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Is Colombia an example of successful containment of the 2020 COVID-19 pandemic? A critical analysis of the epidemiological data, March to July 2020



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ARTICLE INFO

Article history:

Received 10 June 2020

Received in revised form 5 August 2020

Accepted 5 August 2020

Keywords:

SARS-Cov-2

COVID-19

Epidemiology

Colombia

Pandemic

Lockdown

ABSTRACT

Background: Colombia detected its first coronavirus disease 2019 (COVID-19) case on March 2, 2020. From March 22 to April 25, it implemented a national lockdown that, apparently, allowed the country to keep a low incidence and mortality rate up to mid-May. Forced by the economic losses, the government then opened many commercial activities, which was followed by an increase in cases and deaths. This paper presents a critical analysis of the Colombian surveillance data in order to identify strengths and pitfalls of the control measures.

Methods: A descriptive analysis of PCR-confirmed cases between March and July 25 was performed. Data were described according to the level of measurement. Incidence and mortality rates of COVID-19 were estimated by age, sex, and geographical area. Sampling rates for suspected cases were estimated by geographical area, and the potential for case underestimation was assessed using sampling differences.

Results: By July 25, Colombia (population 50 372 424) had reported 240 745 cases and 8269 deaths (case fatality rate of 3.4%). A total of 1 370 271 samples had been analyzed (27 405 samples per million people), with a positivity rate of 17%. Sampling rates per million varied by region from 2664 to 158 681 per million, and consequently the incidence and mortality rates also varied. Due to geographical variations in surveillance capacity, Colombia may have overlooked up to 82% of the actual cases.

Conclusion: Colombia has a lower case and mortality incidence compared to other South American countries. This may be an effect of the lockdown, but may also be attributed, to some extent, to geographical differences in surveillance capacity. Indigenous populations with little health infrastructure have been hit the hardest.

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Introduction

Coronavirus disease 2019 (COVID-19) is a new emerging infectious disease, and more than 17 million cases and more than

680 000 deaths had been reported worldwide by August 1, 2020 (World Health Organization, 2020b). It has been declared a pandemic by the World Health Organization (WHO) and has prompted lockdowns of over 2 months in most countries (World Health Organization, 2020a). The virus has the potential to transmit from symptomatic and asymptomatic individuals, which has made it difficult to control its spread around the globe.

Colombia identified its first imported case of COVID-19 on March 2, and by July 25 had reported 240 745 cases and 8269

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deaths (Instituto Nacional de Salud, 2020a), which is a low incidence compared to other countries in Latin America (Pan American Health Organization, 2020). It has been postulated that this relatively mild behavior of the virus may be explained in part by the lockdown and by demographic features of the population, considering that 86.4% of the Colombian population are under 60 years of age (Departamento Administrativo Nacional de Estadística, 2018).

The mild impact of the COVID-19 pandemic in Colombia is unexpected, given that it is one of the most unequal countries in a very unequal region of the world, with a health system that, despite having high population insurance coverage (94.6%) (Ministerio de Salud y Protección Social, 2018), still struggles to provide good quality healthcare services. In addition, a large number of hospitals are currently underfunded, since financial resources flow from health insurance organizations (HIO) to hospitals through a cumbersome process in which the HIOs have the upper hand and can leverage multiple strategies in order to block payments after a service has been provided. Currently, HIOs

are withholding more than US\$ 3 billion from hospitals for individual health services provided from 2000 through 2019, a debt that doubled over the last 5 years (Asociación Colombiana de Hospitales y Clínicas, 2019).

Given the structural shortcomings of the Colombian health care system, the apparent good standing of the country during the COVID-19 pandemic is a positive but unexpected outcome. This article presents the results of a critical analysis of the epidemiological data from the pandemic in Colombia, 5 months after the report of the first case, and tries to explore the reasons behind the apparent success of Colombia in maintaining a low number of COVID-19 cases.

Methods

Study design

This is a descriptive analysis of PCR-confirmed COVID-19 cases that occurred in Colombia from March 2 to July 25, 2020. Epidemiological data are curated by the Colombian National Institute

