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Original research

Economic burden of measles outbreaks: a cost-of-illness study in a middle-income country in the post-elimination era

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ABSTRACT

Objective. To estimate the direct costs associated with the diagnosis, treatment, and control of measles cases in Brazil from 2018 to 2020.

Methods. This cost-of-illness study utilized a prevalence-based approach, considering direct costs incurred by the Brazilian Public Health System (SUS) related to measles outbreaks, including costs of inpatient care, outpatient care, and laboratory tests, as well as measles-containing vaccines and laboratory tests (viral isolation) used for outbreak control. Costs are presented in 2020 US dollars. Univariate and bivariate sensitivity analyses were performed.

Results. There were 36 236 confirmed measles cases from 2018 to 2020. The estimated outbreaks cost was USD 107 960 122, with the cost per case ranging from USD 2 601 to USD 3 654 (mean USD 2 979).

Conclusions. These findings highlight the substantial economic burden imposed by measles outbreaks in Brazil and emphasize the importance of measles prevention and control measures. Policymakers and public health authorities can use these results to plan and allocate resources, to mitigate the economic impact of future outbreaks.

Keywords Measles; disease outbreaks; health care costs; Brazil.

In 2016, Brazil and the Americas were declared measles free by the Pan American Health Organization (PAHO). In 2018, measles cases imported from the Bolivarian Republic of Venezuela led to an outbreak in the North Region of Brazil, resulting in approximately 10 000 confirmed cases and 12 deaths. In 2019, measles cases imported to São Paulo from Europe and Israel resulted in a large outbreak that spread throughout the country, leading to more than 20 000 confirmed cases and 18 deaths. In 2020, more than 8 000 confirmed cases, most in the North and Southeast regions, and 10 deaths were recorded by the surveillance system (1). Due to the sustained transmission of the same genotype (D8) for more than 12 months, Brazil lost its measles elimination certification in 2019.

Cost-of-illness (COI) studies of measles outbreaks in high-income countries in the post-elimination era (2–8) have noted the high cost of outbreaks and response actions. However, no information on the economic impact of measles outbreaks in Latin American middle-income countries is available. Local studies have described the strategies adopted and effectiveness of surveillance and control measures implemented during previous outbreaks in Brazil (9). However, to date, little evidence on costs of measles outbreaks for the Brazilian Public Health System (Sistema Único de Saúde – SUS) is available.

The lack of evidence on the economic burden of measles outbreaks in Brazil or any Latin American middle-income country

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motivated this study. In an era of diminished financial resources for the public health system, assessing outbreak costs can highlight the potential economic benefits of avoiding measles reemergence. The aim of this study was to estimate the direct costs involved in the diagnosis and treatment of measles cases and the vaccines and laboratory tests used for outbreak control, from 2018 to 2020 in Brazil, from the health system perspective.

MATERIALS AND METHODS

This study used the World Health Organization (WHO) definition of a measles outbreak as two or more laboratory-confirmed cases that are temporally related and epidemiologically or virologically linked (10). A measles case was defined as a patient with rash and either laboratory evidence of infection or an epidemiologic link to a laboratory-confirmed case. We considered cases with the onset of symptoms from 1 January 2018 to 31 December 2020. A systematic review of economic evaluation studies of measles outbreaks that occurred from 2011 onward (11) enabled us to develop the study methodology.

Study design and data sources

A "prevalence-based approach" was adopted in this COI study for the documentation of resource utilization and costs estimation. This approach was used to retrospectively estimate the economic burden of measles over three years (2018 to 2020) (12). The study was conducted from the perspective of SUS, which is the main body responsible for the immunization program and outbreak response in Brazil. The analysis included only direct costs borne by SUS.

Costs were classified according to the Drummond classification (13). We retrospectively collected and analyzed data on direct costs related to measles outbreaks, including costs of inpatient care, outpatient care, laboratory tests, and measles-containing vaccines and laboratory tests (viral isolation) used for outbreak control. A gross-costing top-down approach was applied for inpatient care, laboratory tests, and vaccines. A microcosting bottom-up approach was used for outpatient care.

