……*

Depuis le 24 février (à la fin des vacances scolaires d'hiver/semaine du Mardi Gras), avez-vous eu des symptômes que vous n'avez pas habituellement et qui ont duré au moins 3 jours ? / *Since the 24th February (at the end of the winter school holidays/Mardi Gras week), have you had any symptoms that you don't usually have and that lasted at least 3 days?*

☐ oui / *yes* ☐ non / *no*

Si oui / *If yes:*

Quels symptôme(s) avez-vous eu ? / *What symptom(s) have you had?*

☐ Fièvre ou sensation de fièvre	☐ *Fever or feeling feverish*
☐ Mal à tête	☐ *Headache*

- ☐ Fatigue inhabituelle / ☐ *Unusual fatigue*
- ☐ Courbatures / douleurs musculaires / ☐ *Body aches, muscle pain*
- ☐ Toux / ☐ *Cough*
- ☐ Difficultés respiratoires, essoufflement inhabituel / ☐ *Difficulty breathing, unusual shortness of breath*
- ☐ Nez qui coule / ☐ *Runny nose*
- ☐ Troubles du goût/de l'odorat / ☐ *Taste/smell disorders*
- ☐ Nausées/vomissements / ☐ *Nausea, vomiting*
- ☐ Diarrhée / ☐ *Diarrhoea*
- ☐ Douleurs thoraciques, oppression / ☐ *Chest pain, oppression*
- ☐ Si ≥80 ans : Confusion, chutes répétées / ☐ *If ≥80 years: Confusion, repeated falls*

Quand ont commencé ces symptômes ? *(si plusieurs périodes : prendre les symptômes les plus proches du Covid-19 ou si impossible de différencier prendre la 1ère période)* / *When did these symptoms start? (if more than one period: record the time when the symptoms which most closely resemble those of Covid-19 started, or if it is impossible to differentiate between periods, take the first period)*

- ☐ avant confinement (17/03) / *Before the lockdown (17/03)*
- ☐ Pendant confinement (17/03) et avant 1 mai / *During the lockdown (17/03) and before the 1st of May*
- ☐ après le 1er mai / *After the 1st of May*

> *Si après le 1er mai :* Avez-vous eu des signes au cours des 15 derniers jours ? / *If after the 1st of May: have you had any symptoms in the last fortnight?*
> ☐ oui / *yes* ☐ non / *no*

Ces symptômes vous ont-ils fait penser que vous aviez peut-être le coronavirus ? / *Did these symptoms lead you think that you might have COVID-19?*

☐ Non / *No* ☐ oui peut-être / *Yes, maybe* ☐ oui sûrement / *Yes, definitely*

Avez-vous consulté un professionnel de santé pour ces symptômes ? / *Did you consult a health professional for these symptoms?*

☐ oui / *yes* ☐ non / *no*

> *Si oui* : qui avez-vous consulté ? / *If yes: Who did you consult?*
> ☐ Médecin traitant / *General practitioner*
> ☐ Centre covid / *Covid centre*
> ☐ Hôpital, urgence (sans hospitalisation) / *Hospital, emergency department (without hospitalisation)*
> ☐ Autre, précisez : / *other, specify:* ……

Avez-vous été hospitalisé en raison de ces symptômes ?/ *Were you hospitalized because of these symptoms?*

☐ oui / *yes* ☐ non / *no*

> *Si oui* : combien de temps avez-vous été hospitalisé (en nombre de jours) ? / *If yes: how long were you hospitalised (number of days)?* : ….
> Avez-vous été hospitalisé en service de réanimation ? / *Were you hospitalised in an intensive care unit?*
> ☐ oui / *yes* ☐ non / *no*

Avez-vous eu … ? / *Did you have a … ?*

- ☐ Test PCR (coton-tige) / *PCR test (swab/cotton bud)*
  - Si oui / *If yes* : ☐positif / *positive* ☐négatif / *negative* ☐Ne sait pas / *Don't know*
- ☐ Sérologie (prise de sang) / *Serology test (blood sample)*
  - Si oui / *If yes* : ☐positif / *positive* ☐négatif / *negative* ☐Ne sait pas / *Don't know*
- ☐ Scanner thoracique / *Chest CT scan*
  - Si oui :/ *If yes:* ☐évocateur du Covid-19 / *suggestive* ☐non évocateur / *not suggestive*
  - ☐ Ne sait pas / *Don't know*

A votre connaissance depuis le 24 février, avez-vous été en contact avec une ou plusieurs personnes malades (toux ou fièvre ou test positif ou consultation pour une suspicion de coronavirus) à l'extérieur de votre logement ? / *To your knowledge, since the 24th February, have you been in contact with one or more sick people (cough or fever or positive test or consultation because of suspected COVID-19) outside your home?*

☐ oui / *yes* ☐ non / *no* ☐ Ne sait pas / *Don't know*

Logement :/ *Housing:*

En ce moment, combien de personnes habitent dans le logement où vous vivez actuellement (y compris vous-même) ? / *How many people live in your current home (including you)?* …….

