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Infectious disease implications of large-scale migration of Venezuelan nationals

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Abstract

Background: The ongoing economic and political crisis in Venezuela has resulted in a collapse of the healthcare system and the re-emergence of previously controlled or eliminated infectious diseases. There has also been an exodus of Venezuelan international migrants in response to the crisis. We sought to describe the infectious disease risks faced by Venezuelan nationals and assess the international mobility patterns of the migrant population.
Methods: We synthesized data on recent infectious disease events in Venezuela and among international migrants from Venezuela, as well as on current country of residence among the migrant population. We used passenger-level itinerary data from the International Air Transport Association to evaluate trends in outbound air travel from Venezuela over time. We used two parameter-free mobility models, the radiation and impedance models, to estimate the expected population flows from Venezuelan cities to other major Latin American and Caribbean cities.
Results: Outbreaks of measles, diphtheria and malaria have been reported across Venezuela and other diseases, such as HIV and tuberculosis, are resurgent. Changes in migration in response to the crisis are apparent, with an increase in Venezuelan nationals living abroad, despite an overall decline in the number of outbound air passengers. The two models predicted different mobility patterns, but both highlighted the importance of Colombian cities as destinations for migrants and also showed that some migrants are expected to travel large distances. Despite the large distances that migrants may travel internationally, outbreaks associated with Venezuelan migrants have occurred primarily in countries proximate to Venezuela.
Conclusions: Understanding where international migrants are relocating is critical, given the association between human mobility and the spread of infectious diseases. In data-limited situations, simple models can be useful for providing insights into population mobility and may help identify areas likely to receive a large number of migrants.

Key words: Migration, infectious disease, vaccine-preventable disease, mobility, Venezuela

Introduction

Venezuela was once renowned for its investments in healthcare infrastructure and public health prevention efforts.[1] However, an ongoing political and economic crisis, triggered by declining oil prices, government overspending, international sanctions and inflation, has contributed to the collapse of the healthcare system.[2] Food insecurity is rampant. Access to medications and medical care is severely limited and there has been an exodus of healthcare workers from Venezuela to other countries.[1]

Although official data are sparse, a recent survey of public and private hospitals highlighted shortages of basic medicines and surgical supplies, with 79% of facilities having no access to water.[2] The collapse in public health infrastructure has manifested as increased maternal and infant mortality, and the return of infectious diseases that had previously been eliminated or controlled.[2]

Concurrently, there has been a mass exodus of Venezuelans seeking greater economic security, with the expatriate population increasing from 700 000 to 1.6 million from 2015 to 2017.[3] Over the same period, the number of Venezuelan migrants in South America has increased by an estimated 900% (from 89 000 to 900 000).[3] Given the challenges in documentation, these numbers are likely underestimates. With continued social, political and economic instability, these trends are expected to continue.

Understanding migrant travel patterns, and the infectious disease risks they face in Venezuela is important from both individual and population health perspectives. Travel medicine clinicians should be aware of the prevalence of infectious diseases in Venezuelan migrants and the risks they may pose to vulnerable populations.[4,5] We sought to summarize the current infectious disease risks facing Venezuelan nationals and to improve the understanding of the international mobility of Venezuelan migrant populations.

Methods

Infectious disease events associated with Venezuelan migrants

Data on current infectious disease events in Venezuela and among migrants from Venezuela were obtained by reviewing official government reports, the biomedical literature, ProMED-mail[6] and online news outlets.

Mobility data

Country-level information on Venezuelan nationals living abroad for the years 2015 and 2017 was obtained from the International Office of Migration (IOM).[3] Current estimates (up to May 2018) of asylum seekers and migrants residing in other countries through alternative legal stay arrangements were obtained from the United National High Commissioner for Refugees (UNHCR).[7] Alternative legal stay includes temporary residence permits, labour migration visas and humanitarian visas that allow for temporary residence in a country.[7]

Air travel analysis

We used passenger-level flight itinerary data from the International Air Transport Association (IATA) to evaluate trends in air travel from Venezuela over time. IATA data accounts for ~90% of all commercial air travel with the remaining 10% of trips modelled using airline market intelligence.[8] We quantified monthly outbound passenger numbers from all Venezuelan airports to international destinations for the time period January 2007–December 2017, which represents the most recent available data.

