Seroprevalence of SARS-CoV-2 Antibodies in Children and Adolescents: Results From a Population-Based Survey in 10 Colombian Cities

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Abstract

Background. Understanding COVID-19 dynamics in Colombia during the first pandemic year (2020) gives important insights surrounding population's exposure risk and specific susceptibilities. Seroprevalence studies can aid in having a broader understanding of the disease, offering a more inclusive view of the pandemic's impact across the population. *Methods.* A population-based cross-sectional study to assess antibodies against SARS-CoV-2 in 10 Colombian cities was developed between September and December 2020. Cities were grouped according development typology (Robust (RD), Intermediate (ID) and Incipient (InD)). Detection of total antibodies (IgM + IgG) against SARS-CoV-2 was employed. Univariate Odds Ratios (OR) were estimated for antibody results and selected variables. *Results.* About 3124 children aged between 5 and 17 years were included. Factors related to lower seropositive results were affiliation to the employer-based health insurance in RD and ID cities (OR: 0.579, 95% CI 0.477-0.703, OR: 0.648, 95%CI 0.480-0.874 respectively) and living in a household with adequate access to public services only for ID cities (OR: 0.679. 95% CI 0.491-0.939). Higher seropositivity rates in RD and ID cities were seen in children belonging to the low socioeconomic stratum (RD: OR: 1.758, 95% CI 1.427-2.165; ID: OR: 2.288, 95% CI 1.599-3.275) and living in an overcrowded household (RD: OR: 1.846, 95% CI 1.467-2.323; ID: OR: 2.379, 95% CI 1.769-3.199). *Conclusions.* Children and adolescents showed substantial impact from the COVID-19 pandemic. Disadvantageous living conditions were found to be significantly related to having a positive SARS-CoV-2 antibody test. These results highlight the need to prioritize vulnerable populations in the context of health emergencies.

Keywords
SARS-CoV-2, serology, antibody, pediatric, seroepidemiology study

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Background

In December 2019, a new respiratory virus named the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was identified in Wuhan, China. By July 31, 2021 more than 200 million confirmed cases and over 4 million deaths have been reported worldwide,[1] placing the SARS-CoV-2 pandemic as the number one priority in public health interventions and research efforts.

Colombia confirmed the first SARS-CoV-2 case on March 6, 2020, and since then the country declared a national sanitary emergency adopting measures to mitigate the spread of the disease and reduce adverse health outcomes. Many efforts have been made to perform

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adequate surveillance of the pandemic, mainly through identifying SARS-CoV-2 cases by testing symptomatic or potentially exposed individuals and monitoring the number of intensive care unit admissions and deaths related to this infection. Although this information is important to understand the impact of the SARS-CoV-2 pandemic and decide upon public health measures, it does not give a complete picture of the number of people who have been exposed and infected with the virus.

SARS-CoV-2 diagnosis using RNA detection through real time polymerase chain reaction (RT-PCR) or antigen testing is usually reserved for symptomatic cases and their close contacts, leaving a large proportion of asymptomatic and mildly symptomatic individuals undetected. This situation can underestimate the extent of the pandemic as many SARS-CoV-2 infections fall within the mildly symptomatic or asymptomatic categories,[2,3] a situation that is especially relevant for children and adolescents.

In this sense, population based seroprevalence studies can aid in the understanding of SARS-CoV-2 dynamics by testing the general population and providing a measure of exposed individuals. Published seroprevalence studies have reported higher SARS-CoV-2 antibody positivity rates in populations of 20 to 49 years of age[4,5] demonstrating that although older ages might have a higher health impact after SARS-CoV-2 infection, high exposure rates seem to focus in younger age groups. Within seroprevalence studies that report results in children and adolescents (<18 years of age), higher seropositivity rates lie within children older than 10 years, allocating the younger populations (<10 years) as having the lowest estimated susceptibility to SARS-CoV-2 infection.[6,7]

Although it is currently accepted that children and adolescents seem to carry a small proportion of SARS-CoV-2 disease burden,[8] they have been considered to potentially play an important role in disease transmission.[9] As a result, various pandemic mitigating policies adopted by numerous countries have direct implications on children and adolescents, such as restricted outdoor activities and school closures. In Colombia, school closures began in early 2020 and have been continued throughout 2021 (with some intents to partially reopen schools). School closure has been a topic of high concern as its main objective to mitigate disease transmission can also have unwanted negative impacts like halting academic progress and affecting child and adolescent wellbeing.[9] Colombia's education system accumulated more than 140 days of school closure, almost doubling the average reported by other Organization for Economic Co-operation and Development (OECD) countries (60 days) during the first pandemic year.[10] This places children as important players in pandemic

policies and efforts to comprehend SARS-CoV-2 infection within this population should be prioritized.

Understanding SARS-CoV-2 epidemiology among the young, can also help design effective public health measures to control the spread of the disease and lessen the impact on the population. Although all individuals are potentially susceptible to the virus with differential disease manifestations related primarily to age, various contextual factors are important in determining the risk of exposure and infection. Among these are cultural differences, economic status, housing characteristics, health care access and infrastructure, local and national health policies, and pandemic mitigation efforts.[11]

These contextual characteristics may play a role in the variations in SARS-CoV-2 infection rates seen within and between populations, which can be especially relevant for children and adolescents as contextual factors are recognized as fundamental in determining disease susceptibilities in this population.[12]

During September to December 2020, the Colombian National Institute of Health (INS- Spanish for Instituto Nacional de Salud), along with other academic and government authorities, carried out a population-based seroprevalence study designed to assess the rate of SARS-CoV-2 antibody detection in the Colombian population, including individuals aged 5 to 80 years. This analysis focuses on findings related to SARS-CoV-2 antibody testing in children and adolescents between the ages of 5 to 17 years. Sociodemographic and household characteristics are analyzed to understand factors that interplay in the risk of SARS-CoV-2 infection among this age group.

Methods

Study Design

A population-based cross-sectional study to assess the seroprevalence of antibodies against SARS-CoV-2 in 10 Colombian cities (Barranquilla, Bogotá, Bucaramanga, Cali, Cúcuta, Guapi, Ipiales, Leticia, Medellin, and Villavicencio) was developed between September and December 2020, prior to the beginning of SARS-CoV-2 national vaccination program. The cities were selected according to geographic and demographic criteria established by the Colombian Ministry of Health and Social Protection (MSPS—spanish for Ministerio de Salud y Protección Social) and the National Department of Statistics (DANE spanish for Departamento Administrativo Nacional de Estadísticas).

City Typology Categories

Colombia is a middle-income country with a wide range of social, demographic and economic differences across

its territory. Important variations are seen regarding developmental indexes such as monetary poverty, which can range from 27% to 66% in different regions within the country according to national official data for 2019[13] (DANE). To understand these contextual differences, the Colombian National Planning Department (DNP Spanish for Departamento Nacional de Planeación), proposed a comprehensive methodology to categorize cities and departments into distinct typologies that reflect their particularities. In this sense, 3 typologies related to territorial development status are outlined: (1) Incipient development, (2) Intermediate development, and (3) Robust development. These typologies expose the differential strengths and vulnerabilities within the territory and aid in determining the allocation of economic and public policy resources.[14]

This typology categorization combines different developmental indexes grouped into 6 dimensions: (1) Urban regional dimension, which reflects population settlements, infrastructure, and dwelling characteristics; (2) Social conditions dimension which reflects quality of life and includes indexes such as multidimensional poverty; (3) Economic dimension that seeks to expose economic growth tendencies and population access to science, technology and innovation opportunities, it includes indexes such as city income, internet access and economic disparities; (4) Environmental dimension that aims to identify territorial ecosystems and local governance capacities, it includes indexes such as city forest area and environment-directed inversions; (5) Institutional dimension which measures territorial governance and includes indexes such as municipal fiscal performance, and 6. Security dimension which exposes the territorial risk of violence-derived acts and includes indexes such as number of homicides and abductions (kidnapping) per 100 000 inhabitants and areas with coca leaf plantations within the territory.[14]

For this seroprevalence study, understanding the socioeconomic differences within the study population is relevant to have a better comprehension of the pandemic and its dynamics in the country's diverse contexts. In this sense, the cities included in this study are categorized as follows: (1) Robust development: Bogotá, Medellín, Barranquilla, Bucaramanga, Villavicencio and Cali; (2) Intermediate development: Cúcuta, Leticia and Ipiales; and (3) Incipient development: Guapi.