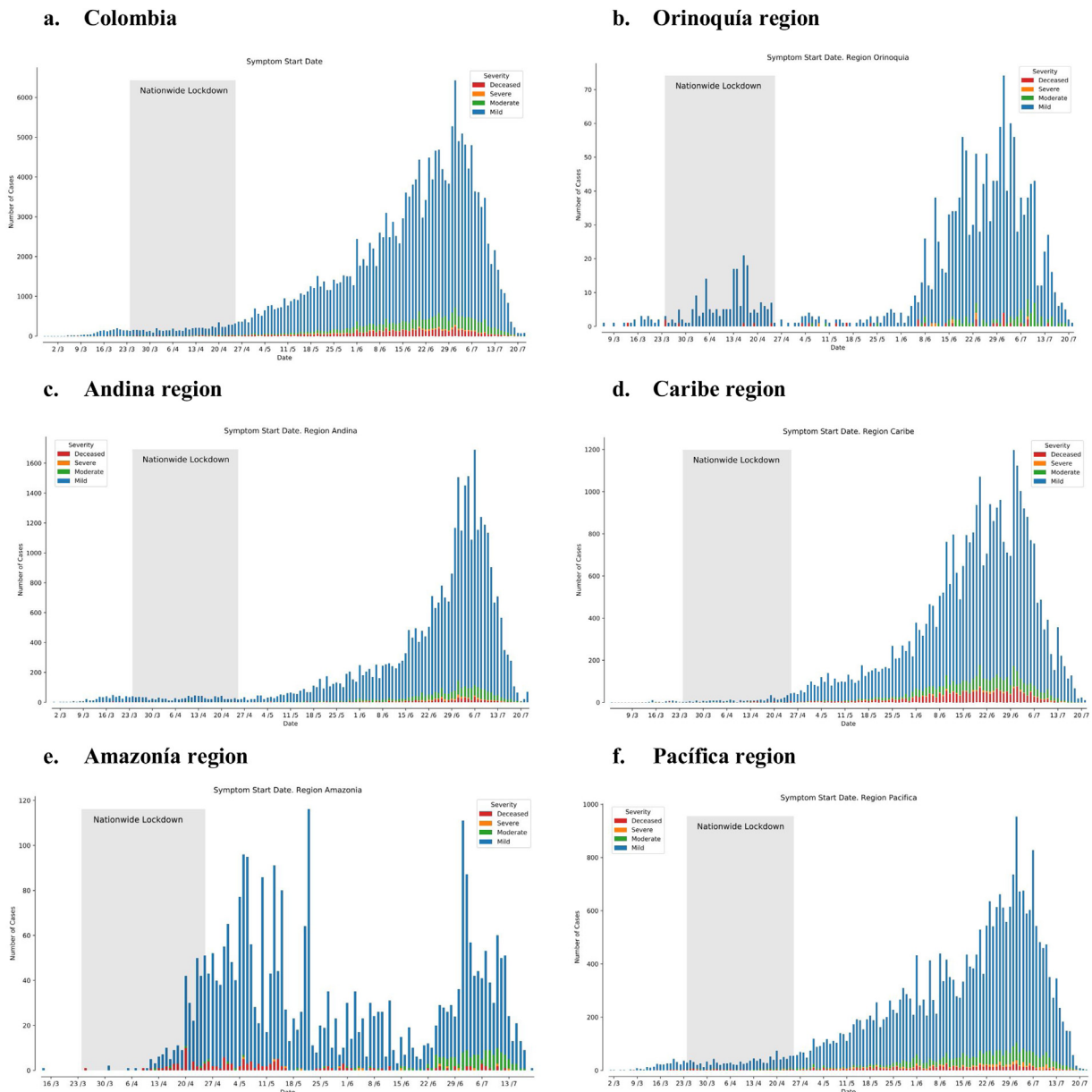


Figure 1. Numbers of deaths, cases, and recovered cases by date of onset of symptoms of COVID-19 in Colombia and its regions up to July 25, 2020.

of Health (Instituto Nacional de Salud (INS) in Spanish). Daily updates of the epidemiological data can be found at <https://www.ins.gov.co/Noticias/Paginas/Coronavirus.aspx> (Instituto Nacional de Salud, 2020a). The INS is the head of the Colombian national surveillance system. It provides technical advice on public health surveillance to local healthcare institutions and coordinates the field investigation of cases and the confirmatory laboratory testing for COVID-19 cases.

Case definitions

Case and severity of disease definitions used for the surveillance of COVID-19 are provided by the INS and can be fully accessed at the following URL: <http://www.ins.gov.co/Noticias/Coronavirus/Estrategia%20VSP%20COVID-19%2023072020.pdf>. From March to June, RT-PCR was predominantly recommended for symptomatic cases with a history of travel or contact with travelers, despite the fact that local transmission replaced imported transmission starting in April. Only in July were testing criteria expanded to include symptomatic and asymptomatic suspected cases with or without risk factors.

Variables

The INS database contains the following information: (1) dates of symptom onset, sample taking, epidemiological reporting, laboratory diagnosis, recovery, and death; (2) age and sex; (3) city of residence; (4) severity of disease classified as asymptomatic, mild, moderate, and severe; (5) place where health care is provided stratified by hospital care, intensive care unit (ICU), or home care.