Mobility modelling

We developed the models of ground mobility to complement the air travel analysis. We restricted the analysis to cities in the Latin American and the Caribbean (LAC) countries, as this was considered a reasonable geographic area for ground travel. Cities located in LAC with populations of 300 000 or more inhabitants were identified using the United Nations World Urbanization Prospects urban agglomerations data.[9] There were 19 Venezuelan cities and 185 other LAC cities that met these criteria, with 20 countries in addition to Venezuela represented. We created an origin–destination matrix for each Venezuelan city to each city outside of Venezuela, using the centroid of each city to compute the geodesic distance between each city pair and 2015 population estimates from the United Nations.[9]

To estimate the expected population flows from Venezuelan cities to neighbouring countries, we used two parameter-free models: the radiation and impedance models. Both models are suitable for use in data-limited situations.[10] The radiation model uses a diffusion principle and assumes that populations are cumulatively 'absorbed' by destination cities as they move outward from their origin.[11,12] The probability of travelling from region i to region j is described by:

$$p_{ij} = \frac{N_i N_j}{(N_i + S_{ij})(N_i + N_j + S_{ij})}$$

where N_i and N_j are the population sizes of regions i and j, respectively, and S_{ij} is the population within a circle of radius equal to the geodesic distance between the two populations, centred on region i and excluding the populations of regions i and j.

The impedance model is based on Ohm's law of electricity[10] and takes the following functional form:

$$p_{ij} = \frac{\frac{N_i + N_j}{d_{ij}}}{\sum_{i \neq j}\left(\frac{N_i + N_j}{d_{ij}}\right)}$$

Here, d_{ij} is the geodesic distance between city centroids i and j. Travel over water was treated the same as land travel when calculating distances. For both models, we calculated the relative probability of travel from each Venezuelan city to each city located outside of Venezuela. We generated the summary estimates of the probability of travel from all Venezuelan cities combined to each destination city by weighting each individual origin–destination probability by the origin city population size. To determine the relative attractiveness of each country for migrants and compare the model results to official statistics, we summed these city-level estimates to the national level to get a rank ordering of country attractiveness for migrants. We calculated percent agreement and Cohen's kappa between the data and models. For the visualization of results, we only included cities where the probability of migration was >1% and presented the results for two major Venezuelan cities, Caracas (the capital of Venezuela) and Ciudad Guayana (the largest city in Bolívar state, which currently experiences high domestic population mobility associated with illegal gold mining in the area).

Table 1. Summary of key infectious diseases events in Venezuela with exportation risk

Disease	Description	Major driver(s)	Exported cases reported?	Source
Diphtheria	1086 confirmed cases (as of 21 April 2018); cases reported across entire country	Low vaccination coverage	Yes	Pan American Health Organization[13]
Measles	2154 confirmed cases (as of 08 June 2018); outbreak concentrated in Bolívar state	Low vaccination coverage	Yes	Pan American Health Organization[14]
Malaria	319 765 cases reported from 01 Jan to mid-October 2017; cases concentrated in Bolívar state	Lack of vector control; shortage of medicine	Yes	Pan American Health Organization[17]
HIV	Approximately 6500 new cases in 2016; highest prevalence among the Warao indigenous population	Lack of testing and treatment	Yes (congenital cases reported in Colombia)	UNAIDS[20]; Daniels[21]; New York Times[50]

Results

Infectious disease landscape in Venezuela

With the ongoing crisis in Venezuela, several infectious diseases that had been previously well controlled or eliminated have emerged as significant public health concerns. These events serve as sentinels of a collapsing health system and an increasingly vulnerable population. We review the major disease events below and a summary is provided in Table 1.