Study Population

Participant selection was based on a multi-stage probabilistic cluster sample design. People residing in the selected cities and sampled units aged between 5 and 80 years were invited to participate. Any individual with contraindication or difficulty in obtaining a blood sample was not included in the study. More detail on population selection has been published by Mercado et al.[15]

Data Collection

Three surveys designed to collect data on family census, household characteristics and individual information were employed. The surveys were previously evaluated and validated by a panel of experts, ensuring clarity, coherence, relevance, and accuracy of the instruments. Surveys were designed and data was captured using the web-based application Research Electronic Data Capture (REDCap® Vanderbilt University).

The census survey was made up of questions to validate participant inclusion criteria. The household survey focused on the characterization of aspects such as: dwelling location and type, socioeconomic stratum, number of bedrooms and access to public services. Both the census and housing surveys were answered by the head of household and data was validated with national statistics. The individual survey included sociodemographic, economic and clinical information and was answered by each family member. Parents or legal guardians answered the survey for children younger than 14 years. For older children (14-17 years) questions were directed to them with parental supervision.

Three variables were constructed based on the survey information. Educational backwardness was considered when there was no school enrollment or when children aged 6 to 15 years referred pre-school as their highest educational level and/or when children older than 15 years referred to primary school as their highest educational level.[16] Household overcrowding was considered when there were more than 2 individuals per available bedroom and adequate access to public services was defined when households had combined access to electricity, aqueduct water and sewerage services.[17]

Laboratory Analysis

Blood samples were drawn from all the participants, and were subsequently stored and allotted for serological analysis in the specialized laboratories. Strict monitoring was carried out on the cold chain in which the samples rested during transport with standardized operating procedures to guarantee their quality and complying with all biosafety protocols for participants and the research team.

The samples were processed with the Advia Centaur-Siemens diagnostic system for the detection of total antibodies (IgM + IgG) against SARS-CoV-2.[18] This is a sandwich-type chemiluminescent (CLIA) technique, selected for its adequate performance as a diagnostic test in Colombian population samples, according to previous

validation studies. The chemiluminescent reaction is measured in Relative Light Units (RLU) and is directly proportional to the amount of total anti-SARS-Cov-2 antibodies present in the patient's sample.

Statistical Analysis

A database using the statistical package R® (version 3.6.2, 2019-12-12) was constructed including information collected within the 3 surveys. Dwelling and individual characteristics and SARS-CoV-2 antibody reactivity were analyzed using descriptive statistics separately for each city. Fisher's exact tests and Chi² test were used to compare frequency distribution of categorical variables. A *P*-value of .1 or less was considered of statistical significance. Univariate Odds Ratios (OR) and their corresponding 95% confidence intervals (95% CI) were estimated for antibody results and selected variables separately for each city and for grouped cities according to their typology.

Ethical Approval and Informed Consent

The study protocol was approved by the ethics and research methods committee of the INS, (approval number CEMIN-09-2020). The study was conducted according to the Declaration of Helsinki and national regulations for human research in Colombia. Written informed consent was obtained from all parents/guardians, with assent from children when appropriate for their age.

Results

During the study period, 17 863 participants and 7075 households within the 10 selected cities were included. Of these, 3146 individuals (17.6%) were aged between 5 and 17 years, 22 (0.7%) were excluded as their serum samples were deemed inappropriate, leaving a final sample of 3124 participants included in this analysis. The number of participants per study site was as follows: Bogotá (n=651; 20.8%), Barranquilla (n=315; 10.0%), Bucaramanga (n=170; 5.4%), Cali (n=312; 9.9%), Cúcuta (n=271; 8.6%), Medellín (n=341; 10.9%), Villavicencio (n=271; 8.6%), Leticia (n=369; 11.8%), Ipiales (n=230; 7.3%), and Guapi (n=194; 6.2%) (Table 1). Figure 1, shows the geographical distribution of the 10 cities displaying selected socioeconomic characteristics.

Population Characteristics

A higher proportion of female participants was seen within study sites, except in Barranquilla and Bogotá,

where most participants were male (Table 1). The median age across study sites was 11 years (range 5-17). After grouping age according to life-course categories (childhood: 5-11 years and adolescence 12-17 years), most cities had a higher proportion of children aged between 12 and 17 years, being highest in Guapi (60.3%), Bogotá (57.5%), and Bucaramanga (55.9%) (Table 1).

As for health insurance, a higher proportion of children referred to belong to the subsidized health insurance as opposed to the employer-based health insurance. The largest proportions of children affiliated to the subsidized system were seen in Guapi (73.7%) and Ipiales (68.3%), and the lowest proportions were seen in Bogotá (19.7%), and Bucaramanga (40.6%).

When asked about previous COVID-19 diagnosis, more than 90% of participants from all cities did not refer a previous SARS-CoV-2 diagnosis. Leticia and Medellín, were the cities where a higher proportion of participants reported a previous COVID-19 diagnosis (3.3% and 3.2% respectively) (Table 1).

More than 90% of the surveyed children within the cities referred themselves as being enrolled in the school system, except for Ipiales, where only 77.1% referred school enrollment (data not shown). Cúcuta and Guapi had the highest proportion of children considered to have educational backwardness (24.0% and 27.3% respectively).

The majority of the study participants lived in dwellings classified in the lowest socio-economic stratum, with the highest proportions of this category seen in Guapi (98.5%), Cúcuta (85.6%) and Leticia (76.7%) and the lowest proportions in Cali (64.4%) and Bucaramanga (51.2%). Concerning household overcrowding, defined by more than 2 individuals per bedroom, Barranquilla, Leticia and Cúcuta had the highest proportions with 41.3%, 40.1%, and 30.3% respectively.

Access to public services defined by the presence of energy, aqueduct water and sewerage was seen in more than 90% of the dwellings in each city, except for Guapi and Leticia, where 86.6% and 48.8% (respectively) of the dwellings were classified as not having access to these combined services (Table 1).