Nous allons maintenant parlé du logement principal dans lequel vous viviez pendant les 2 mois du confinement. (si plusieurs endroits, prendre la plus longue durée)
We are now going to talk about the main accommodation where you lived during the two months of lockdown (if more than one place, take the place where respondent lived longest)

Est-ce le logement dans lequel vous habitez actuellement ? *Is that your current home?*

☐ oui / *yes* ☐ non / *no*

Si le participant répond non : Vous avez passé la majorité de votre confinement dans un logement différent de votre logement actuel. Ce logement était-il dans le quartier :
If the respondent replies 'no': You spent the majority of the lockdown in a home other than your current home. In which neighbourhood was that accommodation located?

- ☐ St Jacques
- ☐ Nouveau logis
- ☐ Haut-Vernet
- ☐ Aucun de ces trois quartiers / *None of these three neighbourhoods*

Ce logement était :/ *This accommodation is/was:*

- ☐ Un appartement / *An apartment*
- ☐ Une maison / *A house*
- ☐ Autre, précisez : …. / *Other, specify:…..*

Combien de pièces comportaient ce logement (hors salle de bain, toilettes, cuisine) ? / *How many rooms are/were in the accommodation (excluding bathroom, toilet and kitchen)?* : ….

Avait-il un espace extérieur privé (jardin, terrasse, balcon) ? / *Is/Was there a private outdoor space (garden, patio, balcony)?*

☐ oui / *yes* ☐ non / *no*

Pendant le confinement, combien de personnes habitaient dans ce logement (y compris vous-même) ? / *During the lockdown, how many people lived in the household (including you)?* …….

Dont combien d'enfants de moins de 12 ans :/ *Including children under 12 years:* …
Dont combien d'enfants de 12 à 17 ans :/ *Including children aged 12-17 years:* …
Dont combien d'adultes de 18 ans et plus :/ *Including adults aged 18 years and over:* …

Depuis le 24 février, combien de personnes vivant dans ce logement (autre que vous) ont été malades (toux ou fièvre ou test positif ou consultation pour une suspicion de coronavirus) ? / From *the 24th of February to the end of lockdown, how many people living in this household (excluding you) have been ill (cough, fever, positive test or consultation for suspected COVID-19)?* : …

Information et comportements face au Covid-19 / *Information and behaviour in the face of Covid-19*

Etes-vous sorti pendant le confinement pour le travail ? / *During the lockdown, did you go out for work?*
☐ jamais / *never* ☐ moins d'1 fois/semaine / *less than once a week*
☐ 1fois/semaine / *once a week* ☐ tous les jours ou presque / *every day or almost every day*

Etes-vous sorti pendant le confinement pour les courses ? / *During the lockdown, did you go out to do the grocery shopping?*
☐ jamais / *never* ☐ moins d'1 fois/semaine / *less than once a week*
☐ 1fois/semaine / *once a week* ☐ tous les jours ou presque / *every day or almost every day*

Etes-vous sorti pendant le confinement pour visiter la famille/des proches ? / *During the lockdown, did you go out to visit family/friends?*
☐ jamais / *never* ☐ moins d'1 fois/semaine / *less than once a week*
☐ 1fois/semaine / *once a week* ☐ tous les jours ou presque / *every day or almost every day*

Etes-vous sorti pendant le confinement pour faire du sport/se promener ? / *During the lockdown, did you go out to play sports/for a walk?*
☐ jamais / *never* ☐ moins d'1 fois/semaine / *less than once a week*
☐ 1fois/semaine / *once a week* ☐ tous les jours ou presque / *every day or almost every day*

Etes-vous sorti pendant le confinement pour une cérémonie ? / *During the lockdown, did you go out for a ceremony?*
☐ jamais / *never* ☐ 1 fois / *once* ☐ plusieurs fois / *several times*

Etes-vous sorti pendant le confinement pour une autre raison ? / *During the lockdown, did you go out for another reason?* : ☐ oui, précisez :/ *yes, specify:* ……..
☐ jamais / *never* ☐ moins d'1 fois/semaine / *less than once a week*
☐ 1fois/semaine / *once a week* ☐ tous les jours ou presque / *every day or almost every day*

Est-ce que des personnes qui n'habitaient pas dans votre logement sont venues chez vous pendant le confinement ? (Par exemple pour amener à manger ou pour des soins)
Did people, other than people who live in the same housing as you, come to your home during the lockdown? (For example, to bring food or provide care or assistance)
☐ jamais / *never* ☐ moins d'1 fois/semaine / *less than once a week*
☐ 1fois/semaine / *once a week* ☐ tous les jours ou presque / *every day or almost every day*

Sur une échelle de 0 à 10, avez-vous eu des informations sur ce qu'il fallait faire pour se protéger et protéger les autres : lavage des mains, confinement, respect des distances avec d'autres personnes, port du masque ? (0=aucune information → 10 = informations complètes)
On a scale from 0 to 10, how much information did you have on what to do to protect yourself and others: hand washing, self-isolation, social distancing, wearing a mask? (0 = no information → 10 = a great deal of information)

0 |_____| 10

Avez-vous pu rester à plus d'un mètre des personnes que vous avez rencontrées à l'extérieure de votre logement pendant le confinement (par exemple : pour discuter ou dans des files d'attente) ? / *Were you able to stay more than one metre away from people you met outside your home during the lockdown ?*

☐ toujours / *always* ☐ souvent / *often* ☐ rarement / *rarely* ☐ jamais / *never*

Vous êtes-vous lavé plus souvent les mains pendant le confinement ? / *Did you wash your hands more often during the lockdown?*