Vaccine-preventable diseases

Vaccine shortages and a lack of vaccination programmes have contributed to a resurgence of vaccine-preventable diseases. A diphtheria outbreak was first reported in July 2016, and as of 21 April 2018, there were an estimated 1086 laboratory-confirmed cases reported in 22 (of 23) states and the Capital District.[13]

Measles returned to the country in 2017, with 2154 confirmed cases reported as of 8 June 2018.[14] Cases have been reported in 17 states and the Capital District, with the majority of cases reported in Bolivar state.[14] Of 35 reported measles deaths, 33 occurred in one state, Delta Amacuro.[14]

Malaria

Prior to 1936, Venezuela had the largest number of malaria cases in Latin America.[15] Intensive malaria control efforts led to Venezuela being recognized by the World Health Organization as the first country to eliminate malaria in densely populated areas in 1961.[15] Despite leading the way in early elimination efforts, there has been a recent resurgence in malaria incidence in Venezuela, with cases increasing annually since 2008.[16] Between 2015 and 2016, reported cases increased by over 75%, from 136 402 to 240 613.[16] Official case report data are only available until mid-October (epidemiological week 42), but with 319 765 cases reported, it is clear that the dramatic upward trajectory in malaria cases continued in 2017.[17] Most of the reported cases in 2017 were due to *Plasmodium vivax* (77%), with 17% due to *Plasmodium falciparum*.[17] Reported cases are focused in Bolivar state (64% of cases in 2017).[16,17]

As with other diseases, there is a severe shortage of antimalarial drugs[18] and a black market exists for the limited drugs that are available, making treatment inaccessible to many. This is of particular concern as untreated individuals can remain infectious for long periods of time, despite resolution of symptoms.[19] Vector-control activities are reduced or non-existent: the number of people protected by indoor residual spraying declined from >2.7 million in 2015 to an estimated 30 000 in 2016.[16]

Other infectious diseases of public health importance

An estimated 120 000 Venezuelans were living with HIV in 2016, among whom 61% were accessing antiretroviral therapy (ART).[20] Observers in Venezuela state that the actual situation is much bleaker than official statistics suggest.[21] ARTs are extremely limited and there are also shortages of diagnostics, medicines to treat opportunistic infections and condoms to prevent sexual transmission.[20,22] Only 48% of pregnant women living with HIV have access to medicines to prevent mother-to-child transmission.[20] Non-governmental organizations are filling the role of government to provide treatment to vulnerable individuals and patients are also travelling to neighbouring countries for treatment and to purchase ARTs.[21]

Venezuela was once renowned for its strong tuberculosis prevention and control programme, but experts have reported a resurgence of tuberculosis in recent years.[23,24] Tuberculosis testing programmes have closed, there is a shortage of medications, and uncontrolled HIV and widespread malnutrition is contributing to the upsurge in cases.[24]

Other vector-borne diseases, including arbovirus infections (Zika, dengue and chikungunya),[25] helminth infections (schistosomiasis and onchocerciasis) and protozoan infections (leishmaniasis and Chagas disease), are all of concern, given the reduction in public health control activities across the country.[1] Indeed, the importance of Venezuela as a source for exported dengue cases has been documented previously.[26,27] One unusual recent occurrence has been the emergence of urban and peri-urban outbreaks of food-borne Chagas disease.[28–30] Outbreaks of waterborne diseases have not been widely reported, but the spectre remains, as water shortages are occurring across the country, particularly affecting the capital region.

International migration of Venezuelan nationals

Estimates of the current country of residence of Venezuelan nationals as well as the number of Venezuelan nationals living abroad as asylum seekers or in alternative legal stay arrangements provide an indication of the relative importance of different international destinations for migrants (Table 2).[3,7] These estimates, which measure different aspects of the migrant experience, show similar trends. Historically, Colombia, Spain and the USA have been the major destinations for Venezuelan migrants, and these countries continue to attract large numbers of migrants (estimated at >70% of migrants in 2017). In Colombia, the population of Venezuelan migrants is estimated to have increased over 10-fold in just 3 years. Increasing

Table 2. Estimated size of the Venezuela-born population living abroad and current estimated number of asylum seekers and those residing in countries under alternative legal stay arrangements

