

# The Epidemiology and Transmissibility of Zika Virus in Girardot and San Andres Island, Colombia

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## Abstract

### *Background:*

Zika virus (ZIKV) is an arbovirus in the same genus as dengue virus and yellow fever virus. ZIKV transmission was first detected in Colombia in September 2015. The virus has spread rapidly across the country in areas infested with the vector *Aedes aegypti*. As of March 2016, Colombia has reported over 50,000 cases of Zika virus disease (ZVD).

### *Methods:*

We analyzed surveillance data of ZVD cases reported to the local health authorities of San Andres, Colombia, and Girardot, Colombia, between September 2015 and January 2016. Standardized case definitions used in both areas were determined by the Ministry of Health and Colombian National Institute of Health at the beginning of the ZIKV epidemic. ZVD was laboratory-confirmed by a finding of Zika virus RNA in the serum of acute cases. We

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report epidemiological summaries of the two outbreaks. We also use daily incidence data to estimate the basic reproductive number  $R_0$  in each population.

*Findings:*

We identified 928 and 1,936 laboratory or clinically confirmed cases in San Andres and Girardot, respectively. The overall attack rate for reported ZVD detected by healthcare local surveillance was 12.13 cases per 1,000 residents of San Andres and 18.43 cases per 1,000 residents of Girardot. Attack rates were significantly higher in females in both municipalities. Cases occurred in all age groups but the most affected group was 20 to 49 year olds. The estimated  $R_0$  for the Zika outbreak in San Andres was 1.41 (95% CI 1.15 to 1.74), and in Girardot was 4.61 (95% CI 4.11 to 5.16).

*Interpretation:*

Transmission of ZIKV is ongoing and spreading throughout the Americas rapidly. The observed rapid spread is supported by the relatively high basic reproductive numbers calculated from these two outbreaks in Colombia.

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*Keywords:* Zika virus, outbreak, epidemiology, Basic reproductive number

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## Research in Context

*Evidence before this study*

The ongoing outbreak of Zika virus disease in the Americas is the largest ever recorded. Since its first detection in April 2015 in Brazil, around 500,000 cases have been estimated, and the virus is spreading rapidly in the Americas region. There are many unanswered questions about the transmissibility and pathogenicity of the virus. Limited data are available from recent outbreaks occurring in islands in the Pacific, and little epidemiological data is available on the current outbreak.

We searched PubMed on March 12, 2016, for epidemiological reports on Zika virus outbreaks using the search terms “Zika” AND “Basic reproductive number”. We applied no date or language restrictions. Our search identified one previous paper assessing the basic reproductive number,  $R_0$  of Zika virus in Yap Island, Federal State of Micronesia and in French Polynesia, but no papers estimating  $R_0$  using data from the Latin American Zika outbreak. Because of the sparsity of the data, we could not do a detailed systematic review at this point in time.

#### *Added value of this study*

We report detailed epidemiological data on outbreaks in San Andres and Girardot, Colombia. Because such reports are currently unavailable, we provide early information on age and gender effects and the functioning of local and national surveillance in the second-most affected country in this epidemic. We provide early estimates of  $R_0$ . Our results can be used by mathematical modelers to understand the future impact of the disease and potential spread.

#### *Implications of all the available evidence*

We report attack rates similar to those reported in the Yap Island outbreak. We find that Zika impacts individuals of all ages, though the most affected age group is 20 to 49 years of age. The surveillance system detected more cases among women in both areas, though this finding may be attributable to reporting bias. Our estimates of  $R_0$  imply that Zika has the capacity for widespread transmission in areas with the vector.

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## 1. Introduction

1 First isolated in the Zika Forest of Uganda in 1947, Zika virus (ZIKV)  
2 is an arbovirus primarily transmitted by *Aedes aegypti* mosquitoes [1]. Al-  
3 though ZIKV has circulated in Africa and Asia since the 1950s, little is known  
4 about its transmission dynamics [2]. Recent outbreaks in Yap Island in the  
5 Federated States of Micronesia (2007), French Polynesia (2013), and other  
6 Pacific islands, including Cook Islands, Easter Island, and New Caledonia  
7 (2014), indicate that ZIKV has spread beyond its former geographic range  
8 [3, 4, 5, 6]. In April 2015 ZIKV was isolated in the Northeast of Brazil [7].  
9 As of March 11, 2016, around 500,000 Zika virus disease (ZVD) cases have  
10 been estimated in Brazil, and autochthonous circulation has been observed

11 in 31 countries in the Americas region. Further spread to countries within  
12 the geographical range of *Ae. aegypti* mosquitoes is considered likely [8].