☐ non, pas plus souvent / *no, not more often*
☐ un peu plus souvent / *a little more often*
☐ beaucoup plus souvent / *much more often*
☐ Ne sait pas / *Don't know*

Sur une échelle de 0 à 10, pensez-vous vous être protégé du virus ? (0=pas du tout → 10 = complètement)
N.B. : si demande de précision : par exemple par votre respect des gestes barrières ou par le confinement
On a scale from 0 to 10, do you think you protected yourself against the virus? (0 = not at all → 10 = completely)
N.B.: if the respondent requests clarification: for example, thanks to you respecting the preventive measures or self-isolating

0 |_____| 10

Si une épidémie de même nature survenait, quelle serait selon vous la mesure la plus efficace à mettre en place pour vous protéger vous et vos proches ? *In your opinion, if an epidemic of the same nature occurred in the future, what would be the most effective measure to take?*
……
……

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6*
Bias	9	Describe any efforts to address potential sources of bias	6 + 14 (discussion)
Study size	10	Explain how the study size was arrived at	Supplemental materials
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	6-7
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	15 (discussion)
		(c) Consider use of a flow diagram	Figure 2
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7-8

		(b) Indicate number of participants with missing data for each variable of interest	7 and figure 2
Outcome data	15*	Report numbers of outcome events or summary measures	8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-12 (table 1 and table 2)
		(*b*) Report category boundaries when continuous variables were categorized	Table 1
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	13-14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14-15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-14 15
Generalisability	21	Discuss the generalisability (external validity) of the study results	14-15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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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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Title: 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 Odds Ratio (aOR)=2.0, 95% CI 1.1 to 3.8). The odds of being seropositive was 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 1-2 rooms had higher odds of being seropositive than those living in a 4-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 the SARS-COV-2 virus 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 underrepresented 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 the SARS-CoV-2 virus, 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 the 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 to 30% of 15-64 year olds 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. 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-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 two 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 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 (INSEE), 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 2-3 eligible persons, two if 3-4 persons, three if 5-6 persons and four if 7 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 standardized questionnaire in French - specifically designed for SCoPe - to collect information on the following: socio-demographic 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 participant 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 was calculated by measuring height and weight and was categorised according to standard cut-off points for obesity (BMI≥30kg/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 600µl for those aged 6-17 years old.

The study protocol was approved by a French ethics committee (*Comité de Protection des Personnes Sud Est II*, Lyon, 2020-A01828-31). All participants were informed about the processing of personal data and of their rights. All gave their prior oral consent to participate. For those under 18 years of age, a parent or legal guardian provided consent.

Laboratory analysis

Samples were stored locally for a maximum of 12 hours at less than 5 degrees 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 immunoglobulin M (IgM) and immunoglobulin G (IgG) antibodies against the SARS-CoV-2 spike (S) 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 from 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 (i.e., the proportion of seropositive individuals) was estimated with a

95% confidence interval (95% CI). Association of seroprevalence with the neighbourhood, other individual characteristics and reported symptoms was preliminary tested by univariable analysis with Rao-Scott χ2 test. Factors associated with seropositivity were then analysed using a multivariable logistic regression taking into account the sampling design. We reported odds ratios (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 <0.1 were retained. Interactions were tested. A p-value <0.05 was considered statistically significant. Data were analysed using Stata V14.2 software (StataCorp, College Station, TX, USA).

Patient and public involvement in research

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 (i.e., 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, females 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≥30kg/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 percent (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 as described in online supplementary table S1.

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 (Odds Ratio (OR)=8.1, 95% CI 4.5 to 14.6, 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 rhinorrhea (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 a RT-PCR test (positive PCR=29.0%). Specifically, 41.8% of seropositive participants had had a positive RT-PCR test 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 were associated with 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 y increased odds of being seropositive. People living in a dwelling with three or fewer rooms (1-2 rooms: OR=2.1, 95% CI 1.2 to 3.8 ; 3 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)[1]	Unadjusted odds ratio (OR, 95% CI)[2]	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[3]				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[4]				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[5]				<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)[6]				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)	

[1] Seroprevalence estimated from weighted data

[2] Unadjusted odds ratio with corresponding 95% confidence intervals and p-values from univariable logistic regressions

[3] For those aged 18 years or older: BMI≥30kg/m^2; for those aged 6-17 years: BMI≥IOTF-30 cut-off points

[4] 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

[5] 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

[6] 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]).

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 odds ratio (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- 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).

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

	Adjusted Odds Ratio (aOR, 95% CI)[1]	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[2]		0.024
No	1 (ref)	
Yes	2.0 (1.1 to 3.8)	0.024
Other medical conditions[3]		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[4]		<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[5]		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)	

[1] Adjusted odds ratio with corresponding 95% confidence intervals and p-values from multivariable logistic regression. Analysis performed on 655/700 sampled individuals.

[2] For those aged 18 years or older: BMI≥30kg/m^2; for those aged 6-17 years: BMI≥IOTF-30 cut-off points

[3] 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

[4] 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

[5] Model includes an interaction term: number of rooms*neighbourhood

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 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 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…) 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 40m² [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 by 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 intra-household 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 future 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.

