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Vaccination services and incomplete vaccine coverage for children: a comparative spatial analysis of the BRISA cohorts, São Luís (Maranhão State) and Ribeirão Preto (São Paulo State), Brazil

Serviços de vacinação e cobertura vacinal incompleta em crianças: uma análise espacial comparativa das coortes BRISA, São Luís (Maranhão) e Ribeirão Preto (São Paulo), Brasil

Servicios de vacunación y niños con su cobertura de vacunación incompleta: un análisis comparativo espacial de las cohortes BRISA, São Luís (Maranhão) y Ribeirão Preto (São Paulo), Brasil

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Abstract

We analyzed the spatial relation between incomplete vaccine coverage for children and the distance from vaccination services. This was a cross-sectional study of children from 13 to 35 months of age from the cities of São Luís (Maranhão State) and Ribeirão Preto (São Paulo State), Brazil, and from basic health units (UBS, in Portuguese). The sample consisted of 2,744 children from São Luís and 3,325 from Ribeirão Preto. Data about incomplete vaccine coverage for children were obtained from the BRISA birth cohorts. Data about the quality of UBS vaccination services were obtained from the first cycle of the Brazilian National Program for Improvement of Access and Quality of Basic Care (PMAQ-AB, in Portuguese). For the spatial analysis, we determined the distance between the residence of the children (with and without a complete vaccine calendar) and the vaccination services of the UBS (classified according to number of structural items). Incomplete vaccine coverage was more pronounced in São Luís, with greater percentages for human rotavirus and triple viral vaccines, with the latter being the least available. In Ribeirão Preto, incomplete BCG vaccine coverage was more pronounced, with the tetravalent vaccine being the least available. Children from the two cities showed similarities: most of them had adult mothers with 9 to 11 years of schooling and did not reside with siblings in the household. They also showed differences: in São Luís, most mothers belonged to the economic class C, while in Ribeirão Preto they belong to the A and B classes. In the two cities with different socioeconomic conditions, complete vaccine coverage seemed not to depend on the location or quality of the vaccination service. Although São Luís showed a better structure of the services, incomplete vaccine coverage was higher compared to Ribeirão Preto.

Child Health; Spatial Analysis; Immunization Programs

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Introduction

Among the more effective public health strategies for the control of transmissible diseases are the immunizations, considered to represent one of the greatest public health conquests of the 20th century and one of the three most important milestones for the prevention of these diseases, representing one of the safest and most cost-effective measures for the health system [1]. Since 1973, when the Brazilian Ministry of Health created the National Immunization Program (PNI, in Portuguese), the rate of childhood morbidity-mortality has being significantly reduced in Brazil [2].

Brazil was a pioneer in the incorporation of various vaccines into the calendar of the Brazilian Unified National Health System (SUS, in Portuguese) and it is also one of the few countries in the world to offer an extensive and comprehensive spectrum of immunobiological agents in a universal and free manner. However, the high coverage rates that used to be one of the major characteristics of the country have been falling over the last few years [3].

In 2016 and 2017, for the first time, the coverage of the polio vaccine was below the established target of 95%. During the same period, the pentavalent vaccine reached only 82.2% of the target population, while the oral human rotavirus vaccine reached 83.3%, and the hepatitis B vaccine reached only 84.1% of babies younger than 1 month. The decline of coverage in the main vaccines offered to the population at no cost started in 2016 and continued over the two subsequent years. This scenario shows that, in 2017, the coverage of the PNI was one of the worst since the year 2000 regarding the main vaccines on the calendar [4].

Thus, in order to maintain the high quality of the immunization program, it is necessary for a child to receive all the necessary vaccine doses according to a correct vaccine calendar, especially during the first few years of life. Indeed, among the primary types of health care, vaccination is the one that elicits an almost immediate response [5].

In Brazil, vaccination is a routine procedure at primary health care services, greatly affecting the general health conditions of children [6]. The Family Health Strategy (FHS) facilitated the access to vaccination rooms by permitting the PNI to expand its actions, getting closer to the communities, and providing more opportunities for vaccination [7].

Despite the importance of this topic, studies evaluating the relationship between childhood vaccination and the quality of health services are still scarce and necessary. Studies relating immunization to health services, with emphasis on missed opportunities for vaccination, are discussed in the literature [8,9].

Other studies have separately analyzed the quality of the services, mainly the structural conditions, physical parameters, staff skills, and equipment performance, as well as indicators of the work process [10,11]. Particularly outstanding is a Brazilian study of national coverage which detected a better quality of both organization and structure of vaccination services in the basic health units (UBS, in Portuguese) located in small Brazilian municipalities [12].

There are also studies that have only analyzed childhood vaccination, most of them investigating individual factors related to incomplete vaccine coverage such as family income, social class, maternal age, number of children in the family, maternal schooling, and frequency of visits [13,14,15,16]. In particular, Silva et al. [17] observed in the city of São Luís (Maranhão State) that incomplete coverage with old and new vaccines was associated with sociodemographic and behavioral factors and the low use of prenatal services.

Considering the relevance of this theme, the scenario of reduced vaccine coverage in Brazil as well as the few studies that have assessed the relationship between incomplete vaccine coverage and the quality of vaccination services, we decided to conduct this study by comparing two cities with different socioeconomic conditions, with the objective of analyzing the spatial relation between incomplete childhood vaccination coverage and the quality of vaccination services in the cities of São Luís and Ribeirão Preto (São Paulo State).

Methods

This was a cross-sectional study nested within two population cohorts of liveborn delivered in 2010 in the cities of São Luís and Ribeirão Preto called BRISA (*Brazilian Ribeirão Preto and São Luís Birth Cohort Studies*). The data used in our study are secondary, regarding children in the age range of 13 to 35 months born in the two cities as well as aspects of the UBS.