Location	Population living abroad[3] 2015	2017	Percent change	Current estimates of asylum seekers and alternative legal stay residents[7]
Worldwide	697 562	1 642 442	135.5	
South America	88 975	885 891	895.7	
North America	273 418	308 832	13.0	
Central America	33 065	78 641	137.8	
Caribbean	21 074	41 693	97.8	
Significant destination countries				
Colombia	48 714	600 000	1131.7	178 188
USA	255 520	290 224[a]	13.6	68 270
Spain	165 895	208 333	25.6	17 851
Chile	8001	119 051	1388.0	86 726
Argentina	12 856	57 127	344.4	63 578
Italy	48 970	49 831	1.8	–
Ecuador	8901	39 619	345.1	52 734
Panama	9883	36 365	268.0	58 542
Brazil	3425	35 000	921.9	60 548
Mexico	15 959	32 582	104.2	29 495
Peru	2351	26 239	1016.1	70 180
Dominican Republic	5417	25 872	377.6	99
Portugal	24 174	24 603	1.8	–
Canada	17 898	18 608	4.0	4228
Costa Rica	6437	8892	38.1	11 528
Uruguay	1885	6033	220.1	3302
Trinidad and Tobago	1732	1743	0.6	2249

[a]Estimate is for 2016.

numbers of migrants are also relocating to countries that had not been major draws in the past, including Chile, Peru, Brazil, Panama, Ecuador and the Dominican Republic.[3]

At the beginning in 2013, there has been a dramatic downturn in outbound air travel from Venezuela (Figure 1). Shifting patterns in destination countries are also apparent in the air passenger data. For example, Panama has experienced a proportionate increase in passengers since the start of the crisis.

The 10 LAC countries with the highest probabilities of receiving Venezuelan migrants differed between the two mobility models (Table 3). The impedance model had greater concordance with the IOM[3] and UNHCR[7] data (80% agreement, kappa = 0.6, P = 0.004 with IOM, and 70% agreement, kappa=0.4, P = 0.04 with UNHCR data) than the radiation model (70% agreement, kappa = 0.4, P = 0.04 with IOM and 60% agreement, kappa = 0.2, P = 0.19 with UNHCR data).

Different origin cities in Venezuela generated different predicted attractiveness to destination cities across the region (Figure 2). The radiation model predicted mobility patterns that were more concentrated around the origin, while the impedance model estimated more widespread dispersal of the population. Both models estimated the highest attractiveness for migrant populations to be cities located in Colombia.

Infectious disease events associated with Venezuelan migrants in other countries

Cases of measles, including secondary transmission, have been reported in Brazil, Colombia and Ecuador, all with links to Venezuelan nationals.[14] Of particular note is an ongoing outbreak in Brazil's Roraima state, where 84 confirmed cases have been reported to date with 69% of cases occurring in Venezuelan migrants residing in Brazil.[14] Two imported cases of diphtheria in Venezuelan children without histories of vaccination were identified in Colombia in 2018.[13] Brazil also reported a case of diphtheria in 2017 in a Venezuelan migrant.[31] To date, none of the imported diphtheria cases has been associated with secondary cases.

The current malaria outbreak in Venezuela has also been associated with exportation of cases to Brazil, Guyana and Colombia.[1] It is estimated that 78 and 81% of imported malaria reported cases in 2016 in Brazil and Colombia, respectively, originated in Venezuela.[18] Cases of congenital HIV and syphilis, both of which are rare in Colombia, are increasing due to Venezuelans seeking medical care in border towns.[21] More broadly, the living conditions experienced by some Venezuelan migrants, including overcrowding and lack of sanitation, are important risk factors that increase migrants' vulnerability to various infectious diseases.

Discussion

The ongoing economic and political crisis in Venezuela has resulted in the re-emergence of previously controlled or eliminated infectious diseases. In this paper, we reviewed challenges in Venezuela due to resurgence of previously controlled infections and used mobility models to identify cities and countries linked to Venezuela as a result of migration and therefore at