13 ZIKV is a flavivirus in the same genus as dengue virus and yellow fever  
14 virus. Infection typically causes a self-limited dengue-like illness character-  
15 ized by exanthema, low-grade fever, conjunctivitis, and arthralgia [9]. While  
16 illness is believed to be mild or asymptomatic in approximately 80% of the  
17 infections [10], an increase in rates of Guillain-Barré syndrome (GBS) has  
18 been observed during ZIKV outbreaks [8, 11, 12]. Furthermore, in October  
19 2015, the Brazilian Ministry of Health reported a dramatic increase in cases  
20 of microcephaly in Northeast Brazil where ZIKV had been circulating [13].  
21 On the basis of the possible link between ZIKV, GBS and microcephaly, the  
22 World Health Organization declared a public health emergency on February  
23 1, 2016 [14].

24 The virus was first detected in Colombia in mid-September 2015 in a  
25 municipality called Turbaco on the Caribbean coast. Turbaco is located ap-  
26 proximately 20 minutes from Cartagena, a well known commercial and tourist  
27 hub (Figure 1). In October 2015, ZIKV spread through the central region of  
28 the country, appearing in areas with endemic dengue and ongoing circulation  
29 of chikungunya (CHIKV) since 2014. Through March 2016, Colombia has re-  
30 ported over 50,000 cases of ZVD, making it the second-most affected country  
31 in this outbreak, after Brazil. There were 2,090 laboratory-confirmed cases  
32 with the rest being suspected cases or confirmed by clinical findings [15]. Up  
33 to March 2016, 280 cases of neurological complications including Guillain-  
34 Barré syndrome (GBS) and three deaths possibly associated with ZVD have  
35 been reported in Colombia [16]. As of March 2016, there have been sev-  
36 eral suspected but no confirmed cases of ZIKV-associated microcephaly in  
37 Colombia [15].

38 In this paper we describe local ZIKV outbreaks in Girardot  
39 and San Andres Island between September 2015 and January 2016 for which  
40 detailed epidemiological data are available. We conduct an investigation  
41 to define the epidemiological features of these outbreaks and to estimate  
42 corresponding transmission parameters.

## 2. Methods

### *San Andres*

43 San Andres is the largest island in a Colombian archipelago in the Caribbean  
44 sea located about 750 km north of mainland Colombia and 230 km east of

45 Nicaragua (Figure 1). The island has an area of 27 km<sup>2</sup>, a population of  
46 54,513 inhabitants across 13,652 households, and a population density of  
47 2,932 habitants per km<sup>2</sup> in 2010 [17, 18]. The average temperature is 27.3°C,  
48 and 80% of the total annual rainfall of 1,700 mm occurs during the heavy  
49 rainy season between October and December. The weather is humid subtrop-  
50 ical with occasional tropical cyclones and hurricanes. The population in San  
51 Andres has two main ethnic groups: Afro-Colombians (17.5%) and Raizal (an  
52 ethnic group of mixed Afro-Caribbean and British descent) (39.2%) [18]. The  
53 most productive breeding sites of *Ae. aegypti* in San Andres are unprotected  
54 water containers located in the households. San Andres has experienced low  
55 dengue transmission since 1983. Since 1995, the frequency of dengue out-  
56 breaks increased to every two to five years with a mean annual incidence  
57 of 43.6 cases per 100,000 inhabitants between 1999 and 2010 [17]. In 2014,  
58 CHIKV began circulating in San Andres, reaching an annual incidence of  
59 365.1 cases per 100,000 inhabitants [19].



Figure 1: Map of Colombia

### *Girardot*

60 The city of Girardot is located 134 km (2 hours drive) from the capi-  
61 tal city of Bogota (Figure 1). Girardot has 102,225 inhabitants across ap-  
62 proximately 23,000 households based on the most recent census from the  
63 National Statistics Department (NSD) [20], though the population triples  
64 during weekends and holidays. Girardot is 289 meters above sea level. The  
65 average temperature is 33.3°C, and the relative humidity is 66%. The mean  
66 annual precipitation is 1,220 mm with a rainy season extending from May  
67 through October [21]. The most productive breeding sites of *Ae. aegypti*  
68 in Girardot are unprotected private water containers, such as water storage  
69 tanks used in the households during the dry and rainy seasons, while public  
70 spaces provide more breeding sites during the rainy season [22]. Girardot has  
71 experienced hyperendemic transmission of dengue since 1990 with simulta-  
72 neous circulation of all four serotypes; the mean annual incidence was 572.2  
73 per 100,000 inhabitants between 1999 and 2010 [17]. In late 2014, CHIKV  
74 began circulating in Girardot reaching an annual incidence of 394 per 100,000  
75 inhabitants in 2014 and 8,416 per 100,000 inhabitants in 2015.