Inpatient care

The absolute yearly number of hospital admissions and their costs were retrieved from the Hospital Information System (Sistema de Informação Hospitalar do SUS – SIH-SUS), an administrative database that stores information on hospital admissions in SUS, which accounts for approximately 70% of all hospitalizations in Brazil (14). The main purpose of SIH-SUS is to provide financial reimbursement to healthcare providers (15). The International Statistical Classification of Disease and Related Health Problems 10th Revision (ICD-10) diagnosis codes for measles (B05.0–9) were used to identify measles cases in the SIH-SUS database. We assumed that all hospital cases received outpatient care before receiving inpatient care, and we added the outpatient costs to hospitalization costs. Note that healthcare reimbursement was used as a proxy for direct healthcare costs of hospitalized measles cases. We used data from SIH-SUS because the Brazilian population (approximately 203 million people) is almost fully covered by SUS, a universal health system funded by taxation. We also retrieved the number of hospital admissions from the Notifiable Conditions Information System (Sistema de Informação dos Agravos de Notificação – SINAN), the surveillance system that records data on measles cases cared for in both public and private health systems.

Outpatient care

To calculate the number of outpatients, we used the total number of annual confirmed measles cases, retrieved from SINAN database. We then subtracted the number of inpatients in each year from the number of confirmed cases.

In an effort to reflect the health resource use in clinical practice in the real world, we consulted a panel consisting of infectious disease and pediatrics physicians working in primary and secondary health care and in the emergency department of SUS services in São Paulo city.

We estimated health resource utilization for two age groups: ≤9 years, and >9 years. Based on the advice of the specialists panel, we assumed that pediatric cases (≤9 years) had two medical visits, 50% of them had a hemogram test, 50% of them underwent a thorax X ray, and 10% a urine analysis. Ninety percent of pediatric cases received vitamin A, and all symptomatic patients received dipyrone or paracetamol. Regarding complications, we assumed that 1% of pediatric measles cases developed pneumonia and were treated with amoxicillin (two vials per case), 9% had acute otitis media and were also treated with amoxicillin (two vials per case), and 8% had diarrhea and received oral rehydration for five days. For cases aged >9 years, we assumed one medical visit without further investigation. All symptomatic cases of this group received dipyrone or paracetamol (10 pills per case) and all patients with complications were hospitalized.

Medical visit and test unit costs were retrieved from Sistema de Gerenciamento da Tabela de Procedimentos, Medicamentos e OPM do SUS (SIGTAP). For medicines, we used the unit costs of the Health Prices Database (Banco de Preços em Saúde – BPS), a national reference for prices of medicines and health products.

Laboratory tests

The absolute yearly number of measles laboratory tests performed by public health laboratories was provided by the Laboratory Environment Manager (Gerenciador de Ambiente Laboratorial – GAL), a computerized system developed in accordance with the protocols of the Ministry of Health (MoH) to generate management and production reports of the public health laboratory networks. This system is implemented in 85% of Brazilian states, covering 66.4% of the country's population (16). The yearly number of measles tests performed for diagnosis (serological tests [ELISA] for IgG and IgM antibodies and real-time polymerase chain reaction [PCR]) and surveillance (viral isolation/genotyping) was multiplied by the unit cost of each test for each year to obtain the total cost per year. The following unit costs were obtained from SIGTAP (http://sigtap.datasus.gov.br/tabela-unificada/app/sec/inicio.jsp): USD 18.6 for PCR, USD 0.9 for IgG tests, and USD 1.2 for IgM tests. Viral isolation unit cost (USD 48.5) was provided by GAL.

Vaccines used for outbreak control

The following vaccination strategies were adopted throughout the outbreak: (1) selective vaccination of contacts of suspected

or confirmed measles cases, according to the National Vaccination Calendar; (2) measles–mumps–rubella (MMR) vaccination for all infants aged 6–12 months (invalid dose for routine schedule); and (3) reinforcement of routine vaccination for all persons aged 1–59 years, particularly healthcare workers, to reduce the number of unvaccinated persons. Furthermore, national vaccination campaigns were conducted as follows: indiscriminate vaccination of all children aged 1–4 years in 2018, aiming to decrease unvaccinated rates and vaccine failures; completion of routine vaccination schedule for children aged 6 months to <5 years and young adults aged 20–29 years in 2019; vaccination targeting all persons aged 20–49 years, regardless of previous vaccination, in 2020; and vaccination targeting all children aged 1–4 years, regardless of prior vaccination, and healthcare workers in 2022.