SARS-CoV-2 Seroprevalence Results and Related Variables

Antibody testing results and corresponding univariate analysis with variables of interest for cities grouped by typology are shown in Table 2 (robust development), 3 (intermediate development) and 4 (incipient development). For most cities, SARS-CoV-2 antibody detection was under 50% of the studied population. The highest seropositivity rates were seen in Guapi (60.8%) (Table 4), Barranquilla (58.7%) (Table 2), and Leticia (50.7%)
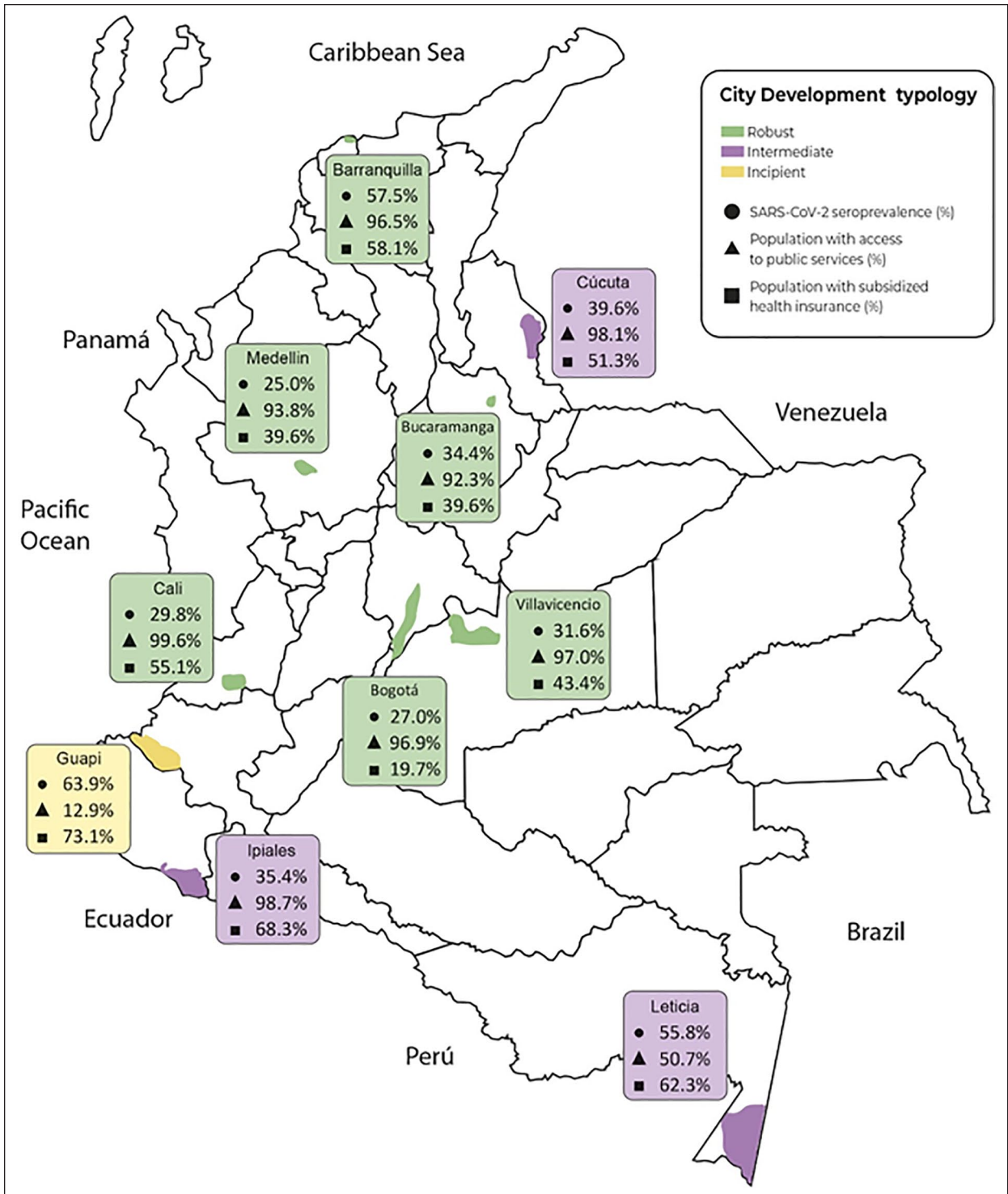
Table 1. Selected Individual and Household Characteristics of the Population of Children Aged 5 to 17 Years Included in the SARS-CoV-2 Antibody Seroprevalence Study in 10 Colombian Cities.

Characteristic	Barranquilla (n=315) n	%	Bogotá (n=651) n	%	Bucaramanga (n=170) n	%	Cali (n=312) n	%	Cúcuta (n=271) n	%	Guapí (n=194) n	%	Ipiales (n=230) n	%	Leticia (n=369) n	%	Medellín (n=341) n	%	Villavicencio (n=271) n	%	Total (n=3124) n	%
Sex																						
Male	162	51.4	327	50.2	78	45.9	134	42.9	134	49.4	85	43.8	105	45.7	180	48.8	177	56.4	126	46.5	1508	48.3
Female	153	48.6	324	49.8	92	54.1	178	57.1	137	50.6	109	56.2	125	54.3	189	51.2	164	52.2	145	53.5	1616	51.7
Age																						
5-11 years	146	46.3	277	42.5	75	44.1	156	50.0	126	46.5	77	39.7	103	44.8	189	51.2	162	51.6	128	47.2	1439	46.1
12-7 years	169	53.7	374	57.5	95	55.9	156	50.0	145	53.5	117	60.3	127	55.2	186	50.4	179	57.0	143	52.8	1691	54.1
Health insurance type																						
Employer-based	114	36.2	455	69.9	87	51.2	116	37.2	86	31.7	36	18.6	63	27.4	132	35.8	172	54.8	134	49.4	1395	44.6
Subsidized	183	58.1	128	19.7	69	40.6	172	55.1	139	51.3	143	73.7	157	68.3	230	62.3	135	43.0	123	45.4	1479	47.3
No insurance	15	4.8	36	5.5	11	6.5	22	7.1	42	15.5	11	5.7	10	4.3	3	0.8	26	8.3	6	2.2	182	5.8
No data	3	1.0	32	4.9	3	1.8	2	0.6	4	1.5	4	2.1	0	0.0	4	1.1	8	2.5	8	3.0	68	2.2
Previous COVID-19 diagnosis																						
No	309	98.1	595	91.4	169	99.4	304	97.4	265	97.8	194	100.0	228	99.1	357	96.7	325	95.3	260	95.9	3006	96.2
Yes	6	1.9	15	2.3	0	0.0	5	1.6	6	2.2	0	0.0	0	0.0	12	3.3	11	3.2	4	1.5	59	1.9
No data	0	0.0	41	6.3	1	0.6	3	1.0	0	0.0	0	0.0	2	0.9	0	0.0	5	1.5	7	2.6	59	1.9
Educational Backwardness*																						
Yes	40	12.7	90	13.8	38	22.4	41	13.1	65	24.0	53	27.3	38	16.5	65	17.6	64	20.4	41	15.1	535	17.1
No	269	85.4	507	77.9	132	77.6	266	85.3	196	72.3	139	71.6	188	81.7	299	81.0	268	85.4	225	83.0	2489	79.7
No data	6	1.9	54	8.3	0	0.0	5	1.6	10	3.7	2	1.0	4	1.7	5	1.4	9	2.9	5	1.8	100	3.2
Socio economic level																						
Low	238	75.6	425	65.3	87	51.2	201	64.4	232	85.6	191	98.5	158	68.7	283	76.7	231	73.6	179	66.1	2225	71.2
Middle-high	66	21.0	208	32.0	74	43.5	111	35.6	36	13.3	1	0.5	68	29.6	80	21.7	110	35.0	90	33.2	844	27.0
No data	11	3.5	18	2.8	9	5.3	0	0.0	3	1.1	2	1.0	4	1.7	6	1.6	0	0.0	2	0.7	55	1.8
Household overcrowding**																						
No	185	58.7	586	90.0	148	87.1	268	85.9	189	69.7	165	85.1	200	87.0	221	59.9	261	83.1	242	89.3	2465	78.9
Yes	130	41.3	65	10.0	22	12.9	44	14.1	82	30.3	29	14.9	30	13.0	148	40.1	80	25.5	29	10.7	659	21.1
Access to public services***																						
No	10	3.2	10	1.5	13	7.6	1	0.3	5	1.8	168	86.6	4	1.7	180	48.8	21	6.2	8	3.0	420	13.4
Yes	304	96.5	631	96.9	157	92.4	311	99.7	266	98.2	25	12.9	226	98.3	187	50.7	320	93.8	263	97.0	2690	86.1
No data	1	0.3	10	1.5	0	0.0	0	0.0	0	0.0	1	0.5	0	0.0	2	0.5	0	0.0	0	0.0	14	0.5

*Defined as any child without school enrollment, children aged 6 to 15 years with pre-school as highest educational level and/or children older than 15 years with primary school as highest educational level.

**Defined as more than 2 individuals per available bedroom in the household.

***Defined as combined access to aqueduct water, electricity and sewerage services.

Figure 1. Map of Colombia displaying geographical distribution, SARS-CoV-2 seroprevalence in population aged 5 to 17 years and selected socioeconomic characteristics of the 10 cities included in the Colombian SARS-CoV-2 seroprevalence study.

(Table 3). Cities with the lowest proportions of antibody seropositivity were Medellín (25.8%), Bogotá (27.2%), and Cali (28.8%) (Table 2).

A statistical analysis to understand the potential relationship between participant and household characteristics and seropositivity rates was performed. In Figure 2,

Table 2. SARS-CoV-2 Antibody Results and Univariate Analysis of Selected Individual and Household Characteristics of the Population of Children Aged 5 to 17 Years Included in the Colombian SARS-CoV-2 Antibody Seroprevalence Study. Results for Robust Development Cities.