CONTRIBUTORS

AB: responsible for data analysis, data interpretation, manuscript writing and submission and participated in study design, protocol writing, data collection (coordination) and training of field investigators ; CD: responsible for study design, online questionnaire and participated in protocol writing, data collection (coordination), data analysis, data manuscript writing ; ML: responsible for protocol writing and participated in study design, data collection (coordination), training of field investigators, data interpretation and manuscript writing ; VS: participated in data collection (coordination), training of field investigators, data interpretation and manuscript writing ; HN and YLS: participated in data analysis and manuscript revision ; DD: participated in data collection (coordination) and manuscript revision ; LC and MM: participated in data collection (serology) and manuscript revision ; PG: responsible for serological analysis ; DM: responsible for organising data collection and ethics committee approval and participated in study design, protocol writing, data collection, data interpretation, manuscript writing and submission ; HA: initiated the study, responsible for organising data collection and participated in ethics committee approval, data interpretation and manuscript writing.

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COMPETING INTERESTS

None declared

DATA AVAILABILITY

Anonymised data are available for researchers from the corresponding author, Damien Mouly, on reasonable request.

ETHICS STATEMENT

The study protocol was approved by a French ethics committee, Comité de Protection des Personnes Sud Est II, Lyon (reference number: 2020-A01828-31).

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FIGURES

Figure 1 - Map of the city of Perpignan and the three neighbourhoods studied

Figure 2 – Flow chart of participants

Figure 3 - Association between seropositivity and reporting symptoms
* Analysis performed on all sampled individuals (n=700) using simple logistic regressions.

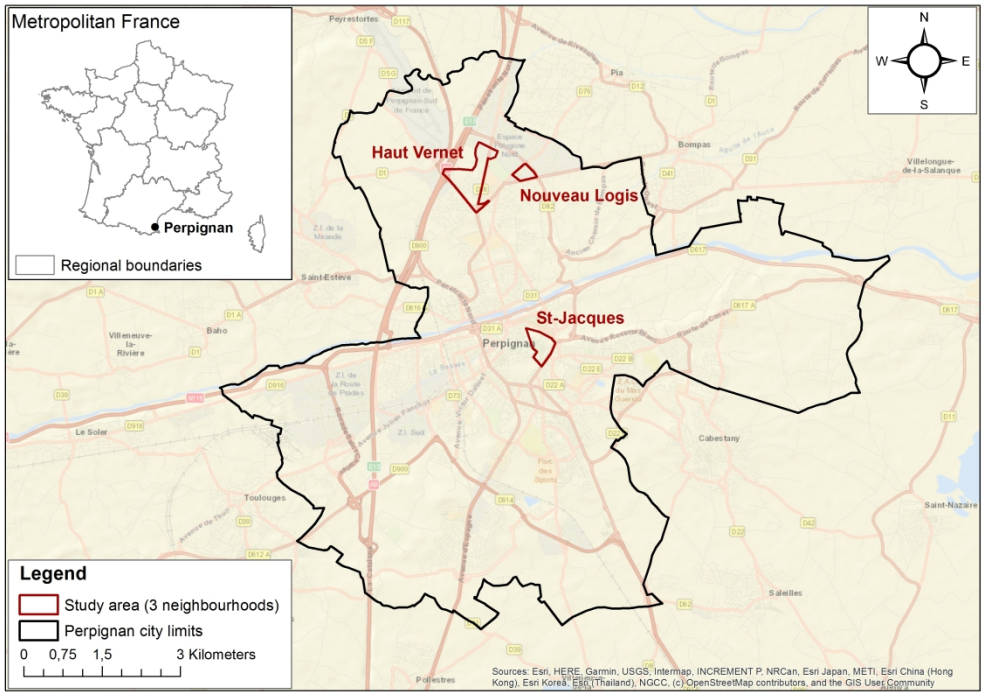

Figure 1 - Map of the city of Perpignan and the three neighbourhoods studied

297x209mm (300 x 300 DPI)

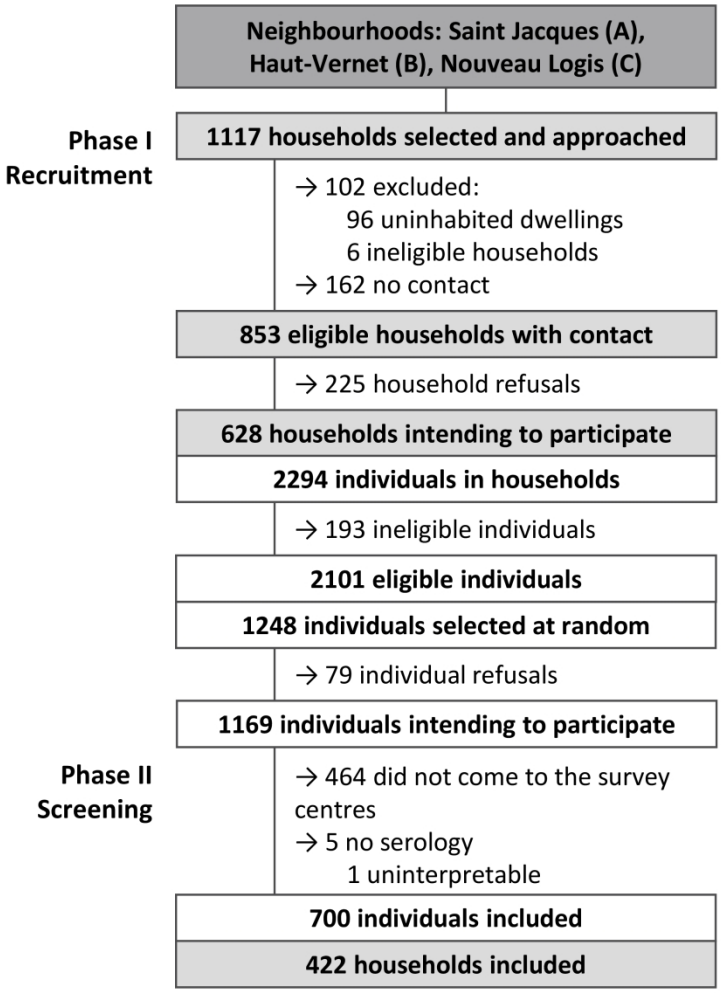

Figure 2 – Flow chart of participants

209x297mm (300 x 300 DPI)