Two measles-containing vaccines were used: measles–rubella (MR) and MMR vaccines. The numbers of MR and MMR vaccine doses administered in Brazil from 2016 to 2020 were retrieved from the Information Technology Department of the Unified Health System (DATASUS) on 5 October 2021.

We considered two years before the measles outbreak (2016–2017), when no confirmed measles cases were reported, to calculate the yearly mean number of MMR doses used in routine immunization. To estimate the number of MMR vaccine doses used to control the outbreak, we subtracted the estimated yearly mean number of MMR vaccine doses used for routine immunization from the total number of MMR doses administered each year from 2018 to 2020. Since both vaccines are available in multidose vials and because the unused doses remaining in open vials must be disposed of at the end of the workday, we considered a 10% waste rate.

Costs

MR and MMR vaccine costs were obtained from the MoH database. Based on the total number of purchased doses and the amount paid, we estimated the mean price per dose for each vaccine in each year. MR mean price was USD 0.65 in both 2019 and 2020. MoH did not acquire MR data in 2018; therefore, we used the 2019 price for 2018 doses. MMR mean price was USD 2.68 in 2018 and USD 1.74 in both 2019 and 2020. Vaccine cost included the cost of the vaccine and the waste rate (10%). We also included the average delivery cost, defined in the WHO-led Consensus Statement (17) of USD 2.59 per dose (as estimated for routine immunization in upper middle-income countries) (18).

All costs were reported in Brazilian reals (BRL). The costs incurred in 2018 and 2019 fiscal years were adjusted for inflation to 2020 Brazilian reals using the Consumer Price Index. Then, all costs were converted to 2020 US dollars using the average exchange rate (USD 1 = BRL 5.16) according to the Central Bank of Brazil.

Sensitivity analysis

Univariate sensitivity analyses were performed by varying costs related to the number and cost of hospital and outpatient cases, number of laboratory tests (20% increase), number of vaccine doses, and vaccine delivery costs. Bivariate sensitivity analyses were performed by varying the number of measles cases (50% increase in the number of both hospital and outpatient cases simultaneously).

The number of hospitalizations also varied according to the SINAN database, which registers a greater number of measles hospitalizations than the SIH-SUS database. We also recalculated costs using the 90th percentile for hospitalization costs. We recalculated outpatient costs considering an increase of 50%.

The numbers of vaccine doses were recalculated by adding or subtracting 15% of the total number of administered doses in each year. Vaccine delivery costs were recalculated using an estimate of USD 5 based on a systematic review of the costs of delivering vaccines in low- and middle-income countries (19).

This study was approved by the ethics committee of Medical School of São Paulo University.

RESULTS

Epidemiology

According to the SINAN database, 100 569 suspected measles cases were reported between January 2018 and December 2020. In 2018, most (79.4%) of the 16 964 suspected cases were reported in the North Region; in 2019, out of the 66 355 cases, 56 902 (85.8%) were reported in the Southeast Region; and in 2020, the North and Southeast regions together accounted for 87.8% of the 17 250 reported cases. Of the 100 569 reported cases, 36 236 cases were laboratory or epidemiologically confirmed (Table 1).

Direct medical costs

Inpatient care. From 2018 to 2020, 2 222 measles hospitalizations were registered in SIH-SUS, which generated a total of 9 300 days of hospitalization reimbursed by SUS. Hospital cases presented an average length of stay of 4.2 days (range 2.2–5.7). The total estimated hospitalization reimbursement cost for the 2 222 cases was USD 154 402 (Table 2). The mean cost per hospitalization was approximately USD 69, and 80% of cases had hospitalization costs ranging from USD 34 to USD 65. The North and Southeast regions, responsible for 46.6% and 40.3%, respectively, of all hospitalizations from 2018 to 2020, had a mean hospitalization cost of USD 55 and USD 62, respectively.

In 2018, hospitalizations of children younger than 1 year represented 34.2% of the total yearly cost. Patients aged 1–4 years, 5–9 years, and 20–29 years accounted for 28.6%, 8.1%, and 10.5%, respectively, of hospitalizations. These age groups were responsible for 81.4% of all hospitalization costs in 2018. In 2019, the year with the highest hospitalization costs in the analyzed period, more than three-quarters of the costs were concentrated in the following age groups: <1 year, 1–4 years, and 20–29 years (45.0%, 20.7%, and 11.5%, respectively). There was an increase in the relative participation in costs among children <1 year. In 2020, distribution of hospitalization costs by age group was quite similar to that in the previous year, with the age groups <1, 1–4, and 20–29 years accounting for 77.7% of hospitalization costs (data available from the authors upon request).