Characteristic	Barranquilla (n=315) (+) n	%	(−) n	%	Bogotá (n=651) (+) n	%	(−) n	%	Bucaramanga (n=170) (+) n	%	(−) n	%	Cali (n=312) (+) n	%	(−) n	%	Medellin (n=341) (+) n	%	(−) n	%	Villavicencio (n=271) (+) n	%	(−) n	%
IgM + IgG																								
Totals	185	58.7	130	41.3	177	27.2	474	72.8	56	32.9	114	67.1	90	28.8	222	71.2	88	25.8	253	74.2	82	30.3	189	69.7
Sex																								
Male	94	29.8	68	21.6	89	13.7	238	36.6	26	15.3	52	30.6	34	10.9	100	32.1	37	10.9	140	41.1	39	14.4	87	32.1
Female	91	28.9	62	19.7	88	13.5	236	36.3	30	17.6	62	36.5	56	17.9	122	39.1	51	15.0	113	33.1	43	15.9	102	37.6
P value	.794				.987				.920				0.240				.032				.817			
OR (95% CI)	0.941 (0.601-1.475)				1.002 (0.710-1.416)				1.033 (0.543-1.962)				0.740 (0.448-1.223)				0.585 (0.358-0.956)				1.063 (0.632-1.787)			
Age																								
5-11 years	81	25.7	65	20.6	85	13.1	192	29.5	27	15.9	48	28.2	44	14.1	112	35.9	38	11.1	124	36.4	35	12.9	93	34.3
12-17 years	4	33.0	65	20.6	92	14.1	282	43.3	29	17.1	66	38.8	46	14.7	110	35.3	50	14.7	129	37.8	47	17.3	96	35.4
P value	.276				.084				.451				.803				.346				.323			
OR (95% CI)	0.778 (0.496-1.221)				1.356 (0.958-1.920)				1.280 (0.673-2.434)				0.939 (0.575-1.533)				0.790 (0.485-1.288)				0.768 (0.455-1.295)			
Health insurance type																								
Employer-based	53	16.8	61	19.4	115	17.7	340	52.2	21	12.4	66	38.8	25	8.0	91	29.2	41	12.0	131	38.4	42	15.5	92	33.9
Subsidized	123	39.0	60	19.0	35	5.4	93	14.3	26	15.3	43	25.3	56	17.9	116	37.2	42	12.3	93	27.3	39	14.4	84	31.0
No insurance	7	2.2	8	2.5	16	2.5	20	3.1	7	4.1	4	2.4	8	2.6	14	4.5	5	1.5	21	6.2	0	0.0	6	2.2
No data	2	0.6	1	0.3	11	1.7	21	3.2	2	1.2	1	0.6	1	0.3	1	0.3	0	0.0	8	2.3	1	0.4	7	2.6
P value	.009				.636				.067				.042				.155				.950			
OR (95% CI)	0.423 (0.262-0.685)				0.898 (0.577-1.398)				0.526 (0.263-1.050)				0.569 (0.329-0.981)				0.693 (0.417-1.149)				0.983 (0.580-1.665)			
Previous COVID-19 diagnosis																								
Yes	5	1.6	1	0.3	11	1.7	4	0.6	0	0.0	0	0.0	2	0.6	3	1.0	10	2.9	1	0.3	4	1.5	0	0.0
No	180	57.1	129	41.0	152	23.3	443	68.0	56	32.9	113	66.5	86	27.6	218	69.9	78	22.9	247	72.4	78	28.8	182	67.2
No data	0	0.0	0	0.0	14	2.2	27	4.1	0	0.0	1	0.6	2	0.6	1	0.3	0	0.0	5	1.5	0	0.0	7	2.6
P value	.721				.001				.318				.144				.000				.001			
OR (95% CI)	3.583 (0.413-31.03)				8.014 (2.514-25.54)				-				1.689 (0.277-10.29)				31.66 (3.990-251.2)				-			

(continued)

Table 2. (continued)

Characteristic	Barranquilla (n=315)				Bogotá (n=651)				Bucaramanga (n=170)				Cali (n=312)				Medellin (n=341)				Villavicencio (n=271)			
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Educational Backwardness*																								
Yes	163	51.7	106	33.7	141	21.7	366	56.2	42	24.7	90	52.9	72	23.1	194	62.2	70	20.5	198	58.1	69	25.5	156	57.6
No	18	5.7	22	7.0	20	3.1	70	10.8	14	8.2	24	14.1	15	4.8	26	8.3	17	5.0	47	13.8	13	4.8	28	10.3
No data	4	1.3	2	0.6	16	2.5	38	5.8	0	0.0	0	0.0	3	1.0	2	0.6	1	0.3	8	2.3	0	0.0	5	1.8
P value	.062				.271				.561				.208				.942				.894			
OR (95% CI)	1.879 (0.962-3.670)				1.348 (0.790-2.298)				0.8 (0.376-1.700)				0.643 (0.322-1.283)				0.977 (0.526-1.813)				0.952 (0.465-1.949)			
Socio economic level																								
Low	157	49.8	81	25.7	135	20.7	290	44.5	32	18.8	55	32.4	58	18.6	143	45.8	57	16.7	174	51.0	62	22.9	117	43.2
Middle-high	24	7.6	42	13.3	40	6.1	168	25.8	17	10.0	57	33.5	32	10.3	70	25.3	31	9.1	79	23.2	20	7.4	70	25.8
No data	4	1.3	7	2.2	2	0.3	16	2.5	7	4.1	2	1.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.7
P value	.000				.001				.058				.996				.489				.037			
OR (95% CI)	3.391 (1.920-5.990)				1.955 (1.309-2.918)				1.950 (0.973-3.909)				1.001 (0.600-1.670)				0.834 (0.500-1.392)				1.854 (1.033-3.327)			
Household overcrowding**																								
Yes	84	26.7	40	14.6	20	3.1	45	6.9	12	7.1	10	5.9	17	5.4	27	8.7	24	7.0	56	16.4	8	3.0	21	7.7
No	101	32.1	84	26.7	157	24.1	429	65.9	44	25.9	104	61.2	73	23.4	195	62.5	64	18.8	197	57.8	74	27.3	168	62.0
P value	.075				.567				.021				.122				.327				.740			
OR (95% CI)	1.518 (0.957-2.409)				1.214 (0.695-2.120)				2.836 (1.141-7.048)				1.681 (0.866-3.266)				1.319 (0.757-2.298)				0.864 (0.366-2.041)			
Access to public services***																								
Yes	180	57.1	124	39.4	174	26.7	457	70.2	47	27.6	110	64.7	90	28.8	221	70.8	83	24.3	237	69.5	80	29.5	183	67.5
No	4	1.3	6	1.9	1	0.2	9	1.4	9	5.3	4	2.4	0	0.0	1	0.3	5	1.5	16	4.7	2	0.7	6	2.2
No data	1	0.3	0	0.0	2	0.3	8	1.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
P value	.222				.839				.000				.261				.829				.493			
OR (95% CI)	2.177 (0.601-7.876)				3.426 (0.430-27.24)				0.189 (0.055-0.647)				-				1.120 (0.398-3.154)				1.311 (0.259-6.638)			

*Defined as any child without school enrollment, children aged 6- to 15 years with pre-school as highest educational level and/or children older than 15 years with primary school as highest educational level.