### *Case definition and laboratory analysis*

76 We analyzed surveillance data from nine local health care sites in San  
77 Andres and twenty-two local health care sites in Girardot. Standardized  
78 case definitions used in both areas were defined by the Ministry of Health  
79 (MoH) and Colombian National Institute of Health (C-NIH) at the beginning  
80 of the ZIKV epidemic. A suspected ZVD case is defined as a person who  
81 lived or traveled in an area below 2,000 meters above sea level who presents  
82 with maculopapular exanthema, temperature higher than 37.2°C, and one  
83 or more of the following: non-purulent conjunctivitis, arthralgia, myalgia,  
84 headache, or malaise. A laboratory confirmed case is a suspected case with  
85 a ZIKV positive reverse-transcriptase-polymerase-chain-reaction (RT-PCR)  
86 result as determined by the C-NIH virology reference laboratory. A clinically  
87 confirmed case is a suspected case that lived or traveled in an area with  
88 laboratory confirmed ZIKV circulation prior to onset of symptoms [23].

89 At the start of the outbreak, all suspected cases were reported based  
90 on the suspected case definition to the Colombian national surveillance sys-  
91 tem. Once laboratory confirmation from C-NIH was performed for cases in  
92 Girardot and San Andres, the new suspected ZIKV cases were laboratory  
93 confirmed if they fell into the risk groups defined by the C-NIH: newborns,  
94 age <1 year, age >65 years, and cases with co-morbidities [23]. After ZIKV

95 circulation was confirmed in the regions, all suspected cases were reclassified  
96 as clinically confirmed.

### *Data collection*

97 The data was collected using the C-NIH standard report form for Zika  
98 surveillance. The form includes socio-demographic variables. We analyzed  
99 a deidentified data set with the following variables: gender, age, pregnancy  
100 status, date of symptom onset, date the case visited the health care facility,  
101 date the case was reported to the national surveillance system, and case type  
102 (suspected, laboratory confirmed, clinically confirmed) [24].

### *Statistical analysis*

103 We calculated overall and age/gender-specific attack rates using popula-  
104 tion census data from NSD [20]. Surveillance data were analyzed using R ver-  
105 sion 3.2.0 [25]. For descriptive results, categorical variables are presented as  
106 proportions and continuous variables by the median and interquartile range  
107 (IQR) or range. The impact of age and gender on attack rates was tested  
108 using log-linear models for case counts with age category, gender, and an  
109 interaction as independent variables with population size as an offset.

110 To estimate the basic reproductive number  $R_0$  in each population, we  
111 used maximum likelihood methods to fit a chain-binomial model to daily  
112 incidence data [26].  $R_0$  is the median effective reproductive number during  
113 the growth phase of the epidemic, after accounting for early under-reporting.  
114 (See Supplementary Online Materials for additional details on the model.)

## **3. Results**

115 In San Andres, we identified 928 reported ZVD cases (Table 1). Of these  
116 cases, 52 (5.6%) were laboratory confirmed by RT-PCR on acute phase sam-  
117 ples collected within five days of symptom onset, and 876 (94.4%) cases were  
118 clinically confirmed.

119 The dates of symptom onset among cases in San Andres ranged from  
120 September 6, 2015, to January 30, 2016 (Figure 2). Though the earliest  
121 case reported symptom onset on September, 6, 2015, the local health care  
122 authorities did not receive laboratory confirmation of ZIKV until October 22,  
123 2015. The number of cases peaked in epidemiological week 45 (November 8  
124 to 14) and subsided in the last week of December. The median time between  
125 symptom onset and visiting a health care facility was 4 days (IQR 1 to 16).

Table 1: Characteristics of reported cases of Zika Virus Disease

Region	San Andres	Girardot
Total number of cases	928	1936
Laboratory confirmed cases	52 (5.6%)	32 (1.7%)
Clinically confirmed cases	876 (94.4%)	1904 (98.3%)
Female	589 (63.5%)	1138 (58.8%)
Median age, years (IQR)	31 (15, 47)	34 (24, 46)
Median time, days, to visit healthcare facility from symptom onset (IQR)	4 (1, 16)	1 (1, 2)

126 79% of cases were reported to the national surveillance system on the same  
 127 day they visited the health care facility. The median age of reported ZVD  
 128 cases in San Andres was 31 years old (IQR 15 to 47; range 12 days to 82  
 129 years). 589 (63.5%) of the reported cases occurred in females. During this  
 130 time period 70 dengue cases and 10 CHIKV cases were confirmed in San  
 131 Andres.