According to SINAN data, there were 1 335 hospitalizations in 2018, 2 685 in 2019, and 1 393 in 2020, with a total of 5 413

TABLE 1. Number of reported, confirmed, and hospital measles cases by region and year, Brazil, 2018–2020

	2018			2019			2020			Total		
Region	Reported	Confirmed	Hospital	Reported	Confirmed	Hospital	Reported	Confirmed	Hospital	Reported	Confirmed	Hospital
Midwest	266	2	–	682	25	19	124	20	5	1 072	47	24
Northeast	995	14	17	3 311	567	94	418	94	28	4 724	761	139
North	13 469	9 237	811	1 211	418	29	9 094	5 038	358	23 774	14 693	1 198
Southeast	1 467	27	28	56 902	16 235	641	6 043	2 228	133	64 412	18 490	802
South	767	47	10	4 249	1 770	25	1 571	514	24	6 587	2 331	59
Total	16 964	9 327	866	66 355	19 015	808	17 250	7 894	548	100 569	36 236	2 222

Source: Prepared by the authors using data from SINAN (Notifiable Diseases Information System) for reported and confirmed cases; SIH-SUS (Hospital Information System) for hospital cases.

hospitalizations across the country in the three years (data available from the authors upon request).

Outpatient care. We estimated that there were 34 014 measles outpatients, accounting for approximately 94% of the confirmed cases. Of the outpatients, 18 207 (53.5%) occurred in 2019 (Table 2). The cost of outpatients was calculated by multiplying the number of cases by the estimated cost, amounting to USD 131 338.

Laboratory tests. According to GAL, 334 534 measles diagnostic tests were performed in SUS from 2018 to 2020. Of these tests, 65% (216 987) were performed in 2019. The predominant laboratory tests used were ELISA, with a total of 140 551 (42%) IgG tests and 143 310 (43%) IgM tests (Table 3).

The estimated annual laboratory test reimbursement costs were USD 272 358 in 2018, USD 920 737 in 2019, and USD 176 954 in 2020, totaling USD 1 370 049 for the three-year period.

Outbreak response

The number and costs of MMR and MR vaccine doses used for outbreak control are presented in Table 4. The costs of vaccine doses were obtained from the MoH database. The total cost of purchasing and delivering vaccines to control the outbreaks was USD 105 937 157.

The cost of laboratory tests for surveillance (viral isolation) was USD 354 095. Table 5 presents detailed estimates by component cost. The total direct medical costs for diagnosis and treatment of measles cases and vaccines used for outbreak control across Brazil totaled USD 107 960 122. The estimated mean direct costs per case in 2018, 2019, and 2020 were USD 3 181, USD 2 601, and USD 3 654, respectively.

The costs of vaccines used for outbreak control accounted for the largest portion of the SUS-covered economic burden (98.1%), followed by laboratory test costs (1.3%), inpatient care costs (0.2%), and outpatient care costs (0.1%).

Sensitivity analysis showed that the total cost varied between USD 93 514 146 (when we subtracted 15% from the administered doses) and USD 164 737 554 (when the USD 5 delivery cost was used) (data available from the authors upon request).

DISCUSSION

This study quantified the direct costs involved in diagnosis and treatment of measles, laboratory tests for surveillance (viral isolation) and vaccine purchase and delivery to control measles outbreaks in Brazil, from 2018 to 2020. We estimated that over this three-year period, the outbreaks cost SUS a total of USD 107 960 122. The cost per case ranged from USD 2 601 (in 2019) to USD 3 654 (2020), with a mean of USD 2 979. Measles persisted in 2021 and 2022 (668 and 43 confirmed cases, respectively); thus, the actual amounts spent by SUS were probably greater. If cases in 2021–2022 are taken into account, considering the mean cost per case during the first three years (USD 2 979), the amount spent by SUS would reach USD 110 078 191 ($107 960 122 + $2 118 069) in 2020 US dollars.