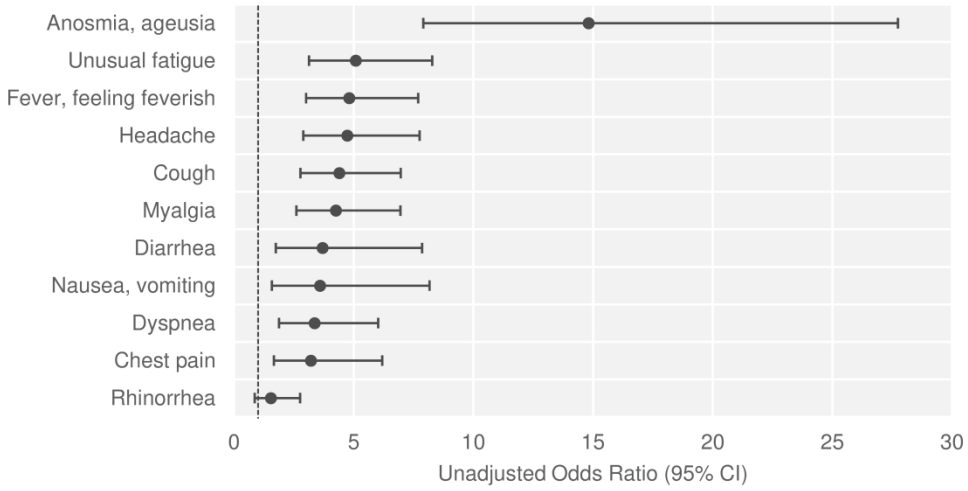

Figure 3 - Association between seropositivity and reporting symptoms
* Analysis performed on all sampled individuals (n=700) using simple logistic regressions.

SUPPLEMENTAL MATERIALS

Survey procedure and logistics

All the interviewers were initially trained in the study method and the use of the survey tools (online questionnaire, household forms, logbooks). They were supervised throughout the survey. In total, the study mobilised almost 80 people.

Local mediators and social workers implemented the selection phase (households and inhabitants) and provided potential participants with information about the survey. For this purpose, they had a map of each neighbourhood describing the starting point and a specific route to be followed. These starting points were defined randomly from a grid of neighbourhood maps as follows: randomly drawing a grid cell and, after assigning a number to each building, randomly choosing one building on that grid cell to be the starting point. The starting direction was also randomly chosen. In neighbourhood A, every 2 out of 5 households were selected, while in neighbourhood B, every 2 out of 3 were selected. In neighbourhood C, all households were selected. These sampling intervals were determined according to the size of the targeted sample, the estimated non-response rate, the number of dwellings in the neighbourhood, and the average number of people per household in the population census. The sampling intervals were then adjusted to take into account field observations during the first days of the survey. The a priori targeted sample size was 1,000 participants, equally distributed among the three neighbourhoods, for an expected prevalence of 10%, a margin of error of 2.5 percentage points and a design effect of 2.

In each selected household, between one and four participants were randomly selected in proportion to the size of the household. The selected inhabitants received information notes and a ticket indicating their name and surname and the fact that they had been selected for participation. They were then invited to visit one of the five centres specifically set up for the survey (2 each in neighbourhoods A and B, 1 in neighbourhood C), and to bring their ticket with them to facilitate their identification and inclusion. All the initially selected households and their inhabitants were monitored using logbooks and forms to record household data. To increase the participation rate, three visits were made at different days and times. When no one was at home, a letter with a phone number was put in the letterbox. People who agreed to participate but who did not visit a survey centre were called back by phone.

In the survey centres, doctors and nurses from the infectious and tropical diseases unit (SMIT) of Perpignan hospital checked the identity of participants, administered a face-to-face questionnaire and took blood samples. Answers to the questionnaire items were entered in real-time online on a secure

Voozanoo™ platform. Children under 18 years had to be accompanied by a parent or legal representative, and participants who did not speak French very well could - if they wished - be accompanied by a family member or friend who did. The weight and height of the participants were measured at the time of the questionnaire. A doctor gave individual results to those tested in July/August 2020.

Questionnaire

French version / *English translation*

Date d'enquête :/ *Survey date:* …./…./2020
Centre de prélèvement : ☐ St Jacques
Test centre ☐ Haut-Vernet
☐ Nouveau logis

Acceptez-vous de participer à cette étude c'est-à-dire de répondre à ce questionnaire et de réaliser un prélèvement de sang ? / *Do you agree to participate in this study, that is to say, to answer this questionnaire and to have a blood sample taken?*

☐ oui / *yes* ☐ non / *no*

Si non, le participant refuse → stopper l'entretien
If no, the participant refuses → end the interview

Age :/ *Age:* …..