**Defined as more than 2 individuals per available bedroom in the household.

***Defined as combined access to aqueduct water, electricity, and sewerage services.
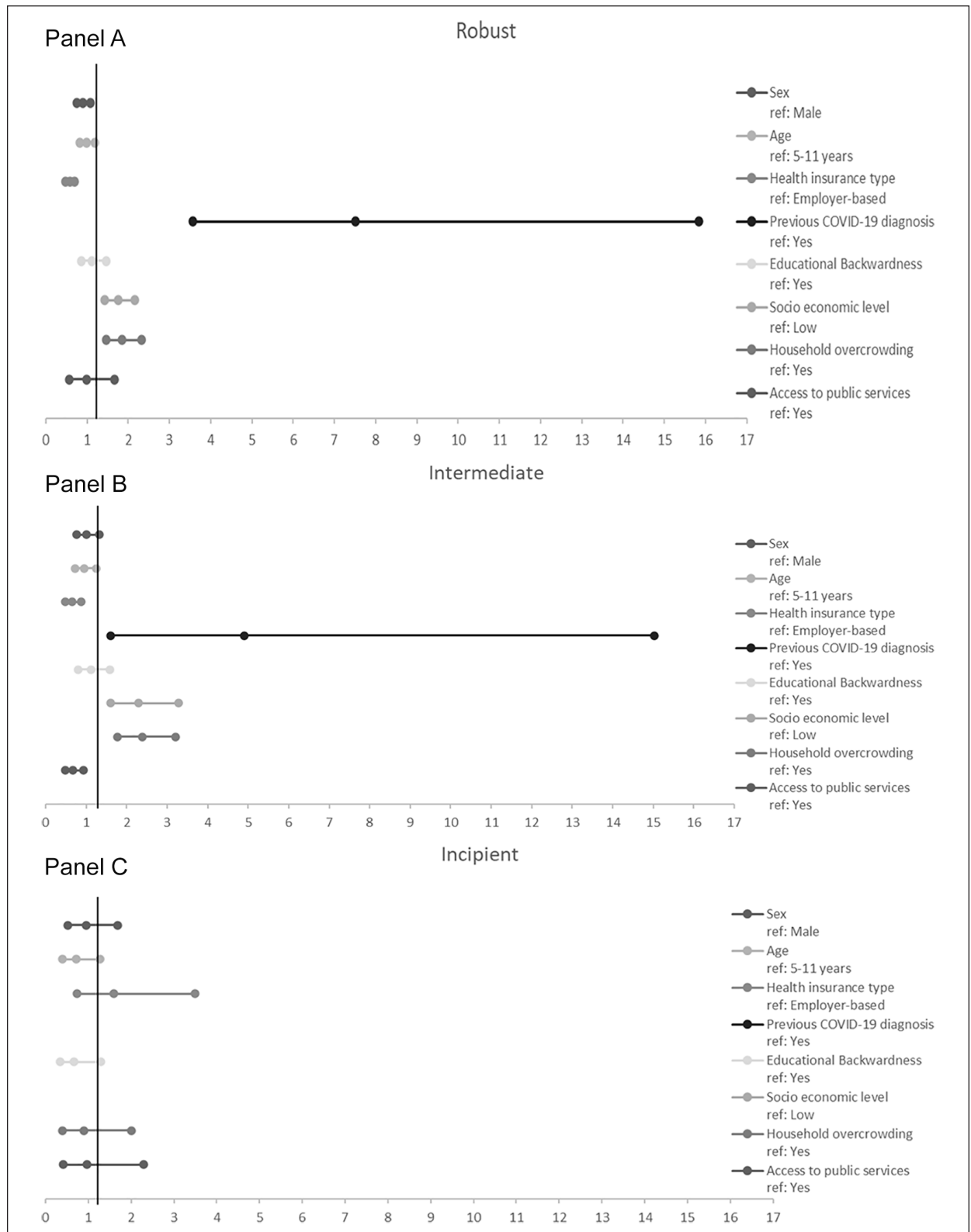
Table 3. SARS-CoV-2 Antibody Results and Univariate Analysis of Selected Individual and Household Characteristics of the Population of Children Aged 5 to 17 Years Included in the Colombian SARS-CoV-2 antibody seroprevalence study. Results for Intermediate Development Cities.

Characteristic	Ipiales (n = 230)				Leticia (n = 369)				Cúcuta (n = 271)			
	n	%	n	%	n	%	n	%	n	%	n	%
IgM + IgG	(+)		(−)		(+)		(−)		(+)		(−)	
Totals	77	33.5	153	66.5	187	50.7	182	49.3	105	38.7	166	61.3
Sex												
Male	35	15.2	70	30.4	93	25.2	87	23.6	50	18.5	84	31
Female	42	18.3	83	36.1	94	25.5	95	25.7	55	20.3	82	30.3
P value	.966				.711				.632			
OR (95% CI)	0.988 (0.570-1.712)				1.080 (0.718-1.625)				0.887 (0.544-1.447)			
Age												
5-11 years	33	14.3	70	30.4	91	24.7	92	24.9	48	17.7	78	28.8
12-17 years	44	19.1	83	36.1	96	26.0	90	24.4	57	21.0	88	32.5
P value	.677				.717				.838			
OR (95% CI)	0.889 (0.511-1.544)				0.927 (0.616-1.394)				0.950 (0.581-1.551)			
Health insurance type												
Employer-based	23	10.0	40	17.4	48	13.0	84	22.8	28	10.3	58	21.4
Subsidized	52	22.6	105	45.7	137	37.1	93	25.2	51	18.8	88	32.5
No insurance	2	0.9	8	3.5	1	0.3	2	0.5	24	8.9	18	6.6
No data	0	0.0	0	0.0	1	0.3	3	0.8	2	0.7	2	0.7
P value	.632				.001				.528			
OR (95% CI)	1.161 (0.630-2.139)				0.387 (0.249-0.603)				0.832 (0.472-1.469)			
Previous COVID-19 diagnosis												
Yes	0	0.0	0	0.0	8	2.2	4	1.1	6	2.2	0	0.0
No	76	33.0	152	66.1	179	48.5	178	48.2	99	36.5	166	61.3
No data	1	0.4	1	0.4	0	0	0	0.0	0	0.0	0	0.0
P value	.300				.415				.014			
OR (95% CI)	-				1.988 (0.588-6.723)				-			
Educational Backwardness*												
Yes	63	27.4	125	54.3	156	42.3	143	38.8	73	26.9	123	45.4
No	12	5.2	26	11.3	27	7.3	38	10.3	28	10.3	37	13.7
No data	2	3.2	2	1.6	4	1.1	1	0.3	4	1.5	6	2.2
P value	.818				.120				.403			
OR (95% CI)	1.092 (0.516-2.307)				1.535 (0.892-2.642)				0.784 (0.443-1.386)			
Socio economic level												
Low	57	24.8	101	43.9	161	43.6	122	33.1	92	33.9	140	51.7
Middle-high	17	7.4	51	22.2	22	6.0	58	15.7	11	4.1	25	9.2
No data	3	1.3	1	0.4	4	1.1	2	0.5	2	0.7	1	0.4
P value	.104				.000				.298			
OR (95% CI)	1.693 (0.894-3.203)				3.479 (2 18-5.995)				1.493 (0.701-3.181)			
Household overcrowding**												
Yes	11	4.8	19	8.3	97	26.3	51	13.8	41	15.1	41	15.1
No	66	28.7	134	58.3	90	24.4	131	35.5	64	23.6	125	46.1
P value	.691				.000				.122			
OR (95% CI)	1.175 (0.528-2.613)				2.768 (1.796-4.265)				1.953 (1.152-3.309)			
Access to public services***												
Yes	77	33.5	149	64.8	94	25.5	93	25.2	102	37.6	164	60.5
No	0	0.0	4	1.7	91	24.7	89	24.1	3	1.1	2	0.7
No data	0	0.0	0	0.0	2	0.5	0	0.0	0	0.0	0	0.0
P value	.841				.848				.262			
OR (95% CI)	-				0.988 (0.656-1.488)				0.414 (0.068-2.524)			

*Defined as any child without school enrollment, children aged 6 to 15 years with pre-school as highest educational level and/or children older than 15 years with primary school as highest educational level.

**Defined as more than 2 individuals per available bedroom in the household.

***Defined as combined access to aqueduct water, electricity and sewerage services.

Table 4. SARS-CoV-2 Antibody Results and Univariate Analysis of Selected Individual and Household Characteristics of the Population of Children Aged 5 to 17 Years Included in the Colombian SARS-CoV-2 Antibody Seroprevalence Study. Results for Incipient Development City.

Characteristic	Guapí (n = 194)			
	n	%	n	%
IgM + IgG	(+)		(−)	
Totals	118	60.8	76	39.2
Sex				
Male	51	26.3	34	17.5
Female	67	34.5	42	21.6
P value	.835			
OR (95% CI)	0.940 (0.526-1.680)			
Age				
5-11 years	43	22.2	34	17.5
12-17 years	75	38.7	42	21.6
P value	.249			
OR (95% CI)	0.708 (0.393-1.274)			
Health insurance type				
Employer-based	25	12.9	11	5.7
Subsidized	84	43.3	59	30.4
No insurance	7	3.6	4	2.1
No data	2	1.0	2	1.0
P value	.240			
OR (95% CI)	1.596 (0.729-3.494)			
Previous COVID-19 diagnosis				
Yes	0	0.0	0	0.0
No	118	60.8	76	39.2
No data	0	0.0	0	0.0
P value	.517			
OR (95% CI)	-			
Educational Backwardness*				
Yes	81	41.8	58	29.9
No	36	18.6	17	8.8
No data	1	0.5	1	0.5
P value	.220			
OR (95% CI)	0.659 (0.338-1.286)			
Socio economic level				
Low	117	60.3	74	38.1
Middle-high	1	0.5	0	0.0
No data	0	0.0	2	1.0
P value	.685			
OR (95% CI)	-			
Household overcrowding**				
Yes	17	8.8	12	6.2
No	101	52.1	64	33.0
P value	.792			
OR (95% CI)	0.897 (0.402-2.003)			
Access to public services***				
Yes	15	7.7	10	5.2
No	102	52.6	66	34.0
No data	1	0.5	0	0.0
P value	.928			
OR (95% CI)	0.970 (0.411-2.289)			

*Defined as any child without school enrollment, children aged 6 to 15 years with pre-school as highest educational level and/or children older than 15 years with primary school as highest educational level.
**Defined as more than 2 individuals per available bedroom in the household.
***Defined as combined access to aqueduct water, electricity and sewerage services.