Analysis

Data were described according to the level of measurement. Proportions were used for nominal or ordinal variables, and means or medians were used for continuous variables. Incidence rates of confirmed COVID-19 cases were estimated by department (state) and for several municipalities stratified by age and sex. COVID-19 mortality rates were also estimated by department and for selected municipalities stratified by age and sex.

The capacity of the departmental surveillance systems was assessed using several indicators: (1) cumulated proportion of samples taken per million people by department; (2) mean number of positive contacts for every imported case; (3) average interval in days between the onset of symptoms and date of diagnosis; (4) average interval in days from the date when the case was detected to the date of diagnosis.

A conservative assessment of the potential underestimation of cases was done using the following approach: (1) the ratio of samples taken per million people by department and district was estimated and the geographical area with the highest ratio was identified. (2) That ratio was projected to the population of every department/district, in order to estimate the 'potential number of samples' that the surveillance system would have obtained if the same effort had been made for every geographical area. (3) The positivity ratio of samples by department was obtained by dividing the number of positive samples in a department/district by the total number of samples taken in that department. (4) A 'potential number of cases' by department was obtained by multiplying the 'potential number of samples' of a particular department by its positivity ratio (see **Supplementary Material** Table S1).

A visual analysis of how COVID-19 was disseminated around the country during the first month of transmission was performed by mapping departments and municipalities where local cases – not linked to imported transmission – were detected during March 2020. Also, these territories were aggregated into geographic regions to describe the differential trends in the number of cases

(mild, moderate, severe) and deaths (**Supplementary Material** Figure S1).

All data were analyzed using Microsoft Excel, Epi Info 7.2, Stata 12 (Stata Corporation, College Station, TX, USA), and Python v3.6 (packages: Pandas, Geopandas, Matplotlib, and Seaborn).

Results

General characteristics of COVID-19 cases

By July 25, Colombia had confirmed 240 795 cases of COVID-19 and 8269 deaths, with differential trends by geographic region (Figure 1). Males accounted for 53.6% of cases, while 72% of cases occurred in persons aged 0–49 years (Table 1). Most cases (90.1%) were asymptomatic or presented with mild clinical manifestations, 0.7% were in the ICU and 51.5% have recovered so far. The cumulated incidence of infection was 478 per 10⁵ persons and the average incidence density was 97.6 cases per 10⁵ person-months. The incidence rate was lower among persons <20 years of age (<50 cases per 10⁵ person-months), and it increased to more than 100 cases per 10⁵ person-months among adults >20 years of age. The case incidence was higher in males than in females (524 vs 434 cases per 10⁵ persons, respectively) (Table 2).

The case fatality rate (CFR) was 3.4% and the specific cumulated mortality rate was 16.4 per 10⁵ persons. The CFR increased by age group, from less than 1% among younger people (0–39 years) to more than 30% among the oldest (80 years and older). The specific mortality rate also increased from less than 1 per 10⁵ among younger people (<20 years old) to more than 200 per 10⁵ people among the oldest (>80 years old). The CFR was higher among males compared to females (4.3% vs 2.4%, respectively) and the same trend was observed for the mortality rate (21.3 vs 11.8 cases per 10⁵) (Table 2).

Table 1
Characteristics of the population with COVID-19; Colombia, July 25, 2020.

Variable	N = 240 795	%
Sex		
Male	128 979	53.6
Female	111 816	46.4
Age (years)		
0–9	8971	3.7
10–19	15 546	6.5
20–29	52 848	21.9
30–39	56 989	23.7
40–49	39 251	16.3
50–59	31 585	13.1
60–69	19 051	7.9
70–79	10 182	4.2
80–89	6372	2.6
Clinical presentations		
Asymptomatic	32 994	13.7
Mild	183 899	76.4
Moderate	13 626	5.7
Severe	1499	0.6
Death	8269	3.4
NA	508	0.2
Healthcare type		
Intensive care unit (ICU)	1517	0.7
Hospitalized	12 613	5.4
Home care	98 241	42.2
Recovered	119 667	51.5
NA	488	0.2
Case type		
Imported	969	0.4
Related	18 796	7.8
In study ^a	221 030	91.8

NA, not available.

^a Cases likely associated to local transmission, with no link to imported cases.

Table 2

Incidence, mortality, and fatality in the population with COVID-19, according to age groups; Colombia, July 25, 2020.