The municipality of São Luís, the state capital of Maranhão, in the Northeast region of the country, is located on an island along the north coast of its state. Its area is 834,785km2. In 2010, it had a 7.4% proportion of children younger than 5 years [18].

The municipality of Ribeirão Preto is located in the State of São Paulo, Southeast region of the country. Its area is 650,916km2. In 2010, it had a 7.2% proportion of children younger than 5 years [18].

The study was conducted on children aged 13 to 35 months, born in 2010 and residing in São Luís and Ribeirão Preto, who were part of the follow-up of birth cohorts of the BRISA study (2011 to 2013). The investigation was carried out by the same research team of the Federal University of Maranhão (UFMA) and the University of São Paulo (USP)/Ribeirão Preto campus, the main objectives being the investigation of risk factors for prematurity. Thus, the study only included data for liveborns with ≥ 20 weeks of gestational age or weighing ≥ 500g, delivered by mothers residing in the abovementioned municipalities [19].

In the city of São Luís, 7,133 of the 21,401 births of 2010 were chosen by drawing lots in all maternities with more than 100 deliveries/year; of these, 5,475 newborns were eligible for the study. There was a loss of 239 newborns (4.4%) due to maternal refusal to participate in the study or early discharge from the hospital. A total of 5,166 of the 5,236 newborns left were liveborns; of these, 3,308 infants attended the follow-up, with a 36% loss due to refusal, failure to attend or impossibility to locate the mothers. Infants who were not georeferenced (n = 362, 10.9%) or whose health card could not be visualized by the interviewer (n = 202, 6.8%) were excluded. The final sample amounted to 2,744 infants aged 13 to 35 months (Figure 1) [17].

In Ribeirão Preto, all 2010 births and all maternities were included in the study. Out of the total of 8,103 eligible newborns, 7,794 were included, with a loss of 309 (3.8%) infants due to maternal refusal to be interviewed or early hospital discharge. Of these, 42 were stillborns (0.5%) and 7,752 were liveborns; 68 infants died. A total of 3,805 infants attended the follow-up session and 3,879 (50.5%) did not, due to refusal or failure to locate the mother. Infants who were not georeferenced (n = 122, 3.2%) and whose vaccine card was not presented to the interviewer for visualization (n = 358, 9.7%) were excluded from the study. The final sample amounted to 3,325 infants (Figure 1).

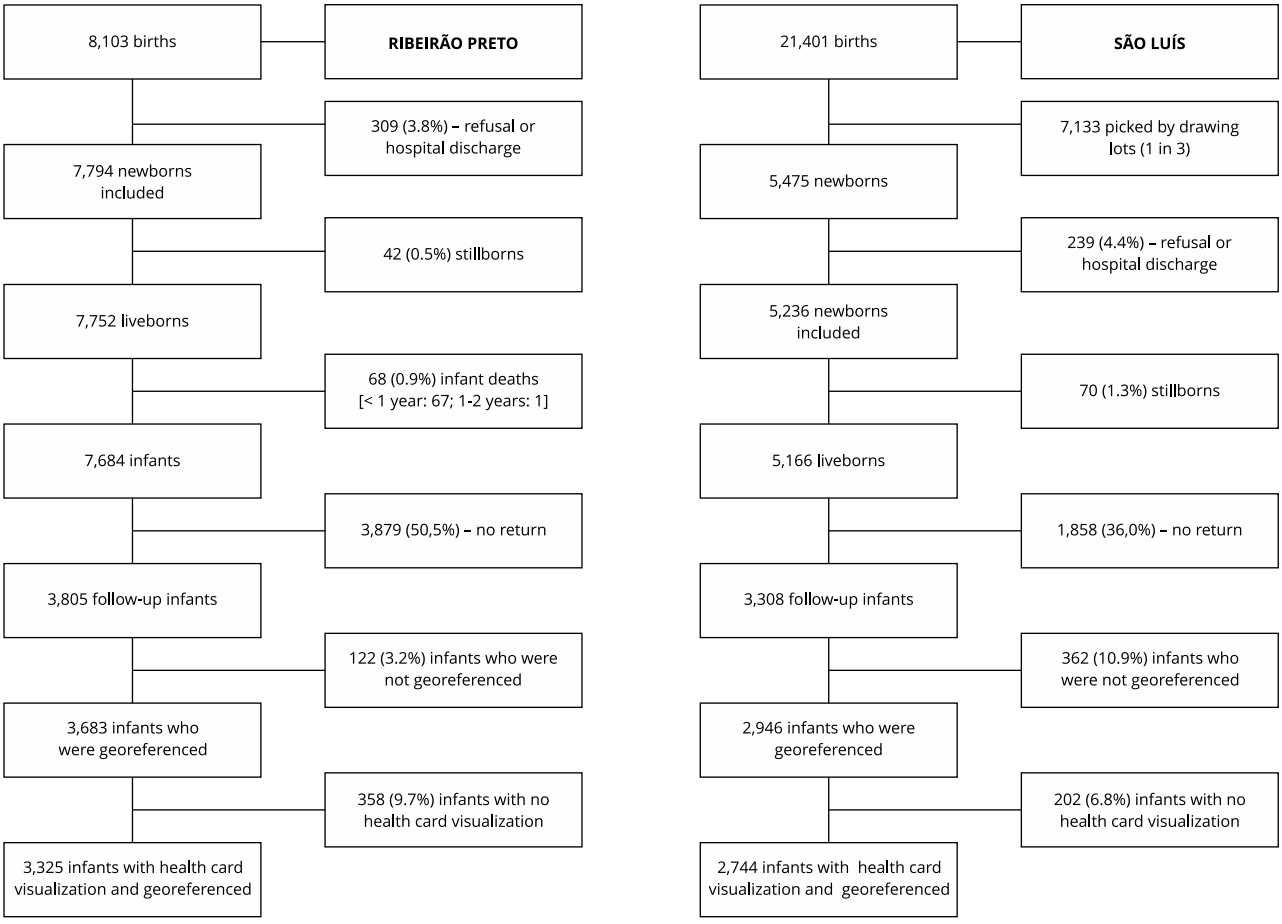
Data for the BRISA research were collected at two time points. At childbirth: in both cities, data were collected daily at hospitals from January to December 2010. The puerperal women were interviewed within the first 48 hours after delivery and additional data were obtained from the medical records of mothers and newborns. Births were registered in the order of occurrence. In the follow-up, all the mothers initially included in the study were contacted via telephone and home visit, and were invited to attend a new interview, taking their babies with them for health assessment. The follow-up data were collected from January 2011 to March 2013 in São Luís and from February 2011 to September 2013 in Ribeirão Preto [17].