Sexe :/ *Sex:* ☐ Homme/Garçon / *Male* ☐ Femme/Fille / *Female*

Poids (en kg) :/ *Weight:* ……

Taille (en cm) :/ *Height:* …….

Antécédents médicaux :/ *Medical history:*

☐ Aucun	☐ *None*
☐ grossesse en cours	☐ *Current pregnancy*
☐ Asthme /	☐ *Asthma*
☐ Autres maladies respiratoires (bronchite chronique…)	☐ *Other respiratory diseases*
☐ Hypertension	☐ *Hypertension*
☐ maladie cardiaque (angine de poitrine, infarctus)	☐ *Heart disease*
☐ diabète traité	☐ *Treated diabetes*
☐ Cancer en cours de traitement (sauf hormonothérapie)	☐ *Being treated for cancer (excluding hormone therapy)*
☐ VIH et autres troubles de l'immunité	☐ *HIV and other immune disorders*
☐ maladies chroniques du foie	☐ *Chronic liver disease*
☐ maladies rénales chroniques	☐ *Chronic kidney disease*
☐ autre ALD, précisez : ……	☐ *Other chronic disease: ……*

Depuis le 24 février (à la fin des vacances scolaires d'hiver/semaine du Mardi Gras), avez-vous eu des symptômes que vous n'avez pas habituellement et qui ont duré au moins 3 jours ? / *Since the 24th February (at the end of the winter school holidays/Mardi Gras week), have you had any symptoms that you don't usually have and that lasted at least 3 days?*

☐ oui / *yes* ☐ non / *no*

Si oui / *If yes:*

Quels symptôme(s) avez-vous eu ? / *What symptom(s) have you had?*

☐ Fièvre ou sensation de fièvre	☐ *Fever or feeling feverish*
☐ Mal à tête	☐ *Headache*

☐ Fatigue inhabituelle	☐ *Unusual fatigue*
☐ Courbatures / douleurs musculaires	☐ *Body aches, muscle pain*
☐ Toux	☐ *Cough*
☐ Difficultés respiratoires, essoufflement inhabituel	☐ *Difficulty breathing, unusual shortness of breath*
☐ Nez qui coule	☐ *Runny nose*
☐ Troubles du goût/de l'odorat	☐ *Taste/smell disorders*
☐ Nausées/vomissements	☐ *Nausea, vomiting*
☐ Diarrhée	☐ *Diarrhoea*
☐ Douleurs thoraciques, oppression	☐ *Chest pain, oppression*
☐ Si ≥80 ans : Confusion, chutes répétées	☐ *If ≥80 years: Confusion, repeated falls*

Quand ont commencé ces symptômes ? *(si plusieurs périodes : prendre les symptômes les plus proches du Covid-19 ou si impossible de différencier prendre la 1ère période)* / *When did these symptoms start? (if more than one period: record the time when the symptoms which most closely resemble those of Covid-19 started, or if it is impossible to differentiate between periods, take the first period)*

☐ avant confinement (17/03) / *Before the lockdown (17/03)*

☐ Pendant confinement (17/03) et avant 1 mai / *During the lockdown (17/03) and before the 1st of May*

☐ après le 1er mai / *After the 1st of May*

> *Si après le 1er mai :* Avez-vous eu des signes au cours des 15 derniers jours ? / *If after the 1st of May: have you had any symptoms in the last fortnight?*
> ☐ oui / *yes* ☐ non / *no*

Ces symptômes vous ont-ils fait penser que vous aviez peut-être le coronavirus ? / *Did these symptoms lead you think that you might have COVID-19?*

☐ Non / *No* ☐ oui peut-être / *Yes, maybe* ☐ oui sûrement / *Yes, definitely*

Avez-vous consulté un professionnel de santé pour ces symptômes ? / *Did you consult a health professional for these symptoms?*

☐ oui / *yes* ☐ non / *no*

> *Si oui* : qui avez-vous consulté ? / *If yes: Who did you consult?*
> ☐ Médecin traitant / *General practitioner*
> ☐ Centre covid / *Covid centre*
> ☐ Hôpital, urgence (sans hospitalisation) / *Hospital, emergency department (without hospitalisation)*
> ☐ Autre, précisez : / *other, specify:* ……

Avez-vous été hospitalisé en raison de ces symptômes ?/ *Were you hospitalized because of these symptoms?*

☐ oui / *yes* ☐ non / *no*

> *Si oui* : combien de temps avez-vous été hospitalisé (en nombre de jours) ? / *If yes: how long were you hospitalised (number of days)?* : ….
> Avez-vous été hospitalisé en service de réanimation ? / *Were you hospitalised in an intensive care unit?*
> ☐ oui / *yes* ☐ non / *no*

Avez-vous eu … ? / *Did you have a … ?*

- ☐ Test PCR (coton-tige) / *PCR test (swab/cotton bud)*
  - Si oui / *If yes* : ☐positif / *positive* ☐négatif / *negative* ☐Ne sait pas / *Don't know*
- ☐ Sérologie (prise de sang) / *Serology test (blood sample)*
  - Si oui / *If yes* : ☐positif / *positive* ☐négatif / *negative* ☐Ne sait pas / *Don't know*
- ☐ Scanner thoracique / *Chest CT scan*
  - Si oui :/ *If yes:* ☐évocateur du Covid-19 / *suggestive* ☐non évocateur / *not suggestive*
  - ☐ Ne sait pas / *Don't know*