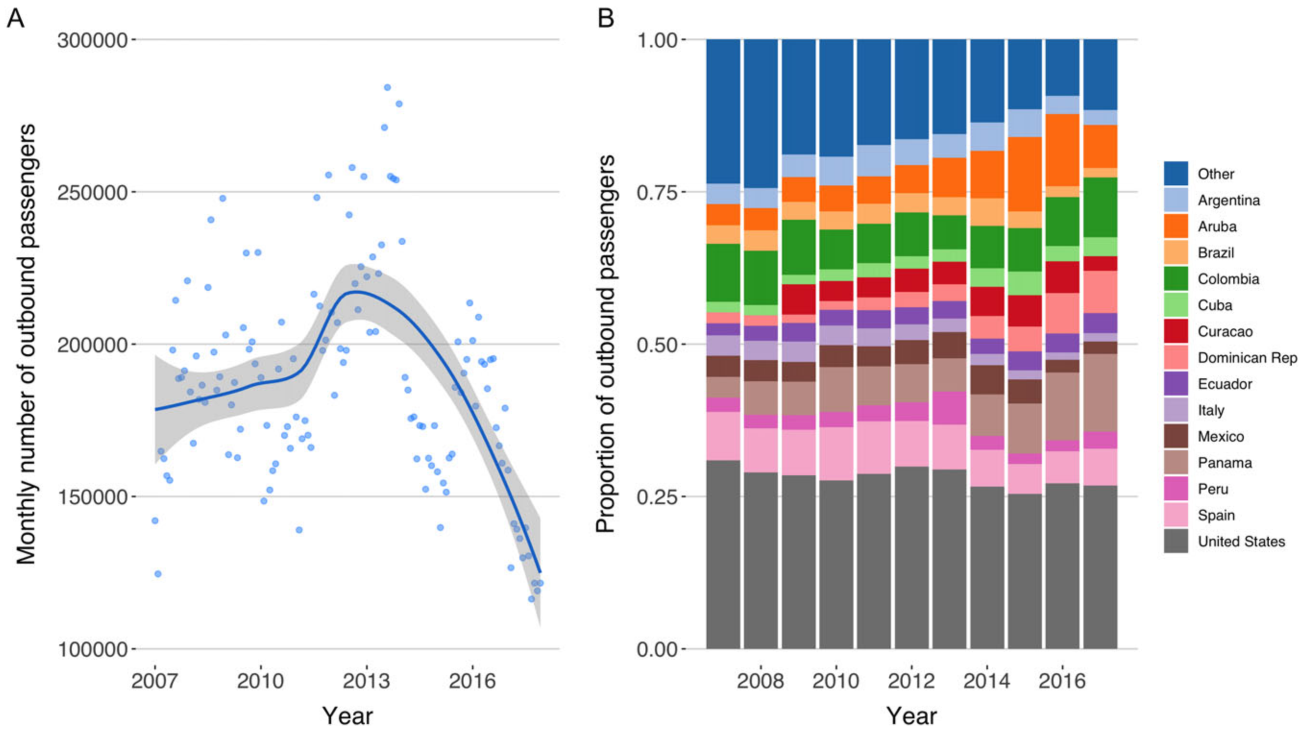

Figure 1. Trends in outbound air travel from Venezuela, 2007–17. (A) Monthly number of outbound passengers to all international destinations (points). The solid line represents the locally weighted smoothing interpolation to the data points (LOESS) and the grey-shaded area shows the 95% confidence interval. (B) Proportionate distribution of destination countries for outbound passengers from Venezuela over time.

Table 3. Top 10 Latin American and Caribbean destination countries using the radiation and impedance models of population mobility

Rank	Radiation model	Impedance model
1	Colombia	Colombia
2	Brazil	Brazil
3	Mexico	Mexico
4	Dominican Republic	Peru
5	Haiti	Argentina
6	Peru	Dominican Republic
7	Ecuador	Ecuador
8	Cuba	Cuba
9	Panama	Chile
10	Honduras	Haiti

risk for observing cases or outbreaks of these resurgent communicable diseases.

In our review of available data on outbreaks, we find vaccine-preventable diseases to represent a powerful sentinel for the decline in public health and medical care resources in Venezuela. Measles is highly transmissible, with vaccination coverage of ~95% required to achieve herd immunity (the level of population immunity required to prevent ongoing transmission).[32] Measles' outbreaks, such as those observed in Venezuela, are often the first sign of decline in vaccination coverage. However, the resurgence of less infectious diseases, like diphtheria, suggests that vaccination coverage is now even lower, making re-emergence of other previously controlled diseases like rubella, polio, mumps and pertussis possible.[32] Notably, in Colombia and Brazil, estimated measles immunization coverage is below the threshold required for herd immunity, while diphtheria coverage is above the threshold,[33] consistent with the observation of secondary transmission events following introduction from Venezuela of measles but not diphtheria.