The data of the first cycle of the multicenter research study *External Evaluation and Census of the Basic Health Units (PMAQ-AB)*, coordinated by the Department of Basic Care of the Brazilian Ministry of Health, were collected by means of a census in which 38,812 UBS were evaluated, covering 5,542 Brazilian municipalities. The census was held in order to evaluate aspects related to the structure of the UBS, with all of the country's units registered in the National Registry of Healthcare Establishments (CNES, in Portuguese) in 2012 being eligible. The instrument used was module I, in which an external rater verified the structure of the UBS accompanied by a professional of the basic care team. All 50 UBS in the municipalities of São Luís and all 41 UBS in the municipality of Ribeirão Preto were included.

The remaining data for the investigation considered the municipalities and were obtained from the electronic sites of the 2010 Atlas of Human Development [20], of the Brazilian Institute of Geography and Statistics (IBGE) [18], and from the Public Reports of the Basic Care Systems for 2012 [21].

Figure 1

Sample flow diagram of infants with a visualized health card and georeferenced belonging to the BRISA birth cohort, at birth and at follow-up of children younger 13 and 36 months. Ribeirão Preto (São Paulo State) and São Luís (Maranhão State), Brazil, 2010-2013.



The variables were analyzed according to the characteristics of the municipalities (sociodemographic aspects and coverage of policies/services of support of vaccination) and of the children (sociodemographic and maternal aspects and use of health services).

The variables related to the characteristics of the municipalities were: Gini coefficient [18], Municipal Human Development Index (MHDI) [20], proportion of children younger than 5 years [18], Gross Domestic Product (GDP) [18], demographic density [18], coverage by the Family Fellowship Program (FFP) [21], by teams of community health agents (TCHA) [21], by the FHS [21], by basic care [21], ratio between the number of UBS with a vaccination service [22] and the total population of the municipality [18], and number of establishments that performed childbirth [19].

The variables of the vaccination service of the UBS were obtained from the Brazilian National Program for Improvement of Access and Quality of Basic Care (PMAQ-AB, in Portuguese; 2012) data bank and characterized as follows:

(1) Organizational: UBS offering human resources (the presence of at least one nurse) and with minimum opening hours of two shifts, five days a week.
(2) Structural: UBS with at least one vaccination room, with properly functioning equipment (1 air conditioner and 1 refrigerator for exclusive vaccine storage), always available material (at least a thermal box for the vaccines, a maximum and minimum temperature thermometer, disposable syringes and needles, and a disposable container for sharp objects), and immunobiological agents of the 2010 childhood calendar (BCG-ID, hepatitis B, rotavirus, poliomyelitis, tetravalent, yellow fever, triple viral vaccine).

The variables regarding the characteristics of the children were obtained from the data bank of the BRISA study, as described below:
(1) Sociodemographic: mother's age (≤ 19 or > 20 years); economic class of the family according to the Brazilian Association of Research Companies – ABEP, in Portuguese – (A/B, C or D/E, with class A being the richest and E, the poorest) [23]; mother's schooling (years of study); number of siblings of the child in the household.
(2) Maternal: planned pregnancy; new pregnancy soon after the birth of the child under study; low birth weight and preterm birth.
(3) Use of health services: beginning of prenatal care; number of prenatal visits; the child's possibility of visitation, hospitalization or obtaining a vaccine; place of vaccine administration.

The children's variables were chosen according to the study by Silva et al. [17], who identified factors associated with the vaccination schedule of the children of the BRISA cohort in São Luís.

The following variables were analyzed regarding infant vaccination: complete vaccine coverage with each of the seven vaccines of the 2010 National Calendar of Children's Vaccination (1 dose for the BCG vaccine, 3 doses for hepatitis B, 2 for rotavirus, 3 for poliomyelitis, 3 tetravalent, 1 triple viral, and 1 for yellow fever) [24], excluding the meningococcal and pneumococcal vaccines, whose data were obtained from the BRISA data bank. The vaccination scheme variable was later obtained from the set of the seven vaccines and categorized as complete and incomplete. Vaccination scheme was considered to be complete when a child received all the doses of each of the seven vaccines of the 2010 National Childhood Calendar, and incomplete when the child did not receive at least one dose of one of the seven vaccines.

Data were submitted to descriptive analysis and determination of absolute and relative frequencies for both the individual and municipal variables, with comparison of the two cities: São Luís and Ribeirão Preto. The analyses were carried out using the Stata software, version 14.0 (https://www.stata.com).

The difference between two independent samples of the characteristics of the children from the two cities was determined by the chi-square test. The variables showing $p < 0.05$ were submitted to the adjusted standardized residue test in order to determine whether there was significance based on a positive value of more than 1.96 [25].

The geographic coordinates of the UBS and the children's home address were used for spatial analysis. The geographic coordinates were obtained from the home address available in the data bank of the BRISA cohort (3,308 children in São Luís, 3,805 in Ribeirão Preto). Information from the UBS was obtained directly from the PMAQ-AB data bank (50 in São Luís, 41 in Ribeirão Preto).