A votre connaissance depuis le 24 février, avez-vous été en contact avec une ou plusieurs personnes malades (toux ou fièvre ou test positif ou consultation pour une suspicion de coronavirus) à l'extérieur de votre logement ? / *To your knowledge, since the 24th February, have you been in contact with one or more sick people (cough or fever or positive test or consultation because of suspected COVID-19) outside your home?*

☐ oui / *yes* ☐ non / *no* ☐ Ne sait pas / *Don't know*

Logement :/ *Housing:*

En ce moment, combien de personnes habitent dans le logement où vous vivez actuellement (y compris vous-même) ? / *How many people live in your current home (including you)?* …….

Nous allons maintenant parlé du logement principal dans lequel vous viviez pendant les 2 mois du confinement. (si plusieurs endroits, prendre la plus longue durée)
We are now going to talk about the main accommodation where you lived during the two months of lockdown (if more than one place, take the place where respondent lived longest)

Est-ce le logement dans lequel vous habitez actuellement ? *Is that your current home?*

☐ oui / *yes* ☐ non / *no*

Si le participant répond non : Vous avez passé la majorité de votre confinement dans un logement différent de votre logement actuel. Ce logement était-il dans le quartier :
If the respondent replies 'no': You spent the majority of the lockdown in a home other than your current home. In which neighbourhood was that accommodation located?

- ☐ St Jacques
- ☐ Nouveau logis
- ☐ Haut-Vernet
- ☐ Aucun de ces trois quartiers / *None of these three neighbourhoods*

Ce logement était :/ *This accommodation is/was:*

- ☐ Un appartement / *An apartment*
- ☐ Une maison / *A house*
- ☐ Autre, précisez : …. / *Other, specify:…..*

Combien de pièces comportaient ce logement (hors salle de bain, toilettes, cuisine) ? / *How many rooms are/were in the accommodation (excluding bathroom, toilet and kitchen)?* : ….

Avait-il un espace extérieur privé (jardin, terrasse, balcon) ? / *Is/Was there a private outdoor space (garden, patio, balcony)?*

☐ oui / *yes* ☐ non / *no*

Pendant le confinement, combien de personnes habitaient dans ce logement (y compris vous-même) ? / *During the lockdown, how many people lived in the household (including you)?* …….

Dont combien d'enfants de moins de 12 ans :/ *Including children under 12 years:* …
Dont combien d'enfants de 12 à 17 ans :/ *Including children aged 12-17 years:* …
Dont combien d'adultes de 18 ans et plus :/ *Including adults aged 18 years and over:* …

Depuis le 24 février, combien de personnes vivant dans ce logement (autre que vous) ont été malades (toux ou fièvre ou test positif ou consultation pour une suspicion de coronavirus) ? / From *the 24th of February to the end of lockdown, how many people living in this household (excluding you) have been ill (cough, fever, positive test or consultation for suspected COVID-19)?* : …

Information et comportements face au Covid-19 / *Information and behaviour in the face of Covid-19*

Etes-vous sorti pendant le confinement pour le travail ? / *During the lockdown, did you go out for work?*
☐ jamais / *never* ☐ moins d'1 fois/semaine / *less than once a week*
☐ 1fois/semaine / *once a week* ☐ tous les jours ou presque / *every day or almost every day*

Etes-vous sorti pendant le confinement pour les courses ? / *During the lockdown, did you go out to do the grocery shopping?*
☐ jamais / *never* ☐ moins d'1 fois/semaine / *less than once a week*
☐ 1fois/semaine / *once a week* ☐ tous les jours ou presque / *every day or almost every day*

Etes-vous sorti pendant le confinement pour visiter la famille/des proches ? / *During the lockdown, did you go out to visit family/friends?*
☐ jamais / *never* ☐ moins d'1 fois/semaine / *less than once a week*
☐ 1fois/semaine / *once a week* ☐ tous les jours ou presque / *every day or almost every day*

Etes-vous sorti pendant le confinement pour faire du sport/se promener ? / *During the lockdown, did you go out to play sports/for a walk?*
☐ jamais / *never* ☐ moins d'1 fois/semaine / *less than once a week*
☐ 1fois/semaine / *once a week* ☐ tous les jours ou presque / *every day or almost every day*

Etes-vous sorti pendant le confinement pour une cérémonie ? / *During the lockdown, did you go out for a ceremony?*
☐ jamais / *never* ☐ 1 fois / *once* ☐ plusieurs fois / *several times*

Etes-vous sorti pendant le confinement pour une autre raison ? / *During the lockdown, did you go out for another reason?* : ☐ oui, précisez :/ *yes, specify:* ……..
☐ jamais / *never* ☐ moins d'1 fois/semaine / *less than once a week*
☐ 1fois/semaine / *once a week* ☐ tous les jours ou presque / *every day or almost every day*

Est-ce que des personnes qui n'habitaient pas dans votre logement sont venues chez vous pendant le confinement ? (Par exemple pour amener à manger ou pour des soins)
Did people, other than people who live in the same housing as you, come to your home during the lockdown? (For example, to bring food or provide care or assistance)
☐ jamais / *never* ☐ moins d'1 fois/semaine / *less than once a week*
☐ 1fois/semaine / *once a week* ☐ tous les jours ou presque / *every day or almost every day*