Age (years)	Population in 2020	Person-months (4.9 months of follow-up)	Cases of COVID-19	Deaths from COVID-19	Cumulative incidence $\times 10^5$	Incidence density $\times 10^5$ person-months	CFR (%)	Mortality rate per 10^5 persons
Total								
0–9	7 863 825	38 532 743	8971	14	114	23.3	0.2%	0.2
10–19	8 112 327	39 750 402	15 546	11	192	39.1	0.1%	0.1
20–29	8 551 856	41 904 094	52 848	107	618	126.1	0.2%	1.3
30–39	7 470 681	36 606 337	56 989	269	763	155.7	0.5%	3.6
40–49	6 130 204	30 038 000	39 251	612	640	130.7	1.6%	10.0
50–59	5 434 890	26 630 961	31 585	1181	581	118.6	3.7%	21.7
60–69	3 795 322	18 597 078	19 051	1894	502	102.4	9.9%	49.9
70–79	2 003 827	9 818 752	10 182	2081	508	103.7	20.4%	103.9
80+	1 009 492	4 946 512	6372	2100	631	128.8	32.9%	208.0
Total	50 372 424	246 824 878	240 795	8269	478	97.6	3.4%	16.4
Male								
0–9	4 018 776	19 692 002	4523	9	113	23.0	0.2%	0.2
10–19	4 132 721	20 250 333	8197	6	198	40.5	0.1%	0.1
20–29	4 281 591	20 979 796	28 123	65	657	134.0	0.2%	1.5
30–39	3 654 091	17 905 046	31 040	167	849	173.4	0.5%	4.6
40–49	2 916 820	14 292 418	20 965	446	719	146.7	2.1%	15.3
50–59	2 524 743	12 371 241	17 021	812	674	137.6	4.8%	32.2
60–69	1 735 695	8 504 906	10 305	1213	594	121.2	11.8%	69.9
70–79	897 276	4 396 652	5597	1328	624	127.3	23.7%	148.0
80+	433 169	2 122 528	3208	1193	740	151.1	37.2%	275
Total	24 594 882	120 514 922	128 979	5239	524	107.0	4.1%	21.3
Female								
0–9	3 845 049	18 840 740	4448	5	116	23.6	0.1%	0.1
10–19	3 979 606	19 500 069	7349	5	185	37.7	0.1%	0.1
20–29	4 270 265	20 924 299	24 725	42	579	118.2	0.2%	1.0
30–39	3 816 590	18 701 291	25 949	102	680	138.8	0.4%	2.7
40–49	3 213 384	15 745 582	18 286	166	569	116.1	0.9%	5.2
50–59	2 910 147	14 259 720	14 564	369	500	102.1	2.5%	12.7
60–69	2 059 627	10 092 172	8746	681	425	86.7	7.8%	33.1
70–79	1 106 551	5 422 100	4585	753	414	84.6	16.4%	68.0
80+	576 323	2 823 983	3164	907	549	112.0	28.6%	157.4
Total	25 777 542	126 309 956	111 816	3030	434	88.5	2.7%	11.8

CFR, case fatality rate.

All departments had reported cases, but 292 municipalities were apparently free of COVID-19 (26%) and 373 (33.2%) had seen limited transmission. The incidence rate by department ranged from 1.8 to 3160 cases per 10^5 people, with the highest rate reported in Amazonas (seven times the average national rate), a southern region that shares borders with Brazil and Peru. Another four departments (Atlántico, Caquetá, Cesar, and Sucre) and four special districts (Bogotá DC, Barranquilla DE, Buenaventura DE, and Santa Marta DT) exceeded the national average rate (Table 3).

Figure 1 shows the epidemic curve for the country and for the five main geographical areas. It suggests that widespread transmission started in June, after the lockdown was relaxed and gradual opening of commercial activities had started. By May 16, after 14 weeks of transmission, Colombia had reported 15 000 cases and 560 deaths, and by June 15, 5 weeks later, the number of cases had tripled (47 000 cases and 1545 deaths). Early peaks of transmission were detected in the Amazon, which started while the lockdown was still in place.

Specific mortality rates by department ranged from 0 in Vichada to 1278 in Amazonas, which had 7.8 times the national rate (Incidence Rate Ratio (IRR) = 7.8, 95% confidence interval (CI) 6.4–9.5). Eight additional areas (Atlántico, Barranquilla DE, Bogotá DC, Buenaventura DE, Caquetá, Chocó, Santa Marta DT, and Sucre) surpassed the national mortality rate (Table 3).

The average age increased with the severity of clinical presentation, being 37.5 years (standard deviation (SD) 17.6 years) for mild disease, 51.9 years (SD 20.5 years) for moderate disease, 54.6 years (SD 19.7 years) for severe clinical presentations, and 68.1 years (SD 16.5 years) for people who died. These differences persisted by geographical area (Table 4).

Selected surveillance characteristics

The Colombian surveillance system had taken 1 370 271 samples (27 203 samples per million people), but there was wide variability in the number of samples taken by department (range 2664 to 158 681/ 10^6). The positivity ratio (number of cases/number of samples) varied from 0.2% to 79.3%, with a national average of 17% (Supplementary Material Table S1).