As the health information systems lack data on outpatient care, our outpatient cost estimates were based on expert opinions and are the most uncertain parameter. However, in the sensitivity analysis, increasing outpatient costs by 50% had no impact on results. According to our sensitivity analyses, only the vaccine delivery cost impacted our results (a 93% increase in delivery cost resulted in a 52.6% increase in the total cost estimate). This was expected, since vaccination to control the outbreak accounted for the largest portion of SUS-covered economic burden (98.1%), and the vaccine delivery cost (USD 2.59) was greater than the mean per-dose vaccine cost paid by MoH for measles vaccines used for outbreak control (MR dose USD 0.65 and MMR dose USD 1.74/2.68). A previous study evaluated the costs of vaccination programs in low- and middle-income countries. The authors showed that the cost of delivering vaccines was nearly equivalent to the cost of the vaccines themselves, which played an important role in total costs (20). In the case of traditional less expensive vaccines, such as measles-containing vaccines, which have lower prices, delivery costs could be higher than the vaccine cost itself. The lack of standardization in terminology, transparency, and accuracy of measles outbreak cost estimates hampered the comparisons among COI studies conducted in low- and middle-income countries. The large variety of items included in each cost component highlights the variability of the scope of previous COI studies (21–26), in which the per-case cost varied from USD 495 to USD 17 481 (11).

Vaccination in response to the outbreak accounted for the largest portion of the SUS-related economic burden (98.1%) (USD 105 937 157). In a study from China, the vaccination campaign in response to an outbreak accounted for 64% of total costs (21), while in a study from the Federated States of Micronesia the vaccination campaign accounted for 68% of total costs (26).

The COVID-19 pandemic might have impacted the measles outbreak in Brazil. Measures to reduce SARS-CoV-2 transmission, such as face mask use, handwashing, social distancing, school and childcare facility closures, and remote work, decreased transmission of respiratory viruses, such as

TABLE 2. Number and cost of hospital cases by region and year and number and cost of outpatient cases, by age group and year (costs in 2020 US dollars), Brazil, 2018–2020

Hospitalizations	2018			2019			2020			Total		
	No. of cases	Mean cost (min–max)	Total cost (min–max)	No. of cases	Mean cost (min–max)	Total cost (min–max)	No. of cases	Mean cost (min–max)	Total cost (min–max)	No. of cases	Mean cost (min–max)	Total cost (min–max)
Midwest	–	–	–	19	41 (37–52)	789 (706–983)	5	93 (11–343)	463 (56–1 716)	24	45 (11–343)	1 252 (56–1 716)
Northeast	17	66 (12–191)	1 128 (207–3 254)	94	87 (9–2 163)	8 167 (884–203 299)	28	159 (36–3 162)	4 450 (996–88 524)	139	104 (9–191)	13 746 (207–203 299)
North	811	63 (10–2 587)	50 734 (7 887–2 097 903)	29	48 (37–123)	1 398 (1 078–3 563)	358	55 (9–1 914)	19 842 (3 222–685 345)	1 198	55 (9–914)	71 975 (1 078–2 097 903)
Southeast	28	43 (10–243)	1 192 (291–6 807)	641	82 (9–2 650)	52 853 (6 027–1 698 629)	133	62 (9–1 212)	8 203 (1 197–161 227)	802	62 (9–650)	62 247 (291–1 698 629)
South	10	44 (38–52)	441 (385–517)	25	78 (12–375)	1 937 (294–9 376)	24	117 (9–1 406)	2 804 (216–33 747)	59	80 (9–406)	5 182 (216–33 747)
Total	866	54 (10–2 587)	53 496 (8 422–2 240 177)	808	67 (9–2 650)	65 144 (7 597–2 141 173)	548	97 (9–3 162)	35 762 (4 932–1 732 544)	2 222	69 (9–3 162)	154 402 (4 932–2 240 177)
Outpatient care	**No. of cases**	**Cost per case**	**Total cost**	**No. of cases**	**Cost per case**	**Total cost**	**No. of cases**	**Cost per case**	**Total cost**	**No. of cases**		**Total cost**
≤9 years old	2 626	6.8	17 979	5 860	7.2	42 440	1 921	6.3	12 154	10 407	–	72 573
>9 years old	5 835	2.6	14 894	12 347	2.5	30 581	5 425	2.4	13 289	23 607	–	58 764
Total	8 461	–	32 873	18 207	–	73 021	7 346	–	25 443	34 014	–	131 338

Source: Prepared by the authors using data from the following sources: SIH-SUS (Hospital Information System) for the number of hospital cases and hospitalization costs; the number of outpatient cases was estimated based on the number of measles-confirmed cases in SINAN (Notifiable Diseases Information System) and hospitalized cases in SIH-SUS.

