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Transmission of SARS-CoV-2 infection among children in summer schools applying stringent control measures in Barcelona, Spain

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Summary

Transmission rates among children and adults in summer-school settings, implementing strict preventive measures, were low in comparison with community transmission rates. These results support current policies of keeping schools open for children's benefit, under strict preventive measures

Abstract

Background

Understanding the role of children in SARS-CoV-2 transmission is critical to guide decision-making for schools in the pandemic. We aimed to describe the transmission of SARS-CoV-2 among children and adult staff in summer schools.

Methods

During July 2020 we prospectively recruited children and adult staff attending summer schools in Barcelona who had SARS-CoV-2 infection. Primary SARS-CoV-2 infections were identified through: (1) surveillance program in 22 summer schools' of 1905 participants, involving weekly saliva sampling for SARS-CoV-2 RT-PCR during 2-5 weeks; (2) cases identified through the Catalonian Health Surveillance System of children diagnosed with SARS-CoV-2 infection by nasopharyngeal RT-PCR. All centres followed prevention protocols: bubble groups, hand washing, facemasks and conducting activities mostly outdoors. Contacts of a primary case within the same bubble were evaluated by nasopharyngeal RT-PCR. Secondary attack rates and effective reproduction number in summer schools (R^*) were calculated.

Results

Among the over 2000 repeatedly screened participants, 30 children and 9 adults were identified as primary cases. A total of 253 close contacts of these primary cases were studied (median 9 (IQR 5-10) for each primary case), among which twelve new cases (4.7%) were positive for SARS-CoV-2. The R^* was 0.3, whereas the contemporary rate in the general population from the same areas in Barcelona was 1.9.

Conclusions

The transmission rate of SARS-CoV-2 infection among children attending school-like facilities under strict prevention measures was lower than that reported for the general population. This suggests that under preventive measures schools are unlikely amplifiers of SARS-CoV-2 transmission and supports current recommendations for school opening.

Keywords: SARS-CoV-2, COVID-19, transmission, children

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INTRODUCTION

The first wave of the COVID-19 pandemic enforced school closures globally, affecting by the end of March 2020 1.6 billion children and teenagers, 80% of the world's enrolled students, who could not physically attend school in 161 countries^{1,2}. This measure was a consequence of the general belief that quarantine reduces dramatically the incidence and mortality during infectious diseases epidemics³⁻⁵. However, lockdown has direct and indirect harmful effects on children, limiting not only their academic learning, but also other wider benefits including the possibility to relate and play with their peers and learn from their teachers⁶. Social disparities widened because not all households have the necessary digital resources for home schooling^{7,8}.

As COVID-19 is almost always mild in children⁹⁻¹², and that, unlike other respiratory viral infections, the rates of transmission among children seemed to be lower than those described in adults¹³⁻¹⁶, the majority of countries have decided to re-open schools after the COVID-19 lockdown¹⁷. In general, guidelines for re-opening have recommended prevention measures. Despite the wide adoption of such policies, there remains a lack of evidence as to whether, in these settings, children have the same, higher or lower transmission rates of SARS-CoV-2 as compared with adults^{1,2,16,18}. Answering this question is fundamental to inform evidence-based strategies for school opening, particularly in the event of new outbreaks. Summer Schools can be a good model to reproduce the conditions of a school setting.

During July 2020 in the city of Barcelona, Spain, summer camps were allowed to open under stringent prevention protocols established by the Catalan Health Department. The aim of this prospective study was to describe the transmission of SARS-CoV-2 among children and adult staff attending summer camps during July 2020.

METHODS

Study description and ethics approval:

We conducted a prospective study including children and adult staff attending summer schools in the Barcelona Metropolitan Region, Spain. The study period spanned 5 weeks, from 29th June to 31st July 2020. Children aged 3 to 15 years old and staff of any age (≥ 16 years old) working at the same facilities and direct contact with children were considered eligible. Family were excluded if they did not consent to take part or if they were unwilling to ensure adequate follow up.