It took a median of 11 days to confirm a case from the date of symptom onset (interquartile range (IQR) 2 days) and 5.6 days from the date of case detection by the health system (IQR 1.7 days). A median of 5 days passed from the beginning of symptoms to case detection (IQR 1.9 days) (Supplementary Material Table S2).

By July 25, 92% of Colombian cases were likely linked to local transmission, while imported cases and those related to imported cases represented 0.4% and 7.8%, respectively. Bogotá DC, Antioquia, and Valle del Cauca had most of the imported cases – 68% out of 969 imported cases – detected by surveillance across the country. There were 18 796 imported-related cases and most of them were identified in Bogotá DC ($n = 5151$), Antioquia ($n = 2156$), Valle del Cauca ($n = 1806$), and Meta ($n = 1140$). At the national level, one imported case was associated with 20 contact cases (related cases) (Supplementary Material Table S3).

Imported cases came from Europe (39%), other Latin American countries (29%), North America (26%), the Middle East (6%), Africa (0.4%), and Australia (0.1%). Spain and the USA were the individual countries from which most imported cases came (258 and 207 cases, respectively). No cases from China were detected.

In March, local transmission (cases without a history of travel or contact with travelers) was identified in 14 different geographical

Table 3
Distribution of cases and death rates by department; Colombia, July 25, 2020.

Department	Population	Cases	Cumulative incidence $\times 10^5$	Deaths	Mortality rate $\times 10^6$	CFR (%)
Amazonas	79 020	2497	3160.0	101	1278.2	4.0
Antioquia	6 677 930	23 035	344.9	321	48.1	1.4
Arauca	294 206	181	61.5	1	3.4	0.6
Archipiélago of San Andrés, Providencia and Santa Catalina	63 692	33	51.8	–	–	–
Atlántico	1 447 878	20 485	1414.8	961	663.7	4.7
Barranquilla DE	1 274 250	27 088	2125.8	1399	1097.9	5.2
Bogotá DC	7 743 955	81 180	1048.3	2115	273.1	2.6
Bolívar	1 152 240	2028	176.0	93	80.7	4.6
Boyacá	1 242 731	759	61.1	25	20.1	3.3
Buenaventura DE	311 827	1998	640.7	131	420.1	6.6
Córdoba	1 828 947	651	63.9	9	8.8	1.4
Caldas	1 018 453	542	132.0	8	19.5	1.5
Cartagena	410 521	213	48.9	4	9.2	1.9
Caquetá DT	1 028 736	14 258	1 386	440	427.7	3.1
Casanare	435 195	1501	100.6	44	29.5	2.9
Cauca	1 491 937	2447	188.9	49	37.8	2.0
Cesar	1 295 387	2802	514.4	89	163.4	3.2
Chocó	544 764	3593	196.5	438	239.5	12.2
Cundinamarca	3 242 999	6928	213.6	161	49.6	2.3
Guainía	50 636	14	27.6	1	19.7	7.1
Guaviare	86 657	77	88.9	–	0.0	0.0
Huila	1 122 622	673	59.9	18	16.0	2.7
La Guajira	965 718	1757	181.9	103	106.7	5.9
Magdalena	888 414	1878	211.4	181	203.7	9.6
Meta	1 063 454	2256	212.1	27	25.4	1.2
Nariño	1 627 589	6610	406.1	197	121.0	3.0
Norte de Santander	1 620 318	1515	93.5	59	36.4	3.9
Putumayo	359 127	532	148.1	22	61.3	4.1
Quindío	555 401	245	44.1	6	10.8	2.4
Risaralda	961 055	1298	135.1	25	26.0	1.9
Santa Marta DT	538 612	3049	566.1	130	241.4	4.3
Santander	2 280 908	2564	112.4	64	28.1	2.5
Sucre	949 252	5119	539.3	327	344.5	6.4
Tolima	1 339 998	2049	152.9	38	28.4	1.9
Valle del Cauca	4 220 325	18 877	447.3	681	161.4	3.6
Vaupés	44 712	61	136.4	1	22.4	1.6
Vichada	112 958	2	1.8	–	0.0	0.0

CFR, case fatality rate.

areas covering the most populated departments. Only the Eastern area of the country did not report such cases at that time (Figure 2).

Using a conservative approach to assess the potential underestimation of cases, it was estimated that, by July 25, Colombia should have detected 1 328 175 cases instead of the actual 240 795 observed, an underestimation of 82% (Supplementary Material Table S1).

Discussion

After approximately 140 days of COVID-19 transmission in Colombia, the numbers of cases and deaths were extremely low compared to projections. A mathematical model estimated that 21 237 000 cases and 212 000 deaths would occur in the first 100 days of the epidemic without interventions (Instituto Nacional de Salud, 2020b). However, only 0.3% of forecasted cases and 0.7% of forecasted deaths were reported after those first 100 days.