TABLE 3. Laboratory tests performed for measles diagnosis, by type and year, Brazil, 2018–2020

Laboratory tests	2018		2019		2020		Total	
	n	%	*n*	%	*n*	%	*n*	%
Molecular biology	9 584	14	34 561	16	6 528	13	50 673	15
ELISA IgG	28 508	42	90 189	42	21 854	43	140 551	42
ELISA IgM	28 990	43	92 237	42	22 083	44	143 310	43
Total	67 082	100	216 987	100	50 465	100	334 534	100

Source: Prepared by the authors using data from GAL (Laboratory Environment Manager).

which has deepened access inequities. Additionally, scientific denialism and fake news have reduced public trust in vaccination actions and increased vaccine hesitancy. The COVID-19 pandemic intensified this trend and health inequities, with clusters of low vaccination coverage in more vulnerable populations (29). None of the Brazilian states reached the MMR coverage target in 2020–2022; therefore, the risk of new measles outbreaks persists (30).

The main cost components related to the public health response to the outbreak, such as case and contact tracing, active surveillance enhancement, immunization campaigns and routine immunization strengthening, personnel, healthcare worker training, communication, and social mobilization, were not included in this study.

TABLE 4. Number of doses and costs (2020 US dollars) of measles-containing vaccines for the measles outbreak response, Brazil, 2018–2020

Vaccines	2018			2019			2020			Total	
	No. of doses*	Per dose cost**	Total cost	No. of doses*	Per dose cost**	Total cost	No. of doses*	Per dose cost**	Total cost	No. of doses*	Total cost
MR vaccine	341	3.3	1 109	1 257	3.2	4 062	685 447	3.2	2 195 886	687 046	2 201 058
MMR vaccine	5 548 043	5.3	29 268 058	11 126 645	4.3	48 124 529	6 197 367	2.34	26 343 512	22 872 055	103 736 099
Total	5 548 384	–	29 269 167	11 127 903	–	48 128 592	6 882 814	–	28 539 398	23 559 100	105 937 157

Notes: MMR: measles, mumps, and rubella; MR: measles and rubella.
* Number of vaccine doses excluding doses administered for routine immunization and considering a 10% waste rate.
** Includes vaccine delivery cost (USD 2.59 per dose).
Source: Prepared by the authors from the study data.

TABLE 5. Health system direct costs of measles outbreaks, Brazil, 2018–2020

Health system direct costs (in 2020 US dollars)	2018	2019	2020	Total
Diagnosis and treatment				
Inpatient care*	58 333 (0.2%)	70 643 (0.1%)	38 508 (0.1%)	167 484 (0.2%)
Outpatient care	32 873 (0.1%)	73 021 (0.1%)	25 443 (0.1%)	131 338 (0.1%)
Laboratory tests (PCR and serology)	272 358 (0.9%)	920 737 (1.9%)	176 954 (0.6%)	1 370 049 (1.3%)
Total cost of cases care	363 565	1 064 401	240 905	1 668 871
Outbreak response				
Vaccines used for outbreak control	29 269 167 (98.6%)	48 128 592 (97.3%)	28 539 398 (99.0%)	105 937 157 (98.1%)
Laboratory tests (viral isolation)	37 352 (0.1%)	255 947 (0.5%)	60 796 (0.2%)	354 095 (0.3%)
Total cost of outbreak response	29 306 519	48 384 538	28 600 194	106 291 252
Total	29 670 084 (100%)	49 448 939 (100%)	28 841 099 (100%)	107 960 122 (100%)
Cost per case	3 181	2 601	3 654	2 979

Note: *We added the cost of one outpatient care to each hospitalization.
Source: Prepared by the authors from the study data.

These outbreak costs were probably underestimated due to measles underreporting to health authorities (SINAN), misdiagnosis in the hospitalization information system (SIH-SUS), and laboratory test underreporting since our source of laboratory data (GAL) did not have universal coverage. In addition, we did not consider the costs of sample transport to regional laboratories (since some municipalities did not have their own laboratories). The medium- to long-term costs of treatment for measles-related complications were also not included.