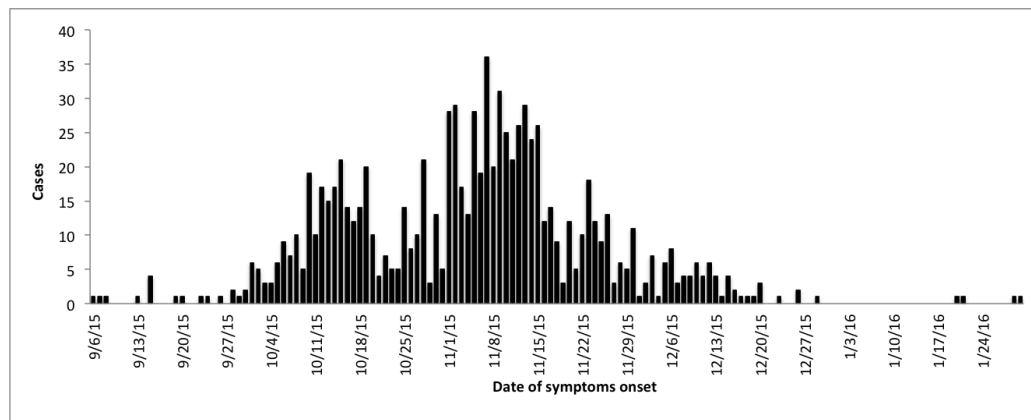


Figure 2: Daily ZVD incidence for San Andres, Colombia

132 The overall attack rate for ZVD reported by local surveillance was 12.13  
 133 per 1,000 San Andres residents. The gender-specific attack rates were 15.34  
 134 per 1,000 females and 8.91 per 1,000 males; the difference was significant  
 135 adjusting for age ( $p < 0.001$ ). Cases occurred among all age groups, but the  
 136 incidence of ZVD detected by local surveillance was highest among persons  
 137 20 to 49 years old (Figure 3); there was significant heterogeneity across the



138 age groups ( $p < 0.001$ ). Attack rates were higher in females across all age  
139 groups 10 years old and above; there was a significant interaction between  
140 age and gender ( $p < 0.001$ ).

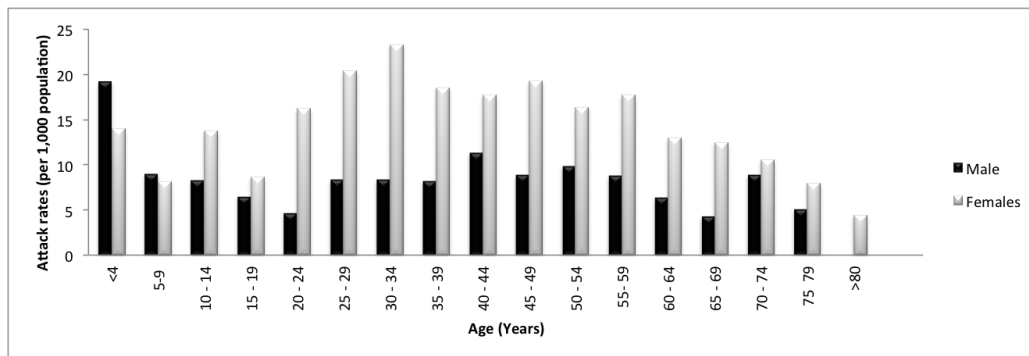


Figure 3: Age- and gender-specific ZVD attack rates for San Andres, Colombia

141 Thirty two pregnant women with ZVD were reported in San Andres and  
142 are being followed according to national guidelines. By March 2016, four-  
143 teen of them had given birth with no microcephaly reported. There were  
144 eight neurological syndromes reported in San Andres, including GBS and  
145 meningoencephalitis attributed to ZIKV and among them one death was re-  
146 ported. The incidence rate of neurological syndromes among ZVD cases in  
147 San Andres is 8.6 per 1,000 cases.

### *Girardot*

148 In Girardot, we identified 1,936 reported ZVD cases (Table 1). Of these  
149 cases, 32 (1.7%) were laboratory confirmed by RT-PCR on acute phase sam-  
150 ples collected within five days of symptom onset and 1,904 (98.3%) were  
151 clinically confirmed. During this time period were confirmed 67 dengue cases  
152 and 37 CHIKV cases in Girardot.