The geographic coordinates of the Geographic Information System, Wikimapia and Google Maps of 2017 were obtained from the correct address or closest possible address (cases of absence/error in residence number), a situation when the central street coordinate (centroid) was chosen.

The spatial analyses were carried out by elaborating maps with the aid of the ArcGis 10.4 software (http://www.esri.com/software/arcgis/index.html). Spatial distribution was determined with the use of point maps in order to identify the residences of the children and the location of the UBS in the two cities. We used the layers of the digital road networks of the two municipalities obtained from the IBGE [26].

The punctual representation of the categories of the child variable was the vaccination scheme (complete and incomplete) while the UBS variable was the quality of the vaccination service based on the availability of the recommended items for a vaccination room availability of human resources,

minimum time open, vaccine room, air conditioning, exclusive refrigerator, thermal vaccine box, maximum and minimum temperature thermometer, disposable syringes and needles, and a disposable container for sharp objects and vaccines (BCG-ID, hepatitis B, rotavirus, poliomyelitis, tetravalent, yellow fever, triple viral vaccine) [27].

Maps with a raster of proximity were used to calculate the distance between the child's residence and an UBS. This analysis was conducted on 2,744 children in São Luís and 3,325 in Ribeirão Preto, while children whose geographic coordinates were not found due to an absent or incomplete address, incorrect address, and migration to other cities were excluded (Figure 1).

Kernel analysis uses inter-Kernel communication to analyze a series of data and their properties. According to Câmara & Carvalho [28], the Kernel method is quite useful by providing a holistic view of the pattern of first-order distribution of the events. According to Matos et al. [29], Kernel estimates can indicate important characteristics such as data asymmetry and multimodality [30].

The study was approved by all Ethics Research Committees: UFMA (protocol n. 223/2009), the Faculty of Medicine of Ribeirão Preto, USP (protocol n. 4116/2008) and the Federal University of Pelotas – UFPel (protocol n. 38/12/2012); according to *Resolution n. 196/1996* of the Brazilian National Health Council, in force at the time.

Results

There were similarities among most of the sociodemographic characteristics of the children. Most children had no siblings living with them in the residence in São Luís or Ribeirão Preto, and were children of adult mothers with 9 to 11 years of schooling. However, São Luís had a higher percentage of class C mothers, while class A and B mothers predominated in Ribeirão Preto (Table 1). Schooling was the only variable that differed significantly between cities ($p = 0.043$).

Regarding the reproductive history of the mothers, the two cities had approximately similar percentages of low weight infants, prematurity, and new pregnancies during the first year after the birth of the child under study (Table 1), with no significant difference between cities.

Regarding the use of health services, there were high percentages of beginning of prenatal care in the first trimester (69.5% in São Luís and 83.8% in Ribeirão Preto) and more than six prenatal visits (68.8% in São Luís and 93.3% in Ribeirão Preto) in the two cities, with a greater emphasis but no significant difference for Ribeirão Preto (Table 1).

Incomplete vaccination scheme was higher in São Luís than in Ribeirão Preto, with the highest percentages of incomplete coverage in both cities being for human rotavirus vaccine (19.9% in São Luís and 6.7% in Ribeirão Preto) and triple viral vaccine (10.9% in São Luís and 4.6% in Ribeirão Preto). Incomplete coverage was higher in São Luís for all vaccines of the childhood vaccine calendar, except for the BCG vaccine (Table 1). There were no statistically significant differences between cities, except for the yellow fever vaccine ($p = 0.007$) which was significantly related to incomplete coverage in both cities.

The lack of vaccines and/or the unavailability of hospital and/or ambulatory care for the children was greater in São Luís. Health center were the most common sites for application of the vaccines in both cities (Table 1).

Comparison of the demographic and socioeconomic characteristics of the municipalities revealed that Ribeirão Preto showed better results, with a higher GDP and lower inequalities, lower population density and a lower proportion of children younger than 5 years. This last variable can be considered a proxy of the demand of children's vaccination services (Table 2).

Regarding coverage by policies and services for the support of vaccination, higher FFP coverage was detected in Ribeirão Preto. In turn, São Luís showed higher coverage related to TCHA, FHS and basic care and had a larger number of facilities performing childbirth. The ratio of UBS with a vaccination service per inhabitant was worse in São Luís (1 UBS/19,171 inhabitants) (Table 2).

Table 1

Characteristics of the children aged 13 to 36 months and incomplete vaccination schedules. São Luís (Maranhão State) and Ribeirão Preto (São Paulo State), Brazil, 2010-2013.

Characteristics	Ribeirão Preto (n = 3,325 *)		São Luís (n = 2,744 *)		p-value **
	n	%	n	%	
Sociodemographic characteristics * **					
Mother's age (years)					0.675
> 20	2,944	86.70	2,262	82.40	
≤ 19	381	13.30	482	17.60	
Mother's schooling level (years)					0.043
≥ 12	724	23.40	263	14.80	
9-11	2,100	60.40	2.016	69.50	
5-8	382	13.60	269	12.70	
0-4	74	2.60	65	3.00	
Economic class #					0.734
A-B	1,542	48.70	496	20.00	
C	1,548	42.00	1.595	54.10	
D-E	235	9.30	653	25.90	
Nubmer of siblings of the child residing in the household					0.593
0	1,756	53.40	1.357	49.40	
1	1,029	30.20	889	32.00	
2-3	474	14.40	430	15.90	
> 3	66	2.00	68	2.70	
Maternal characteristics					
Planned pregnancy ***					0.418
Yes	1,570	47.10	866	31.60	
No	1,746	52.90	1.875	68.40	
New pregnancy during the first year after the birth of the child under study ##					0.966
No	3,031	92.60	2.497	91.50	
Yes	235	7.30	225	8.50	
Low birth weight ##					0.447
Yes	334	10.05	196	7.15	
No	2,991	89.95	2.542	92.65	
Preterm birth ##					0.927
Yes	463	13.92	298	11.00	
No	2,420	72.78	2,102	77.00	
Use of a health service					
Trimester when started ***					0.188
1st	2,664	83.80	1.850	69.50	
2nd	462	15.00	763	28.70	
3rd	38	1.20	50	1.80	
Prenatal visits ***					0.993
≥ 6	2,792	93.30	1.271	68.80	
< 6	194	6.70	567	31.20	
Did the child obtain a visit, hospitalization or a vaccine ##					0.216
Yes	3,020	90.80	1.958	71.00	
Did not obtain a visit /hospitalization	303	9.10	368	13.60	
Did not obtain vaccination due to lack of vaccines	2	0.10	418	15.40	