Figure 2. Forest plots showing Odds Ratios (OR) and 95% Confidence Intervals estimates for positive SARS-CoV-2 antibody results and selected socio economic and clinical variables in cities grouped by typology. Panel A Robust development typology, Panel B Intermediate development typology, and Panel C Incipient development typology.

estimated OR and 95% CI calculated after grouping cities according to their typology is shown.

When analyzing the robust development cities, sex differences were seen between the seropositive and seronegative children in the city of Medellín, as being male, posed a lower probability of having a positive SARS-CoV-2 antibody result (P = .032, OR: 0.585, 95% CI 0.358-0.956) when compared to the female population (Table 2). Similarly, for the city of Bucaramanga, living in a household with adequate public services was protective against having a positive SARS-CoV-2 antibody test (P = .000, OR: 0.189, 95% CI 0.055-0.647) (Table 2). After performing a grouped analysis for these cities, children affiliated to the employer-based health insurance showed lower SARS-CoV-2 seropositive rates (OR: 0.579, 95% CI 0.477-0.703). Factors that were found to be related to a higher probability of having a positive SARS-CoV-2 antibody test were previous COVID-19 diagnosis (OR: 7.517, 95% CI 3.566-15.84), belonging to the lowest socioeconomic stratum (OR: 1.758, 95% CI 1.427-2.165) and living in an overcrowded household (OR: 1.846, 95% CI 1.467-2.323) (Figure 2, panel A).

As for the intermediate development cities, no associations between positive SARS-CoV-2 antibody results and variables such as sex, age group and school backwardness were established either for individual city or grouped analysis (Table 3, Figure 2 panel B). After performing a grouped analysis, children having an employer-based health insurance and living in a household with adequate access to public services, had a lower probability of having a positive SARS-CoV-2 antibody test (OR: 0.648, 95%CI 0.480-0.874 and OR: 0.679. 95% CI 0.491-0.939 respectively). On the other hand, children who referred having a previous COVID-19 diagnosis (OR: 4.903, 95% CI 1.600-15.02), belonged to the lowest socioeconomic stratum (OR: 2.288, 95% CI 1.599-3.275) and lived in an overcrowded household (OR: 2.379, 95% CI 1.769-3.199), were all found to be factors related with a higher probability of having a positive SARS-CoV2 antibody test (Figure 1 panel B).

For the only city categorized in incipient development (Guapi) (Table 4, Figure 2 panel C), no significant relation between demographic and clinical variables and SARS-CoV-2 antibody results were found.

Discussion

This study shows the seroprevalence rate of SARS-CoV-2 antibodies in a population of children aged between 5 and 17 years in 10 Colombian cities. The study took place 6 to 12 months after the beginning of the pandemic in the country and after reaching the country's first pandemic peak (July 2020), which registered 10 086 deaths.[19] Although most cities had seroprevalence results within the expected range (approximately 30%), there were important differences seen within the study sites, where cities like Guapi, Barranquilla, and Leticia were well above the expected SARS-CoV-2 seropositivity rates for the country.

Other authors who have explored SARS-CoV-2 antibody seropositivity in children and adolescents have reported lower rates than what was found within our population. Rostami et al published a meta-analysis where the pooled prevalence for SARS-CoV-2 antibodies in the population younger than 19 years of age was found to be 2.28%,[5] although most of the studies included in this analysis belonged to high-income countries and were developed early in the pandemic. On the other hand Figar et al[20] studied a population in a low-income neighborhood in Buenos Aires, Argentina, reporting a SARS-CoV-2 prevalence of 62% in male adolescents aged 14 to 19 years, being the highest within the studied population. Although it is necessary to account for factors such as the timing of the pandemic, the type of laboratory analysis employed and the population characteristics, these seroprevalence differences also need to be understood within the context surrounding the studied populations.

In our study 3 of the largest and more developed cities in Colombia (Cali, Medellín, and Bogotá), showed the lowest antibody positivity results, compared to smaller and less developed cities, especially Guapi and Leticia that had some of the highest antibody positivity rates. This finding is somewhat unexpected, as Colombia's SARS-CoV-2 surveillance system registers higher infection rates in big cities that concentrate a large proportion of the country's population such as Bogotá and Medellín. These results could be reflecting the gap existing between the infected and exposed individuals, where the latter are not identified through routine disease surveillance systems, leaving an important number of unidentified cases, which can be more prominent in younger populations where disease tends to be asymptomatic. Also, it is possible that populations with more economic restrictions as seen in Guapi and Leticia could face numerous challenges when adopting disease-mitigating activities such as access to personal protective equipment (PPE), increasing the risk of viral exposure.

Interestingly, results from the adult population in this same study show similar findings to the population of children and adolescents,[21] where the rate of SARS-CoV-2 antibody detection displays similar trends between these 2 population age groups. Other studies that have compared pediatric versus adult SARS-CoV-2

seroprevalence have found that younger populations have lower SARS-CoV-2 antibody detection.[4,22-25] In our analysis, belonging to the younger (5-11 years) or older (12-17 years) age groups did not make a difference in terms of SARS-CoV-2 antibody positivity for individual or grouped city analysis. SARS-CoV-2 antibody seropositivity studied among the pediatric age group has shown inconsistent results where both higher seropositivity rates in older[25] and younger age groups have been reported.[23,26]

As is recognized, children and adolescents, although not exempt from disease, do have a lesser burden in terms of number of reported infections and their severity. In spite of this, children have been considered as possible viral reservoirs (similar to influenza virus) and as such have been included in pandemic mitigation policies.[27] In Colombia, since the declaration of the sanitary emergency in March 2020, many public health measures that included the population of children and adolescents were established, such as limited outdoor activities, school closures, use of face masks (for children aged 2 years and older) and restriction to travel. These circumstances made children spend most of the time at their homes, where exposure to SARS-CoV-2 most likely occurred.[27]

Currently, clear risk factors for SARS-CoV-2 disease course are recognized, mainly centering in age, gender and underlying conditions, but less evidence exists regarding SARS-CoV-2 disease exposure risk factors, especially in children and adolescents. As in other childhood diseases, an interplay between individual and contextual characteristics influence disease occurrence. This fact was highlighted by Zar et al,[28] who called for the need to acknowledge that although all individuals were at risk of SARS-CoV-2 infection, certain population characteristics increased these vulnerabilities. Among these were the socioeconomic status, living conditions, type of employment, and access to health care. As shown in our results, contextual factors seem to be playing an important role in SARS-CoV-2 exposure rates in children and adolescents within these 10 Colombian cities.

Guapi, the only city classified within the incipient development typology, is located in the Colombian Pacific Coast, it has a population of 27 616 inhabitants with a large majority being afrodescendentes (97.7%). More than half of the population is aged between 15 and 59 years and only 10% are 60 years or older. Important infrastructure deprivations exist as only 51.7% of the city's households have access to electricity according to the national 2018 census data.[29] In our study, this city showed the highest prevalence of SARS-CoV-2 antibodies among children and adolescents. Although no specific sociodemographic characteristics were associated with SARS-COV-2 antibody results, it is likely that the prevalent social and economic deprivations to which a large proportion of the population is exposed, can explain this high seropositivity rate.