153 The date of symptom onset among cases in Girardot ranged from October  
154 19, 2015, to January 22, 2016 (Figure 4). The first suspected case was  
155 reported on October 23, 2015, with laboratory confirmation obtained on  
156 January 27, 2016. The number of cases peaked in epidemiological week 48  
157 (November 29 to December 5) and subsided in early January. The median  
158 time between symptom onset and visiting a health care facility was 1 day  
159 (IQR 1 to 2 days). 89% of cases were reported to the national surveillance  
160 system on the same day they visited the health care facility. The median age

161 of confirmed ZVD cases was 34 years old (IQR 24 to 46; range 15 days to 92  
162 years). 1138 (58.8%) of the cases occurred in females.

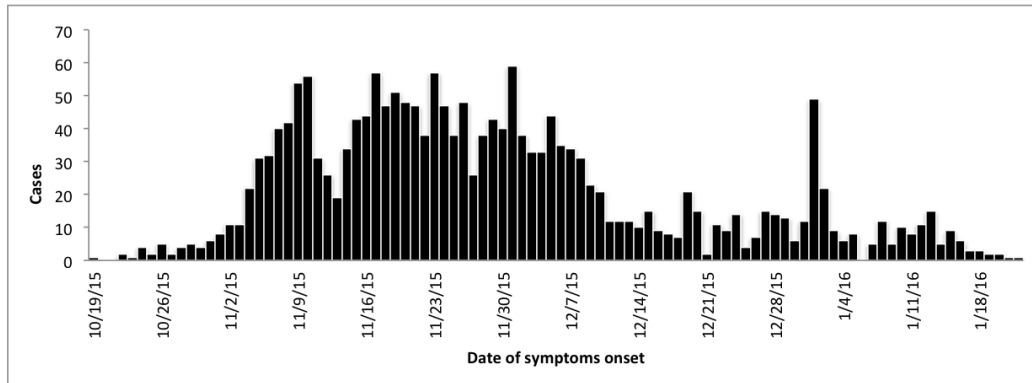


Figure 4: Daily ZVD incidence for Girardot, Colombia

163 The overall attack rate for confirmed ZVD detected by local surveillance  
164 was 18.43 per 1,000 Girardot residents. The gender-specific attack rates  
165 were 20.53 per 1,000 females and 16.07 per 1,000 males; the difference was  
166 significant adjusting for age ( $p < 0.001$ ). Cases occurred among all age groups,  
167 but the incidence of ZVD detected by local surveillance was highest among  
168 persons 20 to 49 years old (Figure 5); there was significant heterogeneity  
169 across the age groups ( $p < 0.001$ ). Attack rates were higher in females in all  
170 age groups except in those 10 to 14 and 65 to 69 years old; there was no  
171 significant interaction between age and gender.

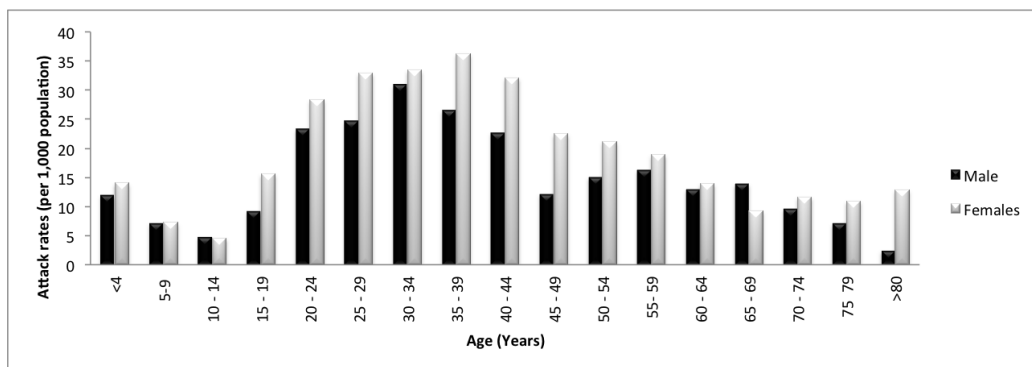


Figure 5: Age- and gender-specific ZVD attack rates for Girardot, Colombia

172 Sixteen pregnant women with ZVD were reported in Girardot and are  
173 being followed according to national guidelines. By March 2016, seven of  
174 them had given birth with no complications or microcephaly reported. Nine  
175 cases with GBS have been reported after an initial suspected ZIKV infection;  
176 laboratory-confirmation of ZIKV is pending. There were no deaths attributed  
177 to ZIKV. The incidence rate of neurological syndromes among ZVD cases in  
178 Girardot is 4.6 per 1,000 cases.