(continues)

Table 1 (continued)

Characteristics	Ribeirão Preto (n = 3,325 *)		São Luís (n = 2,744 *)		p-value **
	n	%	n	%	
Site of vaccination ##					0.369
Health center	3,246	97.60	2.701	98.40	
Private clinic	73	2.40	41	1.60	
Incomplete vaccine coverage ##					
BCG	66	2.10	14	0.50	0.581
Poliomyelitis	91	2.80	119	4.40	0.203
Hepatitis B	95	2.90	156	5.70	0.443
Tetravalent	145	4.40	222	8.20	0.260
Yellow fever	122	3.70	275	10.30	0.007
Triple viral	147	4.60	301	10.90	0.221
Human rotavirus	215	6.70	537	19.90	0.499
Child vaccination schedule	405	12.40	938	34.60	0.726

* Total number of children at follow-up time with a visualized and georeferenced health card. Weighted estimates for sample losses;

** Chi-square test for the determination of a significant difference in proportions between cities;

*** Birth questionnaire;

According to the Brazilian Association of Research Companies (ABEP) [23];

Follow-up questionnaire.

The organizational characteristic of the vaccination services of the UBS were similar, with high percentages of adequacy, although with more emphasis on the municipality of São Luís. Among the structural characteristics, a minimum and maximum thermometer was the material least available in both cities (São Luís: 72%; Ribeirão Preto: 19.51%). The least available vaccines were the tetravalent (56.1%) in Ribeirão Preto and the triple viral (56%) in São Luís (Table 2).

A greater density of children was observed in the northeastern region of São Luís and in the central region of Ribeirão Preto, with a tendency to coverage according to UBS location. However, vacuum points of care close to the residence of some children's groups were observed in both cities (Figures 2 and 3). A total of 2,744 of the 3,308 São Luís children were georeferenced, 1,806 of them with a complete vaccination scheme and 938 with an incomplete one. In Ribeirão Preto, 3,325 of the 3,805 children were georeferenced, 2,918 of them with a complete calendar and 407 with an incomplete one.

In both cities, the UBS are geographically distributed close to broad streets, except for one UBS in the municipality of São Luís (Figures 2 and 3).

In Ribeirão Preto, 14 of the 41 UBS (34.15%) were equipped with less than 50% of the vaccination service items, as compared to 3 of the 50 UBS (6%) in São Luís. Despite the differences in the distance from UBS, with different quality of vaccination service, there were children with both a complete and incomplete vaccination scheme residing at a distance of up to 2km from an UBS (Figures 2 and 3).

Discussion

This comparative study of two cities with different socioeconomic characteristics did not demonstrate a difference regarding proximity to the UBS and complete vaccine coverage. In both cities, although the locations of the UBS accompany most of the distribution of the children's residences, there are care gaps and differences in the quality of the vaccination services located close to the residences of children with either complete or incomplete vaccine coverage.

The hypothesis has been raised that the relationship between the location of the health services and of the children's residences may be a factor that influences adhesion to vaccination [31]. The loca-

Table 2

Characteristics of the municipalities of residence of children. São Luís (Maranhão State) and Ribeirão Preto (São Paulo State), Brazil, 2010-2013.

Characteristics	Ribeirão Preto		São Luís	
Demographic and socioeconomic				
Gini coefficient (0 to 1)	0.54		0.61	
MHDI (0 to 1)	0.800		0.768	
Proportion of children younger than 5 years (%)	6.5		7.4	
GDP (in Brazilian Real)	44,463.80		20,242.70	
Demographic density (inhabitants/km^2)	927.65		1,215.70	
Coverage of policies and services of support for vaccination				
FFP coverage (%)	72.8		35.7	
TCHA coverage (%)	31.4		46.3	
FHS coverage (%)	14.1		32.5	
Basic care coverage (%)	39.1		43.5	
Ratio of UBS with vaccination service per inhabitants	1/14,404		1/19,171	
Number of facilities that perform childbirths	9		11	
Vaccination services in the UBS	**Sample (n = 41)**		**Sample (n = 50)**	
	n	**%**	**n**	**%**
Organizational characteristics				
Offer of human resources				
Presence of at least 1 nurse in the UBS	41	100.0	49	98.0
Hours open				
UBS open in 2 shifts, 5 days/week	36	87.8	46	92.0
Structural characteristics				
Environment				
At least 1 vaccination room in the UBS	26	63.4	48	96.0
Equipment				
At least 1 air conditioner	23	56.1	41	82.0
At least 1 refrigerator exclusively for the vaccines	27	65.8	41	82.0
Material (always available)				
Thermal vaccine box	27	65.8	47	94.0
Maximum and minimum thermometer	8	19.5	36	72.0
Disposable syringes	40	97.6	47	94.0
Disposable needles	40	97.6	48	96.0
Disposable container for sharp objects	39	95.1	46	92.0
Immunobiological agents for 2010 (always available)				
BCG	26	63.4	46	92.0
Hepatitis B	27	65.8	45	90.0
Rotavirus	27	65.8	46	92.0
Poliomyelitis	27	65.8	45	90.0
Tetravalent	23	56.1	33	66.0
Yellow fever	26	63.4	41	82.0
Triple viral	27	65.8	28	56.0

FFP: Family Fellowship Program; FHS: Family Health Strategy; GDP: Gross Domestic Product; MHDI: Municipal Human Development Index; TCHA: teams of community health agents; UBS: basic health units.