Nevertheless, the results of this study can inform the Brazilian Government, which needs to know the cost of measles outbreaks to make decisions on budgeting and to strengthen routine vaccination, increasing and monitoring vaccine coverage and coverage homogeneity (31).

These findings have enhanced our understanding of the extent of the economic burden of measles outbreaks from the public health perspective in middle-income countries in Latin America. The high costs associated with measles outbreak control emphasize the need to strengthen routine immunization, especially in areas with low coverage and in international border regions. Additionally, efforts should be directed toward strengthening surveillance systems for the timely and consistent detection and reporting of measles cases, and toward reinforcing health information systems to improve the quality of epidemiological and economic data. Given regional diversities, federal and local resources must be allocated in order to strengthen health systems in regions with greater vulnerability, reducing inequities. Furthermore, it is important to allocate a budget to address reemerging diseases like measles and focus on preparing for future pandemics, as per WHO

influenza and measles (27, 28). On the other hand, in countries with limited resources, such as Brazil, surveillance of other diseases was impaired due to the transfer of financial and human resources to address the pandemic, which may have jeopardized measles data. Furthermore, MMR vaccination coverage has decreased in all Brazilian regions since 2015. This decline is related to the weakening of SUS and primary health care,

recommendations (32). These measures can help mitigate the economic burden associated with future outbreaks.

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Carga económica de los brotes de sarampión: un estudio del costo de la enfermedad en un país de ingresos medianos durante la fase posterior a su eliminación

RESUMEN

Objetivo. Estimar los costos directos asociados al diagnóstico, tratamiento y control de los casos de sarampión en Brasil desde el 2018 hasta el 2020.

Métodos. Este estudio del costo de la enfermedad utilizó un enfoque basado en la prevalencia, que tenía en cuenta los costos directos que habían supuesto para el Sistema Brasileño de Salud Pública(SUS) los brotes de sarampión, incluidos los costos de atención hospitalaria, atención ambulatoria y pruebas de laboratorio, así como los de las vacunas que incluían la del sarampión y las pruebas de laboratorio (aislamiento viral) utilizadas en el control de los brotes. Los costos se presentan en dólares estadounidenses del 2020. Se realizaron análisis de sensibilidad univariantes y bivariantes.

Resultados. Entre el 2018 y el 2020 hubo 36 236 casos confirmados de sarampión. El costo estimado de los brotes fue de USD 107 960 122, con un costo por caso que osciló entre USD 2601 y USD 3654 (media de USD 2979).

Conclusiones. Estos resultados ponen de relieve la considerable carga económica que suponen los brotes de sarampión en Brasil y subrayan la importancia de las medidas de prevención y control de esta enfermedad. Los responsables de la formulación de políticas y las autoridades de salud pública pueden utilizar estos resultados para planificar y asignar recursos con la finalidad de mitigar el impacto económico de nuevos brotes en el futuro.

Palabras clave Sarampión; brotes de enfermedades; costos de la atención en salud; Brasil.

Carga econômica dos surtos de sarampo: estudo de custo de doença em um país de renda média na era pós-eliminação

RESUMO

Objetivo. Estimar os custos diretos associados ao diagnóstico, tratamento e controle dos casos de sarampo no Brasil de 2018 a 2020.

Métodos. Este estudo de custo de doença usou uma abordagem baseada na prevalência, considerando os custos diretos incorridos pelo Sistema Único de Saúde (SUS) relacionados a surtos de sarampo, inclusive custos de atenção hospitalar, atenção ambulatorial e exames laboratoriais, bem como das vacinas contra o sarampo e exames laboratoriais (isolamento viral) usados para controlar surtos. Os custos são apresentados em dólares americanos de 2020. Foram realizadas análises de sensibilidade uni e bivariadas.

Resultados. De 2018 a 2020, foram registrados 36 236 casos confirmados de sarampo. O custo estimado dos surtos foi de US$ 107 960 122. O custo por caso variou de US$ 2 601 a US$ 3 654 (média de US$ 2 979).

Conclusões. Os achados destacam a carga econômica substancial imposta pelos surtos de sarampo no Brasil e enfatizam a importância das medidas de prevenção e controle do sarampo. Os formuladores de políticas e as autoridades de saúde pública podem usar esses resultados para planejar e alocar recursos, com o propósito de reduzir o impacto econômico de futuros surtos.

Palavras-chave Sarampo; surtos de doenças; custos de cuidados de saúde; Brasil.