In addition to vaccine-preventable diseases, we note a surge in malaria, a disease previously controlled in much of Venezuela. Malaria resurgence highlights the impact of internal migration as a result of economic turmoil, with the largest increases in risk associated with illegal mining activities in Bolivar state and the associated establishment of informal settlements.[1] The highly mobile nature of this population appears to be contributing to reintroduction of malaria to areas previously declared malaria-free, such as the federal capital of Caracas.[16]

The increases in reported infectious diseases within Venezuela are particularly notable, given the limited official public health surveillance data that have been released in recent years. These known events undoubtedly present an incomplete picture of the growing infectious disease burden faced by the population.[2] Given the scarce data from within Venezuela, infectious disease events associated with international migrants may serve as signals for what is occurring within the country.[34,35] Vigilance in healthcare providers treating Venezuelan migrants is important, as individuals may present with diseases not historically associated with the country, and increased prevalence of these diseases may result in cases presenting with less common symptoms.[24]

The increased infectious disease burden described herein is not unique to the current situation in Venezuela; increased

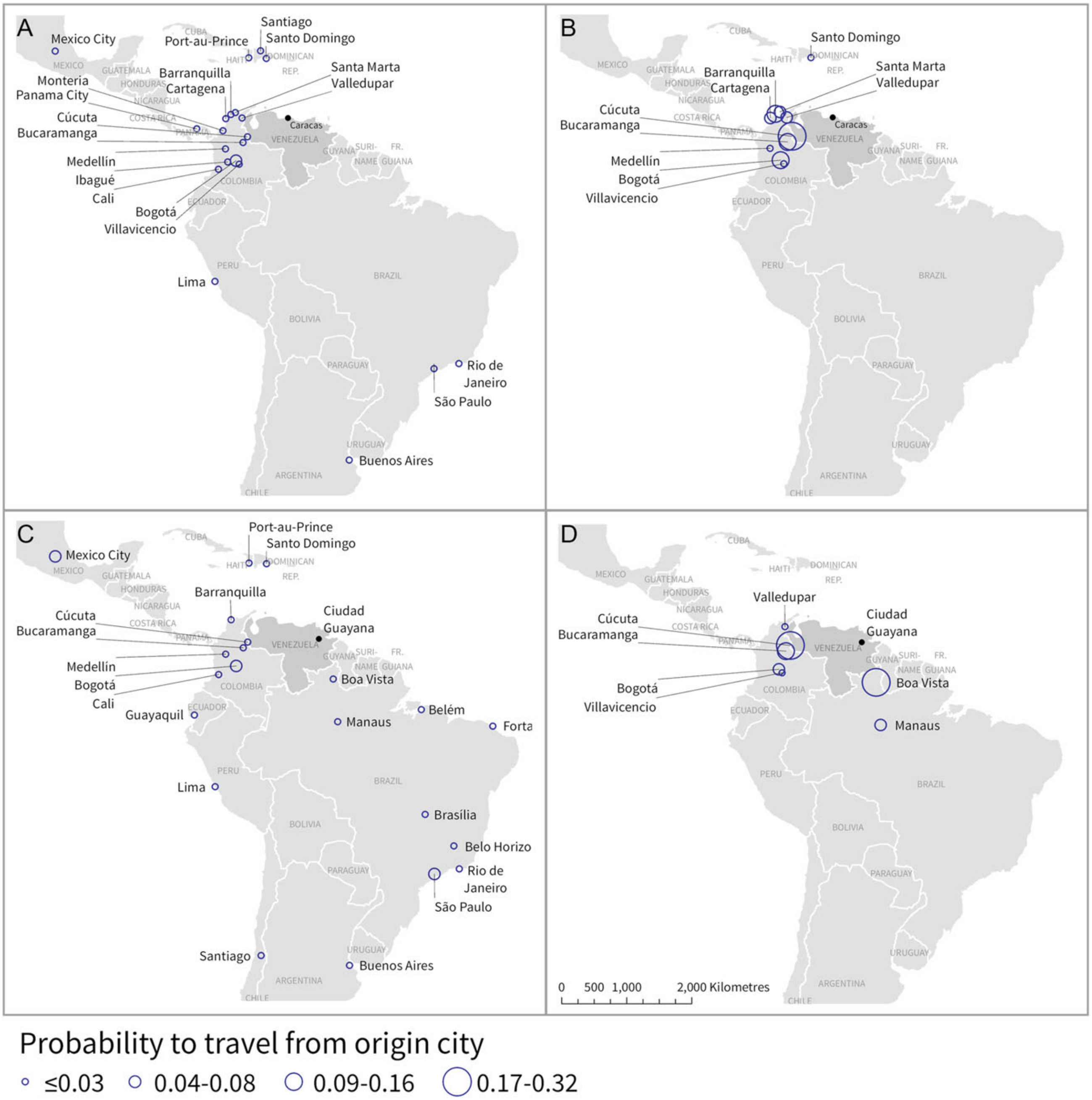

Figure 2. Comparison of impedance (A, C) and radiation (B, D) mobility model predictions of migrant flows to major Latin American and Caribbean cities. Results are shown for the origin cities of Caracas (A, B) and Ciudad Guayana (C, D). Points are proportionate to the probability of travel to a given city. Cities with probability less than 0.01 are not shown.

communicable disease occurrence has been noted in other migrant populations, although the country of origin and local epidemiology in the origin determines the particular diseases observed.[36–38] Physical, mental and social health can be affected by both the circumstances leading to migration and the act of migration itself, which in turn can increase infectious disease vulnerability.[36] The plight of Venezuelan migrants highlights the importance of understanding, anticipating and addressing the health needs of migrant populations, particularly among travel medicine practitioners.[4,5,39]

Understanding where migrants are relocating is critical, given the association between human mobility and the spread of infectious diseases[40–42] and the overall trend of increased global connectivity.