On comparison to other Latin American countries, Colombia had a lower incidence rate per 10^5 people ($478/10^5$), than Peru ($1212/10^5$), Panama ($1507/10^5$), Chile ($1819/10^5$), Brazil ($1157/10^5$), and Bolivia ($636/10^5$). Its mortality rate ($17/10^5$) was lower than Brazil ($42/10^5$), Chile ($49/10^5$), Panama ($33.8/10^5$), Mexico ($33/10^5$), and Ecuador ($32.8/10^5$). In addition, it had a higher rate of sampling than most Latin American countries except Chile, Panama, and Uruguay (Hasell et al., 2020).

One factor explaining Colombia's seeming success in containing the pandemic is the enforcement of a strict lockdown early on. On March 18, 2020, the Colombian government released Decree 420 (Ministerio del Interior) closing schools and universities,

cancelling almost all in-person work activities, stopping national and international land and air travel, cancelling all public and private gatherings (of more than six persons), and imposing self-isolation for people over 70 years of age, among other measures (Ministerio del Interior, República de Colombia, 2020a). These regulations were in place until the first week of May, when a reactivation of economic activities began (Ministerio del Interior, República de Colombia, 2020). In addition, Colombia, through the Colombian Association of Infectious Diseases (ACIN, the acronym in Spanish), promptly generated a consensus for the management of COVID-19 cases (Asociación Colombiana de Infectología and IETS, 2020; Marin et al., 2020), establishing criteria to manage cases at home, which may have contributed to decreasing the rate of nosocomial infections, an important source of transmission.

The decision in Colombia to implement an early lockdown contrasted with actions taken by other countries in the region. The governments of Brazil and Mexico ignored the potential threat of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and, as a result, they have been hit hard. However, other countries that implemented lockdowns (Chile and Peru) have also had higher rates of deaths and cases than Colombia, which may be explained by differences in the efficacy of the lockdown, differences in testing, and social and climatic conditions, some of which will need to be studied in the future (Villalobos et al., 2020; Perez-Brumer and Silva-Santisteban, 2020).

There is no experimental evidence on the effectiveness of social distancing measures, but modelling approaches consistently show that they are followed by a sharp decline in cases and deaths (Institute for Health Metrics and Evaluation (IHME) 2020; Kennedy

Table 4

Average age (years) by COVID-19 severity by department; Colombia, July 25, 2020.

Department	Deaths	Severe	Moderate	Mild	Total
Amazonas	68.3	54.5	48.3	35.2	36.9
Antioquia	71.7	55.4	52.4	36.6	37.9
Arauca	42.0	19.5	36.6	28.1	28.4
Archipiélago of San Andrés, Providencia and Santa Catalina	–	–	–	37.4	37.4
Atlántico	66.4	53.9	50.8	37.9	39.9
Barranquilla DE	68.0	57.3	53.8	38.5	40.7
Bogotá DC	68.8	54.2	52.9	37.4	40.1
Bolívar	69.3	50.0	49.6	37.2	39.7
Boyacá	69.4	59.0	50.8	38.7	41.2
Buenaventura DE	67.3	52.3	54.4	35.8	39.5
Córdoba	72.1	64.0	52.7	40.2	41.5
Caldas	71.0	42.3	47.7	34.7	36.6
Caquetá	67.4	57.6	51.5	37.6	39.1
Cartagena DT	62.0	61.0	43.8	36.2	37.6
Casanare	69.9	54.1	50.4	35.9	38.6
Cauca	66.2	46.1	39.2	35.2	36.2
Cesar	62.7	49.9	50.7	36.2	38.2
Chocó	67.1	53.0	50.1	39.7	44.7
Cundinamarca	65.0	55.2	53.1	36.7	38.8
Guainía	73.0	–	–	27.6	33.3
Guaviare	–	–	46.0	26.6	27.4
Huila	70.8	66.0	48.6	38.3	39.8
La Guajira	64.6	50.9	48.2	36.7	39.3
Magdalena	68.8	43.3	52.7	38.9	43.4
Meta	67.6	51.7	47.3	34.5	35.6
Nariño	65.8	48.9	47.2	36.9	38.6
Norte de Santander	64.5	48.6	52.3	38.2	40.9
Putumayo	60.0	31.6	44.2	36.5	38.7
Quindío	70.3	–	56.6	45.2	46.4
Risaralda	66.6	53.2	52.8	37.0	38.4
Santa Marta DT	66.4	49.6	48.0	37.5	39.6
Santander	68.2	62.5	53.1	36.9	39.6
Sucre	70.4	56.4	52.0	38.1	41.9
Tolima	67.1	62.8	61.9	36.1	37.6
Valle del Cauca	69.7	57.1	52.4	38.1	40.6
Vaupés	70.0	–	–	36.1	36.9
Vichada	–	–	78.0	–	78.0
Total	68.1	54.6	51.9	37.5	39.8

et al., 2020). With our data, we may cite the low number of cases in the department of Cundinamarca as evidence of the success of the lockdown imposed in Bogotá DC, the country's capital. Bogotá DC is surrounded by a myriad of Cundinamarca's municipalities, containing around three million people, and there is continuous mobility of people from and to Bogotá DC. The lockdown stopped this mobility, and so far Cundinamarca has had an incidence rate approximately five times lower than Bogotá DC.