Sur une échelle de 0 à 10, avez-vous eu des informations sur ce qu'il fallait faire pour se protéger et protéger les autres : lavage des mains, confinement, respect des distances avec d'autres personnes, port du masque ? (0=aucune information → 10 = informations complètes)
On a scale from 0 to 10, how much information did you have on what to do to protect yourself and others: hand washing, self-isolation, social distancing, wearing a mask? (0 = no information → 10 = a great deal of information)

0 |_____| 10

Avez-vous pu rester à plus d'un mètre des personnes que vous avez rencontrées à l'extérieure de votre logement pendant le confinement (par exemple : pour discuter ou dans des files d'attente) ? / *Were you able to stay more than one metre away from people you met outside your home during the lockdown ?*

☐ toujours / *always* ☐ souvent / *often* ☐ rarement / *rarely* ☐ jamais / *never*

Vous êtes-vous lavé plus souvent les mains pendant le confinement ? / *Did you wash your hands more often during the lockdown?*

☐ non, pas plus souvent / *no, not more often*
☐ un peu plus souvent / *a little more often*
☐ beaucoup plus souvent / *much more often*
☐ Ne sait pas / *Don't know*

Sur une échelle de 0 à 10, pensez-vous vous être protégé du virus ? (0=pas du tout → 10 = complètement)
N.B. : si demande de précision : par exemple par votre respect des gestes barrières ou par le confinement
On a scale from 0 to 10, do you think you protected yourself against the virus? (0 = not at all → 10 = completely)
N.B.: if the respondent requests clarification: for example, thanks to you respecting the preventive measures or self-isolating

0 |_____| 10

Si une épidémie de même nature survenait, quelle serait selon vous la mesure la plus efficace à mettre en place pour vous protéger vous et vos proches ? *In your opinion, if an epidemic of the same nature occurred in the future, what would be the most effective measure to take?*
……
……

Supplementary table S1: Demographic and behavioural characteristics (weighted) by neighbourhood

	All (n=700)	Neighbourhood A (n=312)	Neighbourhood B (n=173)	Neighbourhood C (n=215)
Characteristics	**Col%**	**Col%**	**Col%**	**Col%**
Sex				
Male	49.6	50.8	49.3	43.3
Female	50.4	49.2	50.7	56.7
Age (years)				
6-14	18.7	22.0	12.4	13.5
15-19	15.6	15.9	15.3	14.8
20-64	37.3	39.6	27.3	45.9
≥ 65	16.4	11.7	27.0	20.1
Obesity [1]				
No	59.3	56.1	71.3	51.4
Yes	40.7	43.9	28.7	48.6
Other medical conditions [2]				
No	70.7	72.7	66.6	67.7
Yes: one	17.8	16.2	21.1	20.0
Yes: several	11.5	11.1	12.4	12.3
Clinical COVID-19 cases in the household [3]				
No	50.1	38.9	69.2	72.5
1 person	25.3	28.3	20.8	17.7
>1 person	24.6	32.8	10.1	9.8
Housing type				
Apartment	52.0	71.5	17.5	15.1
House	45.8	28.5	73.9	83.9
Other	2.2	0.0	8.6	1.1
Presence of a private outdoor space				
No	47.9	72.2	1.5	9.6
Yes	52.1	27.8	98.5	90.4
Number of rooms				
1-2 rooms	18.4	21.0	10.9	19.6
3 rooms	31.1	38.4	18.9	16.5
≥ 4 rooms	50.5	40.7	70.2	63.9
Number of people per room (except living room) [4]				
> 1 person	71.1	75.3	55.5	80.5
1 person	16.7	16.2	19.7	13.1
< 1 person	12.3	8.5	24.9	6.4
At least one child in the household				
No	35.3	32.2	49.5	22.7
Yes	64.7	67.8	50.5	77.4

	All (n=700)	Neighbourhood A (n=312)	Neighbourhood B (n=173)	Neighbourhood C (n=215)
Characteristics	**Col%**	**Col%**	**Col%**	**Col%**
Went out for work during the lockdown				
No	96.4	97.4	93.6	97.1
Yes	3.6	2.6	6.4	2.9
Went out for a walk during the lockdown				
Never	81.2	81.9	84.3	70.9
Sometimes (≤1 time a week)	7.4	6.7	9.6	6.6
Almost every day	11.4	11.4	6.1	22.5

Percentages were weighted by sampling and post-stratification weights.

[1] For those aged 18 years or older: BMI≥30kg/m^2; for those aged 6-17 years: BMI≥IOTF-30 cut-off points

[2] 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

[3] 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

[4] 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]).

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6*
Bias	9	Describe any efforts to address potential sources of bias	6 + 14 (discussion)
Study size	10	Explain how the study size was arrived at	Supplemental materials
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	6-7
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	15 (discussion)
		(c) Consider use of a flow diagram	Figure 2
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7-8

		(b) Indicate number of participants with missing data for each variable of interest	7 and figure 2
Outcome data	15*	Report numbers of outcome events or summary measures	8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-12 (table 1 and table 2)
		(*b*) Report category boundaries when continuous variables were categorized	Table 1
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	13-14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14-15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-14 15
Generalisability	21	Discuss the generalisability (external validity) of the study results	14-15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.