Source: Brazilian Institute of Geography and Statistics (IBGE) [18]; Brazilian National Program for Improvement of Access and Quality of Basic Care (PMAQ-AB).

Figure 2

Distribution of basic health units (UBS) according to vaccination service items and of the children according to complete vaccination schedule. São Luís, Maranhão State, Brazil, 2010-2013.

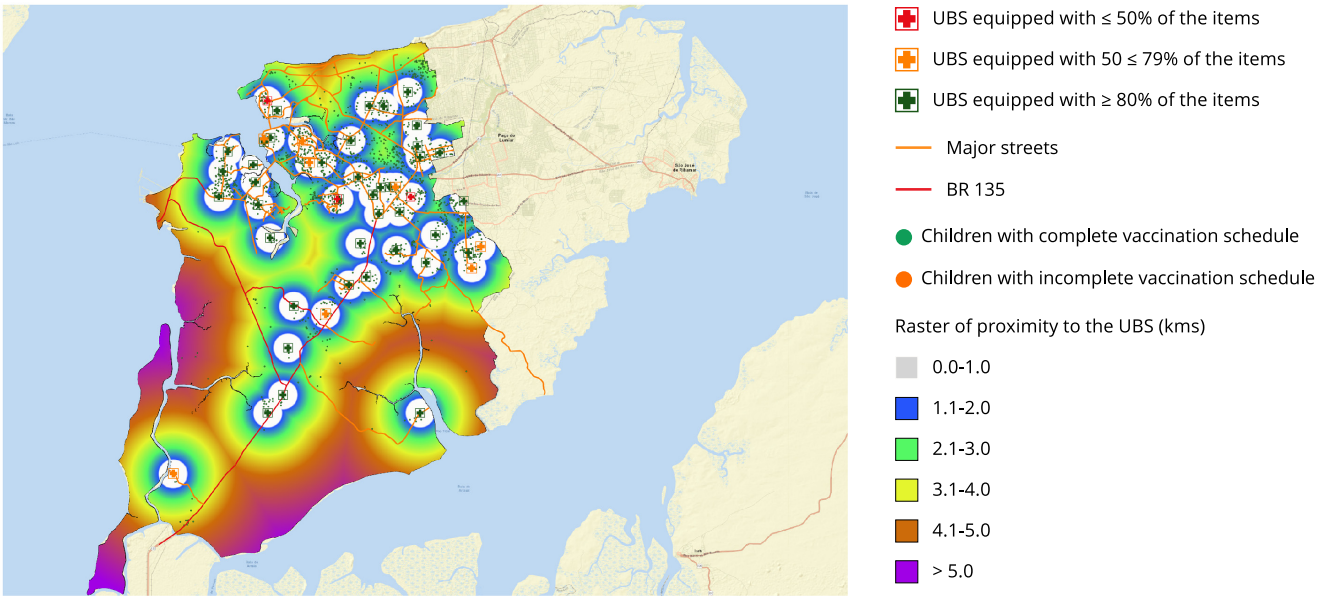
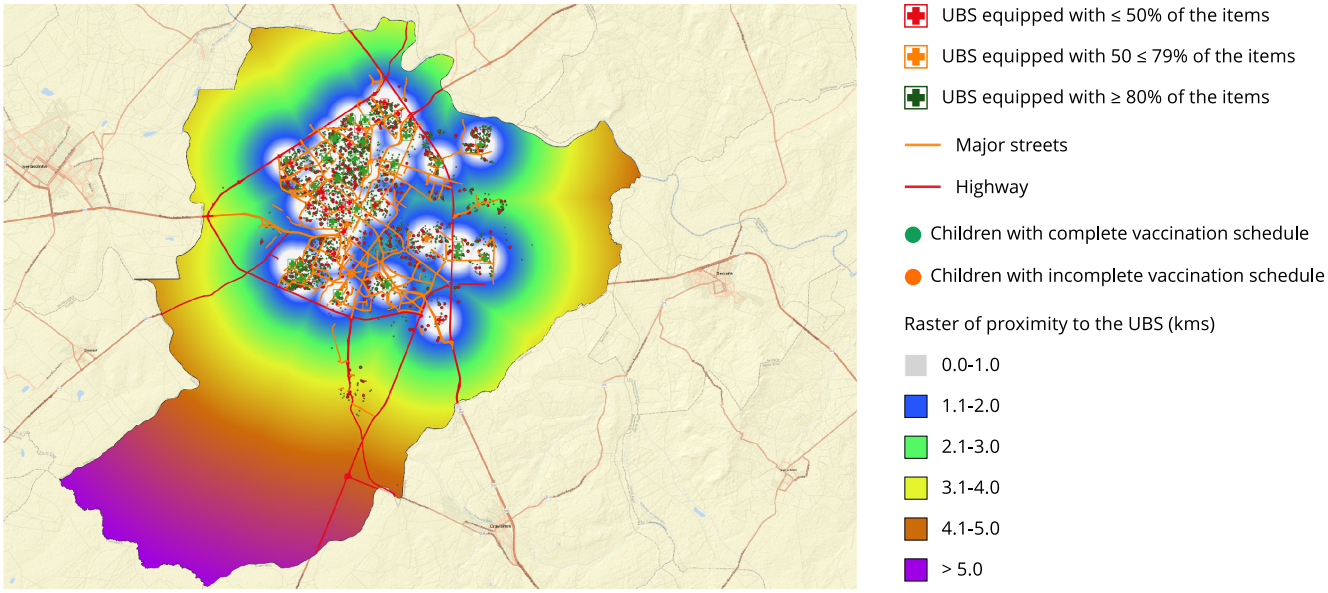


Figure 3

Distribution of basic health units (UBS) according to vaccination service items and of the children according to complete vaccine coverage. Ribeirão Preto, São Paulo State, Brazil, 2010-2013.



tion of the UBS may represent a barrier to accessibility since its poor distribution within a municipality requires the user to cover long distances on foot or to have financial resources to pay for transportation [32], possibly representing a factor that hinders the use of the service. In our study, only the municipality of São Luís had a UBS located far from major avenues.