Recruitment pathways

The main goal of the study was to recruit children with SARS-CoV-2 infection who attended a school-like facility, and therefore potentially acting as index cases in these settings. Cases were identified and recruited through two pathways. The first pathway (RP1) was an active surveillance cohort study in 22 summer schools, consisting of longitudinal follow-up of a large number of children and accompanying adult staff with weekly screening for SARS-CoV-2 infection. A baseline saliva sample for RT-PCR analysis was obtained at enrolment and subsequently repeated on a weekly basis for as long as the child remained in the summer school. In one of the summer camps paired NF samples were also taken. For each summer school campus, data on the specific preventive measures implemented were confirmed using standardized questionnaires.

The second pathway for recruitment (RP2) included cases identified by the Catalonian Health Surveillance System of SARS-CoV-2 infection diagnosed by nasopharyngeal RT-PCR while attending other summer schools or children's foster homes in the area of Barcelona. These included children that were tested for SARS-CoV-2 PCR based on symptoms or because a positive contact case.

In all these facilities, children were organized in subgroups (bubbles) of 8-14 children. Additional preventive measures included frequent handwashing, facemask wearing (mandatory for children older than 6 years, and recommended outside) and conducting most activities outdoors.

For both recruitment pathways, once a potential index case was identified by a positive RT-PCR from saliva or nasopharyngeal swab, the child was considered a potential index case. In those providing consent, a questionnaire for Covid-19 symptoms was completed and a blood sample for anti-SARS-CoV-2 antibodies was taken to rule out past infection. Subsequently, all children and staff members who were close contacts of the index case were asked to participate in the study. Evaluation of close contacts included a questionnaire for COVID-19 symptoms and nasopharyngeal swabbing for RT-PCR at 0, 7 and 14 days, and serology testing at 0 and 5 weeks.

Outcomes

The primary outcome of the study was to determine children and adults index cases rates of transmission, to other children and adults, based on RIC and reproduction number.

SAR was defined as the ratio (number of secondary infections)/ (number of contacts evaluated).

$$SAR = \frac{\text{Number of secondary cases inside summer school}}{\text{Number of contacts inside summer school}} \cdot 100$$

Additionally, we aimed at comparing the transmission rate inside the summer schools with that observed in the general population from communities surrounding the summer schools during the same period (the used method is described in the supplementary file). While the reproduction number is generally used to estimate transmission rates in the general population, previous studies¹⁹ have evaluated transmission inside households using a household effective reproduction number (Re^*), which is defined as the average number of households infected by each infected household. Analogously, we defined the effective reproduction number in summer schools (Re^*) as the average number of participants infected by each index case:

$$Re^* = \frac{\text{Number of secondary cases inside summer school}}{\text{Number of primary cases}}$$

By definition, the reproduction number in general population (Re) describes the transmission occurring at any time during a given time period. However, children spent in summer schools only 8 hours during weekdays, which could result in a falsely low reproduction number as compared to that occurring in the general population (exposed theoretically during a longer period/day; i.e. 24h). Therefore, we defined a renormalized effective reproduction number in summer schools (\widehat{Re}^*) in order to allow comparison with the one in the general population, using the ratio of hours in the summer school in a week as a factor.

$$\widehat{Re}^* = Re^* \cdot \frac{\text{Total hours in a week}}{\text{Weekly hours in the summer school}}$$

We assumed that participants spent around 40 hours a week in the summer school, which represents a 24 % of the 168 hours in a week.

Statistical analysis

Sample size calculation:

Sample size was estimated on 1st of June using epidemiological data from Portal de Transparència (<https://analisi.transparenciacatalunya.cat/>). The Universitat Politècnica de Catalunya (UPC) team developed a method to estimate real incidence in regions²¹, using the methodology described in <https://www.medrxiv.org/content/10.1101/2020.05.01.20087023v1>, that was validated by the Instituto Salud Carlos III results of seroprevalence study, in Spanish regions (<https://portalcne.isciii.es/enecovid19/>) and was also utilized for the sample size calculation. Detailed sample size calculations are described in supplementary material (supplementary text and table 1)

Analytical Plan

Chi-square test was used for comparisons of categorical data; and Student's t-test or U of Mann-Whitney for quantitative variables, according to the normal distribution or not. To compare the epidemiological and microbiology results at the different diagnostic times, the Wilcoxon signed rank test was used to compare paired numerical data. Index cases (diagnosed by PCR and or seroprevalence conversion) and transmission rates by reproduction number in summer schools (R^*) were calculated. SPSS®22.0 statistical package (IBM Corp. software, Armonk, NY) and R programs were used.