Two additional factors may have influenced the low incidence and mortality rates: weather and demographic profile. In Colombia, peaks of respiratory virus transmission and related mortality occur mostly during rainy seasons (Porras Ramírez et al., 2009; Cotes et al., 2012). However, since October 2019, the country has experienced an unusually longer dry season that has extended through June 2020 (El Tiempo, 2020). This year, the rainy season started late in June in most regions of the country, coinciding with the end of the lockdown. The potential role of both factors in the increase in cases and deaths observed after May has yet to be ascertained. In addition, Colombia has a relatively young population, which may have attenuated the SARS-CoV-2 impact on mortality (Amariles et al., 2020).

Underreporting and surveillance weaknesses may also have contributed to hide the real numbers of cases and deaths in Colombia. Colombia kept a conservative case definition (see Methods) for the first 2.5 months of transmission because of shortages in biological and laboratory supplies to perform PCR tests. While stringent criteria for sampling and testing may succeed in keeping demand at bay, they also contribute to the underestimation of cases.

Some surveillance indicators suggest that Colombia may have missed a substantial number of cases. First, the sampling ratio was found to differ widely by department. Results in **Supplementary Material Table S1 suggest that if the sampling ratio in Amazonas had** been reached by other departments, the number of cases would have increased eight-fold. Second, the ratio of COVID-19-positive contacts per imported case suggests that some departments were unable to track most imported cases. In three departments/districts with the highest incidence rates, the ratio of positive contacts to imported cases was four to 12 times the national average (19 to 1). Although super-spreaders of COVID-19 may exist, large ratios of positive contacts to imported cases suggest a lack of capacity to detect and track all imported cases (Pung et al., 2020).

Although the first imported case was detected on March 2, it is highly likely that transmission started in February or even in late January. The map in **Figure 2** shows that there was simultaneous detection of local cases without known links to imported cases in several distant areas in March. One of the first cases reported symptoms on February 29, several days before the first imported case was detected. The role of undetected transmission during February in the subsequent pattern of disease spread is difficult to establish given the limitations in testing during March and April.

Colombia has increased its surveillance capacity. It jumped from taking less than 3000 samples/week in the first week to >600 000 in July (**Supplementary Material Table S4**). However, wide gaps between departments remain. The three largest cities have 60% (36/60) of the laboratories able to perform PCR testing, whereas 12 out of 33 departments have no such facilities. Public