To note, the population in Guapi in spite of having the highest seropositivity rates, had the lowest referral of previous COVID-19 diagnosis within children and adolescents. This finding is somehow unexpected as a referral of previous COVID-19 diagnosis was associated with SARS-CoV-2 antibody detection, as seen in the intermediate and robust development cities in our analysis. Although numerous factors can explain this finding, given the socioeconomic conditions of this population it is likely that a restriction to COVID-19 testing exists limiting the population`s capacity of getting diagnosed. This restriction to COVID-19 diagnostic tests has been previously documented in marginalized populations,[30] where large disparities were seen not only in disease incidence but also in access to COVID-19 diagnostic tests. This finding should warrant further research as it may help in the adjustment of more adequate public health interventions.

Cities in the intermediate development typology share borders with Brazil (Leticia), Ecuador (Ipiales), and Venezuela (Cúcuta). Leticia is the capital of the Amazon department, has a population of 48 144 inhabitants of which 43.7% are indigenous. Ipiales and Cúcuta are larger cities with 116 136 and 711 715 inhabitants respectively. Almost 60% of the population in all 3 cities are aged between 15 and 59 years and more than 90% of the households have access to electricity according to the national 2018 census data sup.[31-33] Being border cities implies diverse population dynamics, as migration activities are ongoing and increase population movements and interactions. Leticia had the third highest seropositivity rate among the 10 cities, with 50.7% testing positive. The amazon region was one of the first in Colombia to reach the pandemic peak and as it shares a large border with northern Brazil, one of the most affected early in the pandemic, these findings could be a reflection of the pandemic dynamics in this neighbor country.[34]

Cities within the robust development typology account for most of the largest and densely populated cities in the country. Bogotá, Medellín, and Cali have populations of more than 2 million people, being highest in Bogotá with almost 7.5 million people. Barranquilla, Bucaramanga and Villavicencio all have less than 1.5 million inhabitants. None of these cities share borders with other countries and only Barranquilla has a coastline. All 6 cities are considered as districts, which gives them financial and administrative independence. As seen in the other city

typologies, more than 60% of the population are aged between 15 and 59 years and more than 99% of the households have access to electricity[35-39].

Within these cities, Barranquilla was found to have the second highest seropositivity rate with 58.7% of the population of children and adolescents testing positive for SARS-CoV-2 antibody detection. Contrastingly, Bogotá, Cali, and Medellín were the cities with the lowest seroprevalence levels, in spite of having the highest numbers of reported COVID-19 cases.[19] Although these cities share some characteristics, differences in climate, culture and city dynamics are accentuated and can somehow explain the differences in SARS-CoV-2 seroprevalence.

Although living conditions in cities within the intermediate and robust typologies are less deprived than those found in Guapi, high rates of socioeconomic restrictions were present and found to be correlated with SARS-CoV-2 seropositivity among children and adolescents. Advantageous conditions such as having employer-based health insurance (which is correlated with higher family income) and living in a household with adequate public services, decreased by approximately 30% the probability of having previous exposure to SARS-CoV-2 in the intermediate development cities and an employer-based health insurance reduced by 43% the probability of having a positive antibody test in the robust development cities. On the contrary, belonging to the lowest socioeconomic stratum and living in an overcrowded household implied an almost 2-fold increase in the probability of SARS-COV-2 exposure among the intermediate and robust development cities. Different epidemiological analyzes related to the COVID-19 pandemic, show that income and access to health care are fundamental aspects to be addressed in social inequalities especially in low-income countries.[40]

Negative health impacts related to deprived socioeconomic conditions have been recognized for COVID-19 and other diseases. An interplay between a higher biological susceptibility to disease (due to higher prevalence of chronic underlying diseases), inappropriate living conditions (such as overcrowding) and difficulties to perform adequate disease mitigation activities (such as social distancing, access to PPE) can have a cumulative effect in SARS-CoV-2 exposure risk.[41]

Our findings are in accordance with other seroprevalence studies, where socioeconomic contexts are found to play a lead role in terms of SARS-CoV-2 exposure risk and infection. Higher exposure rates have been found in ethnic minority populations,[30,42] children living in poverty, inadequate dwelling conditions,[42] among others. These contextual factors should be accounted for when planning public health interventions aimed to mitigate SARS-CoV-2 impacts.

Conclusions

These results show that children and adolescents in Colombia have had substantial impacts during the first COVID-19 pandemic year, as high proportions of positive SARS-CoV-2 antibodies (and similar to adults in the same population) were detected in this group of children. Important seroprevalence differences across the studied population were identified, with the highest SARS-CoV-2 antibody positivity seen in the city categorized with incipient development where important socio economic deprivations exist. For intermediate and robust development cities, living in advantageous conditions such as higher socioeconomic status, employer-based health insurance and access to public services were important contributors to not being exposed to SARS-CoV-2. These results can help in planning resource allocation directed to reduce the pandemic's negative impacts in the Colombian population, where children and adolescents should be included, prioritizing those with higher social vulnerabilities.

Limitations

Although all cities included in the analysis have had their first pandemic peak when the study was developed, it occurred in different time frames between cities and as such, variations in the date of sample collection between cities could have implications in the differences found in SARS-CoV-2 antibody detection. Albeit previous COVID-19 diagnosis was found to be significantly related to positive antibody detection in children living in the robust and intermediate cities, the identification of this past infection was based solely on individual's referral without official confirmation and thus be subject of referral bias. Official data to compare confirmed positive cases in each city when the study was conducted was not available, leaving important information about disease dynamics unknown. The fact that only one city within the incipient development category was included in the study could limit the understanding of the pandemic dynamics in this type of population.

Author Contributions

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References

1. World health Organization. WHO Director-General's opening remarks at the media briefing on COVID-19. WHO. April 2020:1-4. https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19—11-march-2020. Accesed July 2021.

2. Cui X, Zhao Z, Zhang T, et al. A systematic review and meta-analysis of children with coronavirus disease 2019 (COVID-19). *J Med Virol*. 2021;93(2):1057-1069. doi:10.1002/jmv.26398

3. Perikleous E, Tsalkidis A, Bush A, Paraskakis E. Coronavirus global pandemic: an overview of current findings among pediatric patients. *Pediatr Pulmonol*. 2020;55(12):3252-3267. doi:10.1002/ppul.25087

4. Pollán M, Pérez-Gómez B, Pastor-Barriuso R, et al. Prevalence of SARS-CoV-2 in Spain (ENE-COVID): a nationwide, population-based seroepidemiological study. *Lancet*. 2020;396(10250):535-544. doi:10.1016/S0140-6736(20)31483-5

5. Rostami A, Sepidarkish M, Leeflang MMG, et al. SARS-CoV-2 seroprevalence worldwide: a systematic review and meta-analysis. *Clin Microbiol Infect*. 2021;27(3):331-340. doi:10.1016/j.cmi.2020.10.020

6. Dattner I, Goldberg Y, Katriel G, et al. The role of children in the spread of COVID-19: Using household data from Bnei Brak, Israel, to estimate the relative susceptibility and infectivity of children. *PLoS Comput Biol*. 2021;17(2):e1008559. doi:10.1371/journal.pcbi.1008559

7. Tönshoff B, Müller B, Elling R, et al. Prevalence of SARS-CoV-2 infection in children and their parents in southwest Germany. *JAMA Pediatr*. 2021;175(6):586-593. doi:10.1001/jamapediatrics.2021.0001

8. CDC. Coronavirus disease 2019 in children—United States, February 12–April 2, 2020. 2019. https://www.cdc.gov/coronavirus/2019-ncov/downloads/pui-form.pdf. Accessed October 10, 2021.

9. Williams PCM, Howard-Jones AR, Hsu P, et al. SARS-CoV-2 in children: spectrum of disease, transmission and immunopathological underpinnings. *Pathology*. 2020;52(7):801-808. doi:10.1016/j.pathol.2020.08.001

10. Organization for Economic Cooperation and Development. The state of school education. One year into the COVID pandemic. Preliminary Results, March 2021. https://www.oecd-ilibrary.org/education/the-state-of-school-education_201dde84-en

11. Burström B, Tao W. Social determinants of health and inequalities in COVID-19. *Eur J Public Health*. 2020;30(4):617-618. doi:10.1093/eurpub/ckaa095

12. Dennis-Heyward EA, Shah SN. Pediatric COVID-19 disparities and prioritizing equity—Children are not spared. *JAMA Pediatr*. 2021;175:898. doi:10.1001/jamapediatrics.2021.1682

13. Departamento Administrativo Nacional de Estadística. Pobreza monetaria en Colombia. Actualización metodológica. 2020. https://www.dane.gov.co/files/investigaciones/condiciones_vida/pobreza/2019/Presentacion-pobreza-monetaria_2019.pdf. Accessed August 11, 2021.