RESULTS

Description of the study population

For the active surveillance group, 49 campuses were originally selected, with 22 summer schools (located at 27 different venues) finally enrolled into the study, accounting for a total of 1905 participants to be followed in the RP1, of which 1509 were children. There were taken a total of 5240 saliva samples. The total number of index cases was 12, including 9 (75.0%) children and 3(25.0%) adults.

Additionally, newly index cases were also derived from 18 summer schools coming from the Catalonian Health surveillance systems, and also from one foster centre, accounting 960 summer

school attendings (84.3% children). The total number of referred index cases was 27 including 21 (77.8 %) children and 6 (22.2 %) adults.

Index cases

Altogether, 39 index cases were identified, including 30 children and 9 adults in the study.

Overall PCR screening results per week from the RP1, and calculated incidences, are described in table 1 (both for children and adult staff). From this active surveillance, 17 positive PCR cases were reported at 8 different centres. Of those, 12 were confirmed as index cases, coming from 8 centres (9 children and 3 adult staff). The rest of individuals, all adults, with a positive PCR (n=5) also had a positive IgG serology, being therefore considered past SARS-CoV-2 infections. The reinfection possibility was excluded because participants did not present new symptomatology or changes in the serology result, after 5 more weeks of monitoring by the study protocol.

Two of these 5 cases were the only one who had PCR negative saliva result. It represents the 0.3% of the 580 saliva samples analyzed in the summer camp, in which it was analyzed in parallel to nasopharyngeal swabs, because both cases had an IgG positive serology, these results were not considered false negative saliva PCR, but past SARS-COV-2 infections with nasopharyngeal PCR persistence.

The incidence per week and the expected versus observed cases according to the underlying neighbourhood incidence, in the active surveillance group, are presented in Figures 1 and 2, respectively.

Supplementary Tables 2, 3 and 4 describe general data about the summer schools. Of note, the number of caregivers/day was higher in summer schools with no index cases with respect to those where index cases were detected, $p=0.0059$.

Analysis of the dynamics of SARS-CoV-2 transmission. Active and passive surveillance branches of the study.

The study team identified 253 summer camp contacts from all the index cases, 230 (90.1%) of whom agreed to participate in the study and provided samples. None of the 23 contacts who did not participate in the contacts study were confirmed to become infected after our summer schools' study was finished. We concluded it because no reports of new infections were done from the schools.

From all contacts, 87 came from the RP1 (34.4%) and 166 (65.6) from the RP2; only being 6 (3.6) cases from all the passive surveillance pathway symptomatic.

The mean of contacts studied for each positive case was 9 (IQR 5-10). The group's mean size was 9.4 (IQR 7-10). Among all contacts, 12 (4.7%) were subsequently confirmed to have become infected, with a Re^* of 0.3, and a renormalized reproduction number in summer schools (\hat{Re}^*) of 1.3. Index cases transmitted the infection to different number of contacts (figure 3). No secondary transmission was observed from 22 (73.3%) of child index cases. The transmission was child to child in 9 cases, child to adult in 1 case and adult to child in 2 cases. There were 15/30 (50%) asymptomatic cases observed in children, and 3/6 (50%) asymptomatic cases in adults. There were no significant differences in the children transmission capability with respect to being symptomatic ($p= 0.815$).

The number of contacts evaluated per index case, both in total and also among children less than 18 years of age, are presented in tables 2 and 3. Table 4 describes the different reproduction number in summer schools (R^*) depending on the recruitment pathway and the age, whereby no differences were found. The reproduction number among the general population (R) during the 5 weeks of the study, period during which various outbreaks occurred, ranged between 1.7 and 2, figure 2.

When summer schools' characteristics were compared, according to the confirmation of transmission in their premises, a significantly higher outdoors surface area was found in those whereby no transmission occurred; $p= 0.0036$; once corrected by the total number of children and adults, logistic regression showed a trend $p = 0.064$. With respect to SARS-CoV-2 prevention measures, frequent hand washing was the only variable that was associated with a lower SAR, $p=0.024$. This data is showed in table 5.