In a study in the Amazon region, Castelo-Branco et al. [15] showed that children who lived in houses located at a higher distance from the UBS had a lower chance of being vaccinated, since the cost of taking a child to the vaccination service can be a barrier for some low-income families. In a review article [33], greater adhesion to vaccination was detected among children residing in the urban zone and at a shorter distance from the UBS.

The structure and organization of the service may also be considered to be barriers to access [32]. The Ribeirão Preto map reveals that 34.14% of the UBS (n = 14) had less than 50% of the items recommended for a vaccination service. A study in a municipality in the state of Rio de Janeiro showed that structural factors of the UBS evaluated were considered to be a possible cause of delayed vaccination coverage for the children. However, another UBS with better infrastructure, good location and a larger number of teams showed better results [34].

In our study, regardless of the structure and organization of the vaccination services, there were children with either full or incomplete coverage residing close to these UBS. A possible explanation for this finding is the occurrence of vaccination campaigns that contribute to the achievement of full basic vaccine coverage, as one of the potentialities of the PNI [35]. Partnerships have been established between public and private institutions which act as mobile vaccination stations during the vaccination campaigns [36].

Among the problems detected in the quality of the vaccination services of both cities, the least available device was the minimum and maximum thermometer, especially in Ribeirão Preto (19.5%). Some studies conducted in Brazil had already identified this problem in the UBS, a fact that may contribute to the exposure of immunobiological agents to variations in temperature, causing loss of quality and effectiveness due to physicochemical changes [9,37].

Among the immunobiological agents, the availability of the triple viral vaccine was lower in São Luís, a fact that may explain the second highest incomplete coverage of the children with this vaccine. In Ribeirão Preto, the tetravalent vaccine was the least available, corresponding to the third highest incomplete vaccination scheme of the children. It should be pointed out here that a pentavalent vaccine was introduced in 2013, replacing the tetravalent vaccine [38].

Table 2 underscores the demographic and socioeconomic differences between the two municipalities, with Ribeirão Preto showing better indicators, a situation that, according to the literature, reflects the existing social inequalities [39]. However, Barata et al. [40] detected a closer relationship between living in areas with the best socioeconomic indicators and incomplete vaccine coverage.

Among the policies supporting vaccination, higher coverage by the FFP (72.78%) was detected in Ribeirão Preto than in São Luís (35,68%). One of the conditions for allocation of FFP resources to the families is the maintenance of an updated vaccine calendar for the children. A study conducted in São Luís indicated that this conditionality may not be properly obeyed among families contemplated by the FFP [17].

Comparison of the sociodemographic characteristics of the mothers in the two cities revealed similar percentages of adult age (> 19 years), higher maternal schooling and children not residing with siblings for the two cities. The literature has shown a relationship of all of these findings with greater vaccine coverage of the children [33,41,42,43], indicating that the number of children in the household increases the resources of the family, the time and attention the siblings devote to one another and the household activities. The lack of a social support network may hinder the access of these children to the UBS [42].

Schooling levels, despite having higher proportions in both cities, were higher in Ribeirão Preto. Some studies have pointed out a relationship between maternal schooling and complete vaccine coverage of the infants [44,45], whereas other studies have not [14,40,46,47]. This may be explained by the fact that better maternal education may contribute both in a positive and negative manner to opportune immunization, since access to various sources of information may result in worry about the safety of vaccines, especially considering the dissemination of fake news [47]. To prevent the dissemination of

information without scientific support, the Brazilian Ministry of Health has innovatively created an official and exclusive channel to debunk such news and to certify accurate news reporting [48].

São Luís showed more cases of incomplete vaccination scheme for both rotavirus and triple viral vaccine, in agreement with several other studies [8,15,34,46,49,50]. The triple viral vaccine was also one of those most unavailable at the vaccination services of the São Luís UBS, whereas the BCG vaccine showed the best percent availability compared to Ribeirão Preto, as was reported in other studies [13,14,34,42,43,49]. This finding may be explained by the fact that this vaccine is administered immediately after birth, with infants routinely receiving their dose in São Luís during this same period while still in the maternities [51], whose number is greater than that on Ribeirão Preto.

This study preceded the falls in vaccine coverage, which may possibly represent an outdated scenario. This was the first study comparing two cities with different socioeconomic conditions both regarding children's vaccination and the quality of vaccination services. The data regarding the structure of the vaccination services were verified in loco and the data about the completeness of the vaccination scheme was based on confirmation by the vaccination booklet, conferring greater reliability on the information. The collection of data regarding both the vaccination scheme of the children and the vaccine services was performed in the same year or within a very close period of time.

The difficulties met for the georeferencing of children were due to wrong or incomplete addresses, leading to the loss of some children, especially in São Luís, underscoring the fact that address data should be collected in a better manner. Another aspect was the loss to follow-up typical of cohort studies; however, in order to reduce selection bias, sample losses in the follow-up cohort were weighted by the inverse of the probability of attendance in the follow-up. It should be pointed out that the final sample of georeferenced children was sufficient for spatial analysis, which has been used in few studies with this thematic analysis that involve joint health and vaccination services for children [35].