[43] To better predict the movements of migrants, and the infectious diseases that may accompany them, we used two parameter-free mobility models. These models appear to perform well even with the limited, publicly available data we were able to obtain for validation. Notably, these models make no assumptions about rates of migration or mode of travel. The latter is important, as migrant volumes are increasing despite declining numbers of departing air passengers, implying that migration may occur increasingly by land or maritime routes.[44] Both models highlighted the importance of Colombia as a destination for migrants from Venezuela, suggesting that that country may benefit from enhanced surveillance and disease control assistance from the international community.[44] The impedance model appeared to be better for capturing longer term movements, while the radiation model was more suitable for identifying locations where migrants are initially drawn, possibly en route to final destinations. These different models may thus be applicable to different stages of the migration journey.[4] Our models have limitations, the major one being simplifying assumptions. We considered international migration to large cities only, did not account for road network or landscape features that may limit movement along certain routes and did not incorporate factors such as language, economic prosperity, colonial ties or immigration policies that may influence the choice of destination country.[12,45] Restricting the analysis to cities with population sizes of at least 300 000 may have influenced the results to make countries with a greater number of large cities appear disproportionately attractive to migrant populations. Nonetheless, this approach can be considered a supplement to more resource intensive on-the-ground data collection.[44,46] Although previous research supports the use of these models for predicting within-country human mobility,[10,11] their application to between-country migration would benefit from validation using traditional or novel data sources.[47–49]

In summary, Venezuela is in the midst of an emerging public health crisis, resulting from the collapse of its healthcare system and the re-emergence of previously controlled infectious diseases. Models that predict human migration may be useful tools to rapidly estimate population movement and help focus limited public health resources and prevent the spread of communicable diseases.

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Authors' Contributions

ART, ATB, HA, AW and JY contributed to the design and analysis of the study, as well as the preparation of the manuscript. DB, CH and KP contributed to data acquisition, development of the mobility models, and figure preparation and edited the manuscript. IIB and KK made significant content contributions and edits to the manuscript.

Conflict of interest: KK is the founder of BlueDot, a social enterprise that develops digital technologies for public health. All authors received employment or consulting income from BlueDot during this research.

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