DISCUSSION

This study prospectively assessed the risk of SARS-CoV-2 transmission in school-like environments implementing prevention measures. We found that in these conditions transmission rates to other children and adults was low. We estimated an effective reproduction number in summer schools of $Re^*=0.3$. This transmission rate below 1 suggests that summer schools did not act as amplifiers of the pandemic. During the study period, the community effective reproduction number (Re) was around 1.9 in the surrounding areas, which were following a sustained growth. We acknowledge that the comparison between the two indices is not straightforward, because children spent only a 24 % of the hours in a week in summer schools (8 hours on weekdays). Nevertheless, we believe that the renormalized reproduction number as used in this study can be used as a proxy for a rough

comparison. This renormalization provides a value of $\widehat{Re}^* = 1.3$, which remains lower than that in the community.

We believe that the criteria used for calculating the renormalized reproduction number in summer schools is conservative. For instance, we did not consider in the time ratio that children spend a significant number of hours sleeping in a room either alone or with a close relative at home. In addition, the average number of social interactions is probably higher during the time at the summer school as compared to the rest of the day. Both factors would even reduce the renormalized reproduction number in summer schools. Therefore, the transmission inside summer schools was similar or lower than the transmission among the general population in that period time.

Our results are in agreement with previous studies²²⁻²⁴ suggesting that children were not primary drivers of SARS-CoV-2 transmission in schools in the setting of low community prevalence. Studies reporting transmission rates in, Switzerland, Ireland and Australia during the first months of the COVID-19 pandemic in early 2020, reported lower transmission rates than those observed for other respiratory viruses, such as influenza²⁵. Similar data are shown in other reports in which the paediatric transmission rate was very low and did not point at children as the main culprits of the COVID transmission⁹. Other studies described outbreaks initiated at schools or school-like environments in Israel or the United States^{26,27}. These outbreaks generally occurred in conditions of high and rapidly increasing community prevalence, close contact and absence of preventive measures^{1,2,16}. A frequent concern is the under detection of transmission of SARS-CoV-2 in school like settings due to the frequency of asymptomatic infection. This study represents the first prospective study evaluating transmission rates in school-like environments with routine, asymptomatic testing, that implemented protocols for prevention of Covid-19 transmission. Our results provide evidence to support the notion that, in these circumstances, the transmission rates among children attending schools are low, even accounting for asymptomatic transmission. Secondary infection rates in this study were similar among children and adults. In contrast, several studies have²⁸ reported higher rates of SARS-CoV-2 infection in teachers with respect to children in a school community²⁹ including in the setting of asymptomatic screening. This difference may have been due to a relatively low event rate causing lack of power to detect a difference, or to better adherence to infection prevention protocols by staff members within participating summer schools. Regarding the relationship between transmission rate and age, previous studies suggested a greater risk of transmission in teenagers. In the present study, no differences in transmission rates were observed according to age, albeit the total number of index cases older than 12 was small.

We observed a correspondence between the prevalence of infection per district and the number of new index-cases found in the same district. This finding supports that summer-schools did not act as super spreading hotspots, but rather reflected the underlying community transmission. Our finding concurs with a recent report²⁹ of school outbreaks towards the end of the first wave that concluded that school transmission reflects that in the wider immediate community. Other studies have reported that school reopening does not appear to significantly affect community transmission, especially in with the setting of low levels of community transmission.

From a public health perspective, the results of this study support prevention measure implementation in schools to reduce the burden of COVID-19 in schools and school-like environments. Such measures may be applicable with much less disruption, financial costs, or harm than full closure. Summer schools in Barcelona were allowed to open provided they could guarantee adequate implementation of such preventive measures. Distribution of children in bubble groups of an average size of 10 individuals may have been an efficient measure at containing the spread of infections, facilitating contact traceability and allowing selective quarantines without having to close the entire facility. Interestingly, frequent handwashing was associated with decreased transmission rates.

Of note in this study, some SARS-CoV-2 infections were identified by screening using RT-PCR in saliva. This allowed identification of asymptomatic cases and illustrates the feasibility of using saliva for community screening. Saliva has been described as a reservoir for the virus and diagnostic tests for COVID-19 validated. Most importantly, saliva sampling was well accepted by children. The rate of false negative RT-PCR saliva results in relation with NP samples in those children with paired samples was only 0.8%.