#### *Basic reproductive number calculations*

179 The basic reproductive number ( $R_0$ ) was estimated using daily incidence  
180 data. The model assumes a mean serial interval (time between successive  
181 cases in a chain of transmission) of 22 days, based on a mean incubation  
182 period in humans of 5 days, an extrinsic latent period (time from infection  
183 to infectiousness within the mosquito) of 10 days, and a mean infectious  
184 period in mosquitoes of 10 days. Under-reporting is assumed to be high  
185 (only 10% of cases reported) at the start of the outbreak and full reporting  
186 is assumed to be achieved in four weeks after the outbreak begins to grow.  
187 The estimated  $R_0$  for the Zika outbreak in San Andres was 1.41 (95% CI 1.15  
188 to 1.74), and the  $R_0$  in Girardot was 4.61 (95% CI 4.11 to 5.16) (Table 2  
189 and Figure 6). Odds ratios for gender and age effects were obtained from the  
190 likelihood model, indicating increased odds of transmission among females  
191 and adults aged 20 to 49 years old in both San Andres and Girardot (Table 2).

192 The estimation procedure was also applied to daily incidence data from  
193 a published outbreak in Salvador, Brazil, that occurred between February  
194 15, 2015, and June 25, 2015; 14,835 cases were reported with an overall  
195 attack rate of 5.5 cases per 1,000 Salvador residents [7]. The estimated  $R_0$   
196 of the Zika outbreak in Salvador, Brazil was 1.42 (95% CI 1.35 to 1.49).  
197 Sensitivity analyses are reported in the Supplementary Online Materials,  
198 including varying the incubation period in humans, the infectious period in  
199 humans, the infectious period in mosquitoes, the duration of under-reporting,  
200 and the level of under-reporting at the start of the outbreak.

## **4. Discussion**

201 We report surveillance data on ZIKV outbreaks in two regions in Colom-  
202 bia between September 2015 and January 2016. The first region, San Andres,  
203 is a small, densely-populated island that is relatively isolated from continen-  
204 tal Colombia. The second region, Girardot, is a typical moderately sized