14. Departamento Nacional de Planeación. Tipologías Departamentales y Municipales : Una propuesta para comprender las entidades. 2015:38. https://colaboracion.dnp.gov.co/CDT/DesarrolloTerritorial/Tip-Formato Publicacion.pdf. Accessed August 11 2021.

15. Mercado-Reyes M, Malagón-Rojas J, Rodríguez-Barraquer I, Zapata-Bedoya S, Wiesner M, Cucunubá Z, Toloza-Pérez YG, Hernández-Ortiz JP, Acosta-Reyes J, Parra-Barrera E, Ibáñez-Beltrán E, Quinche GG, Muñoz-Galindo L, Rubio V, Galindo-Borda M, Osorio-Velázquez EG, Bermúdez-Forero A, Pinto-Chacón N, Puerto-Castro G, Franco-Muñoz C, Estupiñan MI, Villar LÁ, Gore-Saravia N, Miranda-Montoya MC, Castellanos J, Valle EM, Navarro-Lechuga E, Oviedo JD, Ospina-Martínez M. Seroprevalence of anti-SARS-CoV-2 antibodies in Colombia, 2020: A population-based study. *Lancet Reg Health Am*. 2022 May;9:100195. doi: 10.1016/j.lana.2022.100195. Epub 2022 Feb 5. PMID: 35156075; PMCID: PMC8817632.

16. Radinger T, Echazarra A, Guerrero G, Pablo J. OCDE Revisión de Recursos Escolares COLOMBIA. 2018. www.oecd.org/education/schoolresourcesreview.htm-www.oecd-ilibrary.org. Accessed July 30, 2021.

17. Departamento Administrativo Nacional de Estadística. Dirección de Regulación, Planeación, Estandarización y Normalización. *Caracterización temática servicios públicos en Colombia*. 2011. https://www.dane.gov.co/files/sen/caracterizaciones/planificacion/CSP.pdf. Accessed August 11, 2021.

18. Siemens Advia Centaur Immunoassay systems. Assay for the detection of total antibodies to SARS-CoV-2. https://www.fda.gov/media/138446/download. Accessed October 13, 2021.

19. Instituto Nacional de Salud. COVID-19 en Colombia. https://www.ins.gov.co/Noticias/Paginas/Coronavirus.aspx. Accessed October 13, 2021.

20. Figar S, Pagotto V, Luna L, et al. Severe acute respiratory syndrome coronavirus 2019. Seroepidemiology study in Argentinian slum. *Medicina*. 2021;81(2):135-142.

21. Instituto Nacional de Salud. Estudio Seroprevalencia de SARS-CoV-2 durante la epidemia en Colombia: estudio país. 2020:1-14. https://www.ins.gov.co/Biblioteca Digital/Seroprevalencia-estudio-colombia.pdf. Accessed November 1, 2021.

22. Havers FP, Reed C, Lim T, et al. Seroprevalence of antibodies to SARS-CoV-2 in 10 sites in the United States, March 23-May 12, 2020. *JAMA Intern Med*. 2020;180(12):1576-1786. doi:10.1001/jamainternmed.2020.4130

23. Torres JP, Piñera C, De La Maza V, et al. Severe acute respiratory syndrome Coronavirus 2 antibody prevalence in blood in a large school community subject to a Coronavirus disease 2019 outbreak: A cross-sectional study. *Clin Infect Dis*. 2021;73(2):e458-e465. doi:10.1093/cid/ciaa955

24. Murhekar MV, Bhatnagar T, Selvaraju S, et al. SARS-CoV-2 antibody seroprevalence in India, August–September, 2020: findings from the second nationwide household serosurvey. *Lancet Glob Health*. 2021;9(3):e257-e266. doi:10.1016/S2214-109X(20)30544-1

25. Stringhini S, Wisniak A, Piumatti G, et al. Seroprevalence of anti-SARS-CoV-2 IgG antibodies in Geneva, Switzerland (SEROCoV-POP): a population-based study. *Lancet*. 2020;396(10247):313-319. doi:10.1016/S0140-6736(20)31304-0

26. Dingens AS, Crawford KHD, Adler A, et al. Serological identification of SARS-CoV-2 infections among children visiting a hospital during the initial Seattle outbreak. *Nat Commun*. 2020;11(1):4378. doi:10.1038/s41467-020-18178-1

27. Irfan O, Li J, Tang K, Wang Z, Bhutta ZA. Risk of infection and transmission of SARS-CoV-2 among children and adolescents in households, communities and educational settings: a systematic review and meta-analysis. *J Glob Health*. 2021;11:05013. doi:10.7189/jogh.11.05013

28. Zar HJ, Dawa J, Fischer GB, Castro-Rodriguez JA. Challenges of COVID-19 in children in low- and middle-income countries. *Paediatr Respir Rev*. 2020;35:70-74. doi:10.1016/j.prrv.2020.06.016

29. Departamento Administrativo Nacional de Estadística. Guapi/Cauca. 2019:96. https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/censo-nacional-de-poblacion-y-vivenda-2018/como-vivimos. Accessed October 13, 2021.

30. Saatci D, Ranger TA, Garriga C, et al. Association between race and COVID-19 outcomes among 2.6 million children in England. *JAMA Pediatr*. 2021;175(9):928-938. doi:10.1001/jamapediatrics.2021.1685

31. Departamento Administrativo Nacional de Estadística. Ipiales/Nariño. 2019:96. https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/censo-nacional-de-poblacion-y-vivenda-2018/como-vivimos. Accessed October 13, 2021.

32. Departamento Administrativo Nacional de Estadística. San José de Cúcuta/Norte de Santander. 2019:96. https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/censo-nacional-de-poblacion-y-vivenda-2018/como-vivimos. Accessed October 13, 2021.

33. Departamento Administrativo Nacional de Estadística. Leticia/Amazonas. 2019:96. https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/censo-nacional-de-poblacion-y-vivenda-2018/como-vivimos. Accessed October 13, 2021.

34. Hallal PC, Hartwig FP, Horta BL, et al. SARS-CoV-2 antibody prevalence in Brazil: results from two successive nationwide serological household surveys. *Lancet Glob Health*. 2020;8(11):e1390-e1398. doi:10.1016/S2214-109X(20)30387-9

35. Departamento Administrativo Nacional de Estadística. Bogotá DC/Cali /Valle del Cauca. *¿Cómo vivimos?* 2019:96. https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/censo-nacional-de-poblacion-y-vivenda-2018/como-vivimos. Accessed October 13, 2021.

36. Departamento Administrativo Nacional de Estadística. Medellín/Antioquia. 2019:96. https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/censo-nacional-de-poblacion-y-vivenda-2018/como-vivimos. Accessed October 13, 2021.

37. Departamento Administrativo Nacional de Estadística. Villaviencio/Meta. 2019:96. https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/censo-nacional-de-poblacion-y-vivenda-2018/como-vivimos. Accessed October 13, 2021.

38. Departamento Administrativo Nacional de Estadística. Barranquilla/Atlántico. 2019:96. https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/censo-nacional-de-poblacion-y-vivenda-2018/como-vivimos. Accessed October 13, 2021.

39. Departamento Administrativo Nacional de Estadística. Bucaramanga/Santander. 2019:96. https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/censo-nacional-de-poblacion-y-vivenda-2018/como-vivimos. Accessed October 13, 2021.

40. Lopez-Valcarcel BG. [COVID-19 inequalities as a challenge for healthcare management]. *J Healthc Qual Res*. 2021;36(4):183-185. doi:10.1016/j.jhqr.2021.07.001

41. Bambra C, Riordan R, Ford J, Matthews F. The COVID-19 pandemic and health inequalities. *J Epidemiol Community Health*. 2020;74(11):964-968. doi:10.1136/jech-2020-214401

42. Levorson RE, Christian E, Hunter B, et al. SARS-CoV-2 Seroepidemiology in Children and Adolescents 1. *medRxiv*. 2021:2021.01.28.21250466. doi:10.1101/2021.01.28.21250466