This study has some limitations. There was a short follow up (minimum of 2 weeks, and up to a maximum of 5 weeks) that could mask further infections and transmissions, secondary to a more prolonged contact between the summer school participants. Secondly, the community rate was low at the time of the study and results could be different under high-transmission community rates. The analysis presented is restricted to PCR results, but serological tests in saliva are pending. This could theoretically demonstrate a higher incidence and transmission rate, although the evaluation of antibodies in saliva for SARS-CoV-2 infections is still pending validation. However, the weekly follow-up with a molecular technique should minimize this possibility. Incidentally, recent studies have suggested that serology (including saliva) may overestimate clinical infections in children, as they may produce antibodies on exposure whilst so rapidly clearing the virus that it never becomes detectable via rt_PCR³⁰. Finally, many summer-camp activities (median value 75%) were outdoors where it is well known that increased ventilation drastically decreases the risk of transmission.

In summary, transmission rates among children and adults in summer-school settings implementing strict preventive measures were low in comparison with community transmission rates. These results support current policies of school opening under strict preventive measures.

NOTES

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TABLES

Table 1. Overall PCR screening results, per week (includes children and staff) and calculated incidence from the RP1.

Type of PCR screening test		Week 1	Week 2	Week 3	Week 4	Week 5	TOTAL Week 1-5
Saliva n (%)	Total	531	1600	1473	1094	542	5240
	Positive	1 (0.2)	3 (0.2)	1 (0.07)	4 (0.4)	3 (0.6)	12 (0.2)
	Negative	524 (98.7)	1589 (99.3)	1471 (99.9)	1090 (99.6)	538 (99.3)	5212 (97.7)
	I	1 (0.2)	0 (0)	1(0.07)	0 (0)	1 (0.2)	3 (0.06)
	NA	5 (0.9)	8 (0.5)	0 (0)	0 (0)	0 (0)	13 (0.2)
	Nasopharyngeal* n (%)	Total	181	136	131	92	40
	Positive	2 (1.1)	1 (0.7)	1(0.8)	1(1.1)	0 (0)	5 (0.9)
	Negative	177 (97.8)	133 (97.8)	130 (99.2)	89 (96.7)	40 (100)	569 (98.1)
	I	1 (0.5)	1(0.7)	0 (0)	2 (2.2)	0 (0)	4 (0.7)
	NA	1 (0.5)	1(0.7)	0 (0)	0 (0)	0 (0)	2 (0.3)
Calculated Summer-Camps overall Incidence for 100,000		187.97	187.50	67.89	365.63	553.51	630.00

RP1: Recruitment Pathway 1. I: indeterminate. NA: Cannot be assessed.

* Nasopharyngeal samples were done paired with saliva samples for saliva verification

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Table 2. Number of contacts evaluated per index case – TOTAL and only children <18 years of age contacts.

Adult cases	TOTAL index cases	TOTAL contacts	TOTAL positive contacts	Contacts/Index
TOTAL	9	114	3	12.66
Recruitment Pathway 1	5	63	1	12.60
Recruitment Pathway 2	4	51	2	12.75
Children < 18 years old	TOTAL index cases	TOTAL contacts	TOTAL positive contacts	Contacts/Index
TOTAL	30	253	12	8.43
Recruitment Pathway 1	9	89	1	9.89
Recruitment Pathway 2	21	164	11	7.80

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Table 3. Total secondary attack rate (SAR) and effective reproduction number in summer schools (Re*), from all recruitment pathways

	<i>SAR (%)</i>		Re*	
	Overall	From Children only	Overall	From Children only
TOTAL	4.09	4.74	0.38	0.40
Recruitment Pathway 1	1.31	1.23	0.17	0.11
Recruitment Pathway 2	6.07	6.70	0.48	0.52

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Table 4. Secondary attack rate (SAR) and effective reproduction number in summer schools (Re*) among different RP, and differences between ages. The table below represents the transmission detected in the school-like environment, stratified by 3 age-groups: 0-12, 13-17, >17 years old.