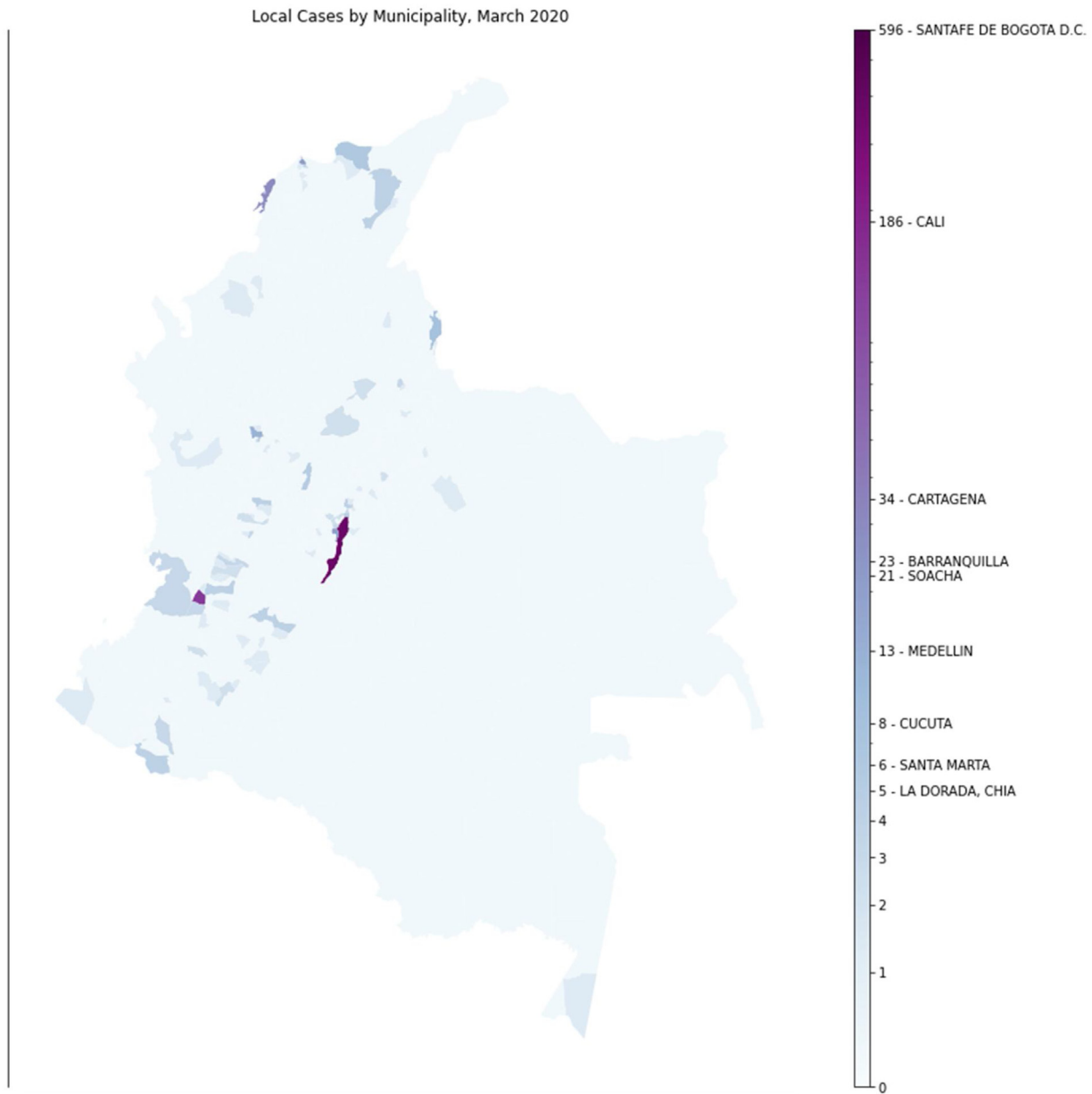


Figure 2. Local cases of COVID-19 by municipality, March 2020.

health officials must wait up to 15 days to confirm cases, which hampers their ability to detect and track contacts.

As reported by others, age is one of the strongest predictors of mortality (Cagnacci and Xholli, 2020; Immovilli et al., 2020). Patients who died were on average older (68 years) than those with mild cases (37 years). In Wuhan, the average age among those who died was 68 years (Chen et al., 2020). Wu et al. first reported that the CFR increases with age. However, the CFR in people aged 70 years and older was lower in Wuhan than in Colombia (14% vs 25%) (Wu and McGoogan, 2020).

Mortality in Colombia varied by geographic region and this may have been related to the availability of ICU beds and quality of care. Public discussions have centered around the number of ICUs with ventilators available in the country, and whether there will be enough to cope with the potential demand produced by COVID-19 (Amariles et al., 2020). Another caveat is the availability of healthcare workers. For example, the only hospital covering the Amazonas population (79 020 inhabitants) has five ICU beds with

ventilators, but lacks personnel trained in critical care. The impact of these shortcomings is reflected in the high mortality rate observed there (approximately eight times the national average), surpassing even the mortality rates observed in Peru ($21/10^5$), Brazil ($20/10^5$), and Ecuador ($23/10^5$). Regional inequalities in the pandemic response capacity and their relationship to mortality in Colombia, mirror those described in China (Ji et al., 2020).

This analysis has limitations. We did not have access to clinical records of infected individuals. Therefore, it was not possible to assess the role of chronic underlying diseases in the mortality by COVID-19. The INS has published a list of the frequency of comorbidities in COVID-19 patients who have died, including hypertension (28%), diabetes (15%), chronic obstructive pulmonary disease (12%), obesity (8%), history of smoking (5%), and hypothyroidism (4%); 13% have had no underlying diseases. However, it is not possible to know how many concurrent diseases were present in each patient, or how they compare to individuals with milder presentations.

One strength of the present study is that it provides a critical overview of the potential explanations for the apparent success of Colombia in mitigating the effect of the pandemic. As well as discussing the effect of the preventive measures adopted by the government, we have discussed the role that weaknesses in the surveillance system, as well as sociodemographic and climatic factors, may have had in the unexpected positive results. This analysis provides a baseline for monitoring the impact that changes in containment strategy, such as relaxing lockdown measures on May 15, may have on COVID-19 transmission. It may also help to assess the impact of the ongoing improvements in laboratory capacity that Colombia is implementing.

Funding source

The authors received no financial support for this research.

Ethics approval and consent to participate

Ethical approval or individual consent was not applicable.

Conflict of interest

The authors declare that they have no competing interests.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.ijid.2020.08.017>.

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