Final considerations

The vaccination services were well structured in São Luís. However, the incomplete vaccination scheme was lower in Ribeirão Preto. This study suggests that a complete vaccination scheme does not depend on the distance of the child from the service or on the quality of structural and organizational items in the UBS.

However, this does not exempt the services from being well-structured, providing more safety in vaccine conservation and thus better guaranteeing their efficacy. Providing vaccination at the appropriate time by the children's caregivers is also an important factor in order to prevent incomplete vaccine coverage and to favor a better guarantee of immunity. Note that, the context within which the child lives and their socioeconomic conditions should always be considered in order to refine the strategies that promote the inclusion of groups with delayed vaccination in the prevention and health promotion network, so that the risk of transmission of diseases that can be prevented by immunization will be reduced in more vulnerable population segments.

Strengthening the relations with the FHS is one of the most important actions needed to improve vaccine coverage. In addition, reinforcing policies that will minimize the inequality of access, eliminating still existing social inequalities, and it is still an important strategy directed at achieving levels of vaccination that can insure protection against preventable diseases for all children.

Contributors

R. C. C. S. Queiroz contributed to the study conception, data interpretation, and writing of the article. R. C. S. Queiroz contributed to the study design, data acquisition and interpretation, writing, and revision of the text. T. A. H. Rocha contributed to the writing and revision of the text. F. S. Silva contributed to data analysis and interpretation, writing, and revision of the text. I. G. Santos and I. P. Silva contributed to spatial analysis of the data and revision of the text. N. C. Silva contributed to the writing of the article. M. A. Barbieri, M. C. P. Saraiva and A. A. M. Silva contributed to data acquisition, interpretation of the results, writing, and revision of the text.

Additional informations

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Resumo

Analisamos a relação espacial entre cobertura vacinal incompleta em crianças e a distância da residência até os serviços de vacinação. Este foi um estudo transversal de crianças entre 13 e 35 meses de idade nas cidades de São Luís (Maranhão) e Ribeirão Preto (São Paulo), Brasil, e das unidades básicas de saúde (UBS). A amostra consistia em 2.744 crianças de São Luís e 3.325 de Ribeirão Preto. Os dados sobre a cobertura vacinal incompleta foram obtidos das coortes de nascimento BRISA. Os dados sobre a qualidade dos serviços de vacinação das UBS foram obtidos do primeiro ciclo do Programa de Melhoria do Acesso e da Qualidade da Atenção Básica (PMAQ-AB). Para a análise espacial, determinamos a distância da residência das crianças (com e sem calendário vacinal completo) até os serviços de vacinação da UBS (classificados de acordo com o número de itens estruturais). A cobertura vacinal incompleta era mais marcante em São Luís, com percentuais mais altos para as vacinas do rotavírus humano e tríplice viral, sendo que esta era menos disponível. Em Ribeirão Preto, a cobertura vacinal incompleta para BCG era mais evidente, enquanto a vacina tetravalente era a menos disponível. As crianças das duas cidades mostraram semelhanças: a maioria tinha mães adultas com 9 a 11 anos de escolaridade e não residia com irmãos no domicílio. Também mostravam diferenças: em São Luís, a maioria das mães pertencia à classe econômica C, enquanto as mães em Ribeirão Preto pertenciam mais às classes A e B. Nas duas cidades, com condições socioeconômicas diferentes, a cobertura vacinal completa parecia não depender da localização ou da qualidade do serviço de vacinação. Embora São Luís tenha demonstrado melhor estrutura dos serviços, a cobertura vacinal incompleta foi mais alta em São Luís quando comparada à de Ribeirão Preto.

Saúde da Criança; Análise Espacial; Programas de Imunização

Resumen

Analizamos la relación espacial entre los niños con una cobertura de vacunación incompleta y la distancia que los separa de los servicios de vacunación. Se trata de un estudio transversal con niños desde los 13 a los 35 meses de edad en las ciudades de São Luís (Maranhão) y Ribeirão Preto (São Paulo), Brasil, y en unidades básicas de salud (UBS por sus siglas en portugués). La muestra consistió en 2.744 niños de São Luís y 3.325 de Ribeirão Preto. Los datos sobre la cobertura de vacunación incompleta de los niños proceden de las cohortes de nacimiento BRISA. Los datos sobre la calidad de los servicios de vacunación en los servicios UBS se obtuvieron del 1er ciclo del Programa Nacional de Mejoría de Acceso y Calidad de la Atención Básica (PMAQ-AB). Para el análisis espacial, determinamos la distancia entre la residencia de los niños (con y sin un calendario de vacunas completo) y los servicios de vacunación de las UBS (clasificados según el número de ítems estructurales). Se destacó una cobertura incompleta de vacunación en São Luís, con porcentajes de vacunas contra rotavirus humano y triple vírica, siendo esta última la menos disponible. En Ribeirão Preto, la cobertura incompleta de la vacuna BCG fue la más destacable y la vacuna tetravalente fue la menos disponible. Los niños de las dos ciudades mostraron similitudes: la mayoría de ellos tenían madres adultas con una escolaridad que oscilaba entre los 9 y los 11 años de edad y no residían con hermanos en el hogar. Asimismo, mostraron también diferencias: en São Luís, la mayoría de las madres pertenecían a la clase económica C, mientras que en Ribeirão Preto pertenecían las clases A y B. En las dos ciudades con condiciones diferentes socioeconómicas, la cobertura completa de vacunación parecía no depender de la localización o la calidad del servicio de vacunación. Sin embargo, São Luís mostró una mejor estructura de los servicios, aunque la cobertura incompleta de vacunación fue más alta comparada con Ribeirão Preto.

Salud del Niño; Análisis Espacial; Programas de Inmunización

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