Transmission variables	Index case age group			
	Age categories	0-10 (n=16)	11-17 (n=14)	Staff (n=9)
$SAR = \frac{\text{Number of new positives}}{\text{Number of Contacts}} (\%)$	0-12	5.26% (8/152)	4.00% (1/25)	1.64% (1/61)
	13-17	- (0/2)	6.90% (2/29)	11.76% (2/17)
	Adult staff	2.7% (1/37)	- (0/8)	- (0/36)
$Re^* = \frac{\text{Number of new positives}}{\text{Number of Index Cases}}$	0-12	0.38	0.11	0.11
	13-17	-	0.22	0.22
	Adult staff	0.05	-	-

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Table 5: Summer schools characteristics, according to the confirmation of transmission in their premises.

Variable	All campuses (n=41)	Campuses where contagion occurred (n=7)	Campuses with no contagion (n=34)	p
Number of children/day	76 (55-120)	60 (42.00-67)	88.5 (57.75-120)	0.0890
Number of adult staff/day	13.5 (10-20)	10 (9-13)	15 (11-20)	0.2224
Number of caregivers/day	12 (9-15)	9 (7.5-12)	12 (9-15)	0.4449
Ratio children/caregiver	10 (9-10)	10 (7-10)	10 (9-10)	0.4853
Indoors surface area	685 (347-1312.5)	600 (350-670)	756 (359-1375)	0.5368
Outdoors surface area (m²)	525 (220-2125)	93 (21-145)	838 (240-2500)	0.0036
Number of communal use toilets o	6 (5-12)	4 (2-9)	6.5 (5-12)	0.1802
Activities conducted outdoors (%)	70 (60-80)	60 (35-77.5)	70 (67-80)	0.2702
Compulsory use of masks indoors	35 (85.4%)	7 (100%)	28 (82.4%)	0.229
Assessed compliance with indoors mask wearing (0-10 scale)	8 (7-9)	8 (7.5-8.5)	8 (7-9)	0.9
Compulsory use of masks outdoors	24 (60%)	4 (66.7%)	20 (58.8%)	0.7176
Assessed compliance with indoors mask wearing (0-10 scale)	8 (6-9)	9 (7.5-9.75)	8 (6-9)	0.2738
Handwashing frequency/day ≥ 5 times/day	26 (63.4%)	1 (14.3%)	25 (73.5%)	0.0030
< 5 times/day	15 (36.6%)	6 (85.7%)	9(26.5%)	
Presence of hydroalcoholic gel dispensers on site	40 (100)	7 (100)	33 (100)	-

Figure legends

Figure 1: Weekly positive samples (—♦—) and weekly incidence (—♦—) among sampled individuals in the summer schools (recruitment path 1)

Figure 2: A) Expected (■) and detected (■) cases in the summer schools of each Care Management Area (CMA), according to the incidence among general population and assuming a diagnostic rate in general population of 30 %. Expected cases and their margins were computed considering the cases detection as a binomial variable with estimated incidence as probability. In all care management areas, observations fell within the 90% margins of expected cases. p-values expected/detected cases were: Baix Llobregat Centre i Font Santa p=0.701; Barcelonès Nord i Baix Maresme p=0.527; Barcelona Esquerra p=0.827; Barcelona Nord p=0.838; Baix Llobregat Litoral i Sant Boi p=0.640; Vallès Occidental Oest p=0.518; Barcelona Litoral Mar p=0.198.

B) Geographical distribution of summer schools in health care assistance areas. Each circle represents one summer school, with its diameter proportional to square root of sampled individuals. In dark grey, those summer schools where cases were found, the number indicating the detected cases. Background colours indicate expected cases in each health care assistance area.