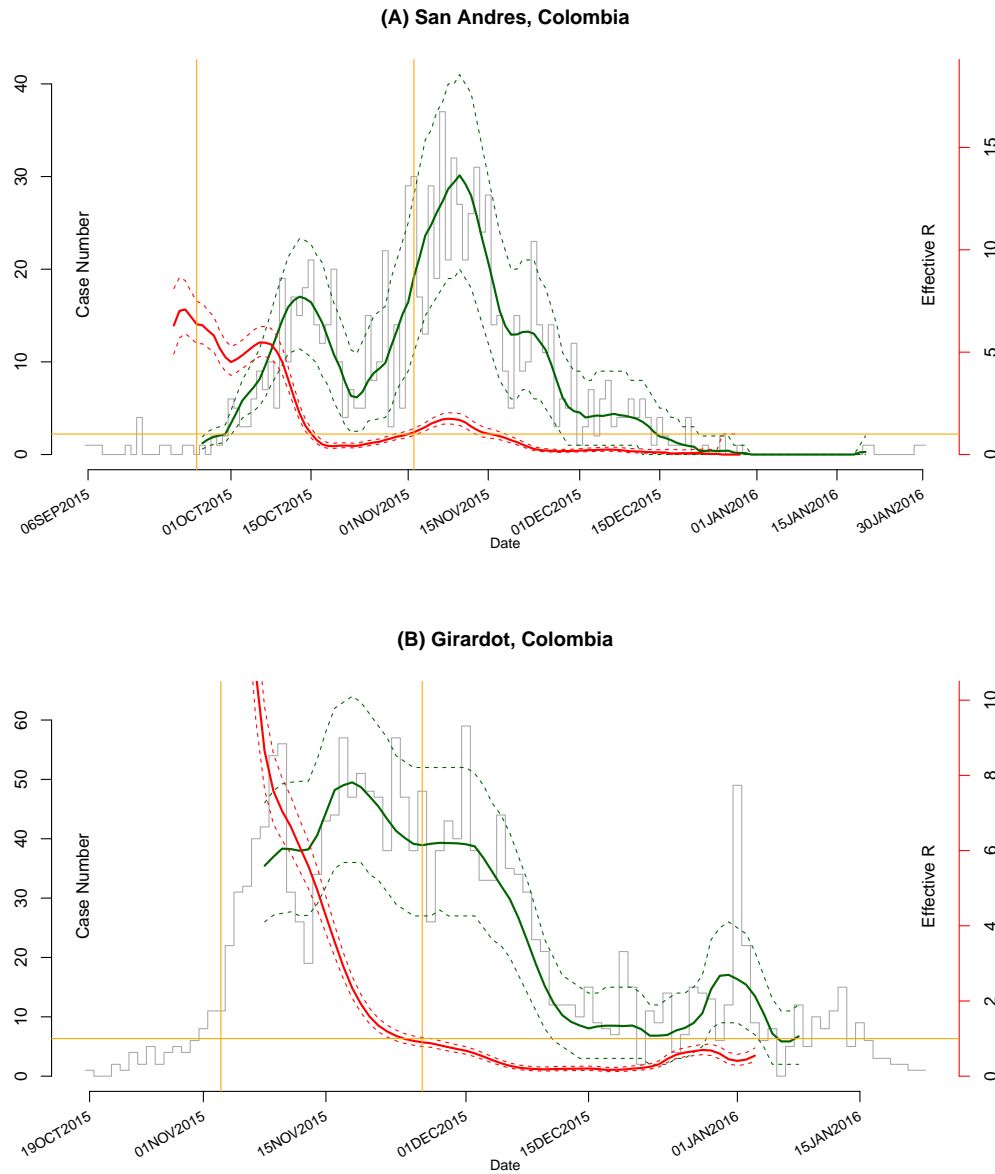


Figure 6: (a) Estimates of effective  $R$  (red) and model-fitted daily case numbers (green) for the outbreak of ZVD in San Andres, Colombia. The reporting ratio is assumed to increase linearly from 10% on and before September 30, 2015, to 100% in 4 weeks. Dashed curves (both red and green) are conservative 95% CIs. Histogram in grey shows the epidemic curve. The horizontal orange line indicates the reference value of 1. The two vertical orange lines indicate the time interval used for the estimation of  $R_0$ . (b) As (a) for Girardot, Colombia. The reporting ratio increases on October 19, 2015.

Table 2: Estimates of  $R_0$ , gender-specific odds ratios for transmission, and age-specific odds ratios for transmission for ZVD in San Andres and Girardot, Colombia.

Parameter	Level	San Andres		Girardot	
		Est.	95% CI	Est.	95% CI
$R_0$		1.41	(1.15, 1.74)	4.61	(4.11, 5.16)
$OR_{gender}$	Male	-	-	-	-
	Female	1.71	(1.50, 1.95)	1.28	(1.17, 1.40)
$OR_{age}$	20-49	-	-	-	-
	0-19	0.86	(0.74, 0.99)	0.37	(0.33, 0.42)
	$\geq 50$	0.74	(0.63, 0.88)	0.46	(0.41, 0.52)

205 Colombian municipality. Both regions have endemic transmission of dengue  
 206 and experienced recent outbreaks of CHIKV. We describe key epidemiologi-  
 207 cal features of the Zika outbreaks and estimate the  $R_0$  from daily incidence  
 208 data.

209 The overall attack rates for ZVD as detected by local surveillance were  
 210 12.13 cases per 1,000 residents of San Andres and 18.43 cases per 1,000 resi-  
 211 dents of Girardot. These attack rates are similar to those reported from Yap  
 212 Island (14.3 per 1,000) [3] but higher than those reported in Salvador, Brazil  
 213 (5.5 per 1,000) [7]. In both areas, significantly higher attack rates are ob-  
 214 served among women, especially those of child-bearing age. The Colombian  
 215 government issued an epidemiological alert on December 2015 to actively  
 216 search for pregnant women with Zika-like symptoms in areas with active  
 217 transmission [27, 28]. This effort may partially explain the findings, though  
 218 differences in gender-specific attack rates persist when only cases occurring  
 219 prior to December are considered. Cases occurred in all age groups, but  
 220 the most affected age group was 20 to 49 year of age, similar to previously  
 221 published outbreaks in Yap Island, Federated States of Micronesia, and in  
 222 Salvador, Brazil [3, 7]. As the population was fully susceptible to Zika trans-  
 223 mission before the outbreaks, it is reasonable that all age groups would be  
 224 affected.