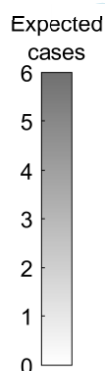


Figure 3: Distribution of the number of infected contacts per index case

Figure 1



Figure 2A

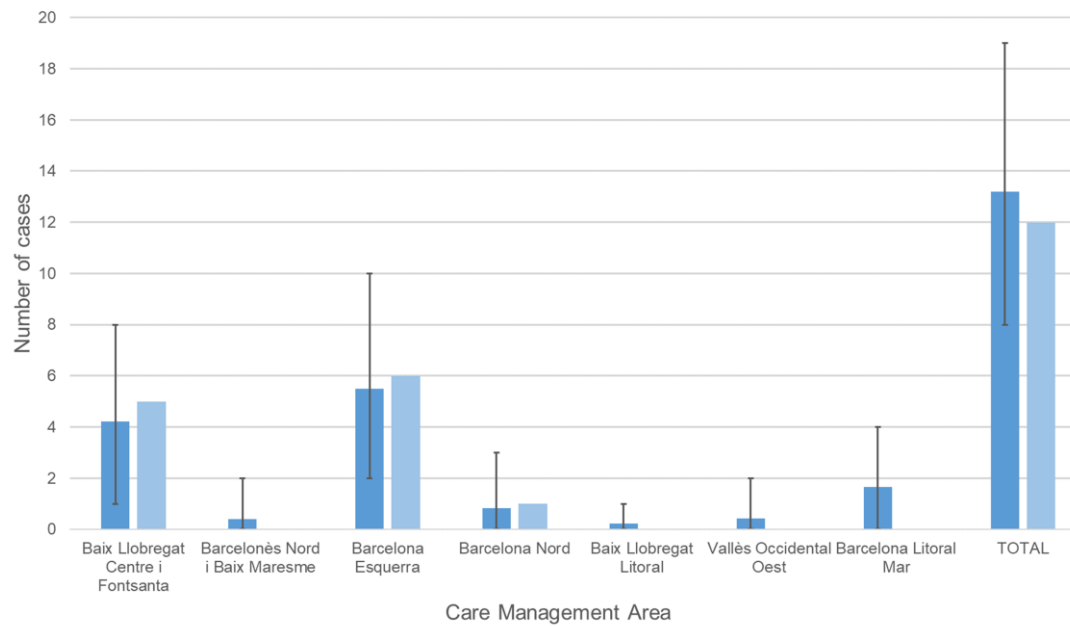


Figure 2B

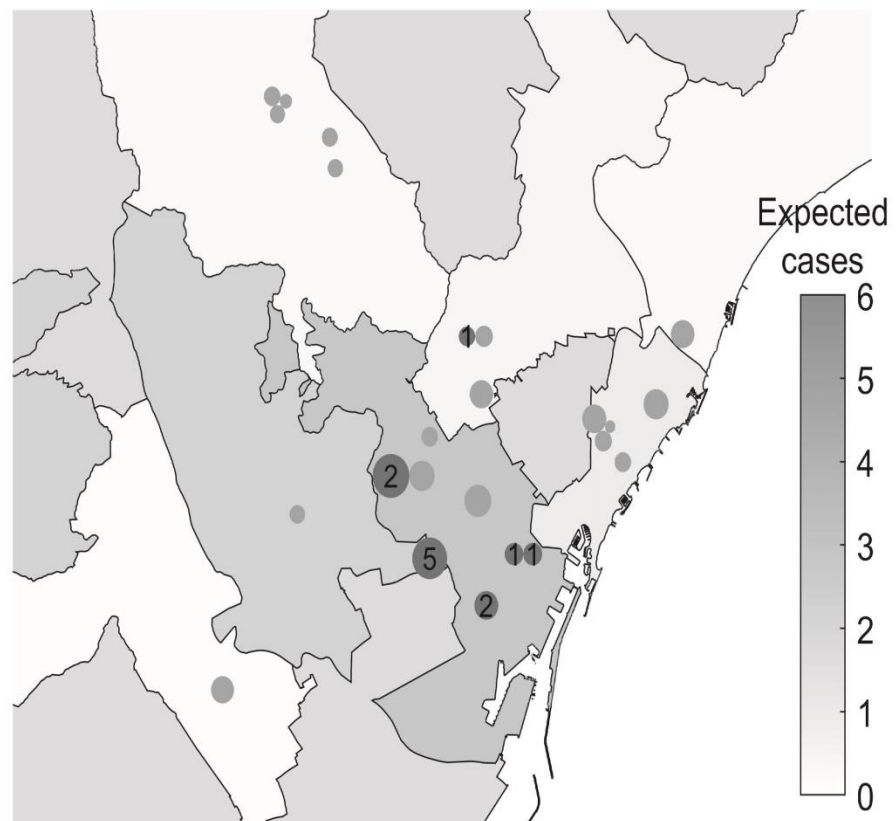


Figure 3