225 Forty-eight pregnant women with ZVD were reported from San Andres  
 226 and Girardot. These women are being followed according to national guide-  
 227 lines [27, 28] with no confirmed cases of microcephaly observed yet. Sev-  
 228 enteen neurological syndromes, including GBS and ZIKV-associated menin-  
 229 goencephalitis, were identified, similar to reports from French Polynesia and

230 Brazil [12, 29]. Laboratory-confirmation of these cases is challenging because  
231 neurological symptoms generally appear two weeks after acute symptoms [30]  
232 at which time ZIKV diagnosis by RT-PCR is not possible and serological tests  
233 are unreliable because of cross-reactivity with dengue [31, 32]. As ZIKV can  
234 be detected in urine longer than in blood [33], using urine samples to confirm  
235 ZIKV in GBS cases may be an alternative [34]. These challenges underscore  
236 the need for reliable diagnostic tests that can detect ZIKV after the viremic  
237 period.

238 The basic reproductive number ( $R_0$ ) was estimated in each area using  
239 daily incidence data. Our estimated  $R_0$  for the Zika outbreak in San Andres  
240 was 1.41 (95% CI 1.15 to 1.74), and the  $R_0$  for Girardot was 4.61 (95%  
241 CI 4.11 to 5.16). Applying the same methods with previously published  
242 data, we estimated that the  $R_0$  for Zika virus in Salvador, Brazil, was 1.42  
243 (95% CI 1.35 to 1.49) [7]. We consider the estimate from San Andres to  
244 be the most reliable because it is a small, densely populated island, while  
245 Girardot has a higher risk of importation because the population fluctuates  
246 during weekends and holidays. The relative magnitudes of  $R_0$  are consistent  
247 with the higher dengue transmission observed in Girardot versus San Andres.  
248 Estimates of  $R_0$  in Zika are not widely available, though reports suggest an  
249  $R_0$  of 4.3 to 5.8 in Yap Island and  $R_0$  of 1.8 to 2.0 in French Polynesia [35].  
250 A recent manuscript considering the French Polynesian outbreak reported a  
251 range from 1.9 to 3.1 [36].

252 Relatively few cases were laboratory confirmed. The majority of cases  
253 were clinically confirmed, and the symptoms could be caused by other eti-  
254 ologies such as dengue. This report only includes symptomatic cases who  
255 attended a health care facility and were captured by the surveillance sys-  
256 tems. ZIKV usually causes relatively mild illness lasting several days, and  
257 around 80% of infections are currently believed to be asymptomatic, so we  
258 are likely missing many mild or asymptomatic cases [10]. We also do not have  
259 a reliable estimate of under-reporting at these sites. Early under-reporting  
260 appeared to be especially apparent in the Girardot outbreak, and the sharp  
261 increase in cases observed may be due to increased public awareness of the  
262 disease. This phenomenon can result in an overestimate of  $R_0$ .

263 Well-designed studies can provide valuable insight. Phylogenetic anal-  
264 yses of circulating ZIKV strains will be critical for understanding whether  
265 mutations in the viral genome are associated with an increased severity of  
266 disease, as manifested by microcephaly and GBS in this outbreak. House-  
267 hold studies can allow for more accurate estimation of transmission dynamics

268 and enhance understanding of asymptomatic infection. Studies are required  
269 to understand the interactions between ZIKV, dengue, CHIKV, and other  
270 co-circulating arboviruses and their impact on disease. It is also necessary  
271 to increase surveillance of neurological syndromes associated with ZVD, like  
272 GBS and encephalitis.

273 The evidence for a causal relationship between ZIKV and microcephaly  
274 is strengthening [37, 38, 39]. Recent evidence from the French Polynesia out-  
275 break suggests an estimated number of microcephaly cases associated with  
276 ZIKV is around one per 100 women infected in the first trimester[40]. Cur-  
277 rently the Colombian Government is following a cohort of pregnant women  
278 that reported Zika-like symptoms anytime during their pregnancy. Those  
279 who are detected during the acute phase are being diagnosed with ZIKV  
280 RT-PCR. All women will be followed until the end of pregnancy, and the  
281 fetus will be evaluated during pregnancy and post-natally for twelve months.  
282 The prospective collection of data through this and other similar national  
283 cohorts will be essential for assessing causality, determining risk factors, and  
284 estimating rates of birth defects.

285 The results of this and other reports concludes that transmission of ZIKV  
286 may be widespread. Vector control has had limited success in controlling  
287 other arboviruses, such as dengue. A safe and efficacious vaccine, especially  
288 for women of child-bearing age, may be needed to reduce the disease burden.

### **Declaration of interests**

All authors have completed the unified competing interest form. None of the authors declared conflicts of interest.

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