Original Article

Vaccination coverage in children up to 2 years old, receiving financial support from the Family Income Transfer Program, Brazil*

doi: 10.1590/S1679-49742021000300010

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*The study received financial support from the Maria Cecília Souto Vidigal Foundation (FMCSV), Itaú Social and the Ministry of Citizenship, with the support of the United Nations Development Programme (UNDP) (BRA/16/019). Santos IS, Matijasevich A, Lira PIC and Victora CG receive financial support in the form of a research productivity scholarship from the National Council for Scientific and Technological Development (CNPq)/Ministry of Science, Technology and Innovation (MCTI). Bortolotto CC receives financial support from the Coordination for the Improvement of Higher Education Personnel (CAPES)/Ministry of Education (MEC) (code 001).

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Abstract

Objective: To assess vaccination coverage, based on the National Immunization Program schedule, among children receiving financial support from the Family Income Transfer Program, Brazil, according to the family socioeconomic status and maternal characteristics. **Methods:** 3,242 children under 12 months old were assessed between August/2018 and April/2019, of whom 3,008 were reassessed between September/2019 and January/2020. The analyses were performed using multilevel models (level 3, Federative Unit; level 2, municipality; level 1, children). **Results:** Vaccination coverage was 2.5 fold higher in the first follow-up (61.0% - 95% CI 59.3;62.6%), compared to the second follow-up (24.8% - 95% CI 22.8;25.9%) (p<0.001). In the first follow-up, coverage was higher in the richest quintile (67.9%) and in children whose mothers had ≥9 years of schooling (63.3%). In the second follow-up, there were no differences. The highest coverage occurred between 0.5-2.5 (93.5%) and 12.5-15.5 months (34.4%), respectively, first and second follow-ups. **Conclusion:** Low coverage was found, both in the first and second year of life.

Keywords: Vaccination Coverage; Child; Immunization; Longitudinal Studies.

Introduction

Vaccines are among the most effective public health measures for the prevention, elimination and control of communicable diseases.[1] Organized immunization programs are considered one of the most cost-effective investments in health.[2] In Brazil, the National Immunization Program (PNI), created in 1973, with universal and free access, provides a wide range of vaccines, free of charge, available in public health services nationwide. In addition, each year, the PNI promotes several mass vaccination campaigns.[3] The universal supply of vaccines in the primary health care and their free access to the population, given a broad primary health care network, together with other surveillance actions, have been fundamental for the elimination and control of diseases such as smallpox, diphtheria, poliomyelitis and measles, historically responsible for a large number of victims in Brazil.[4]

> *Vaccines are among the most effective public health measures for the prevention, elimination and control of communicable diseases.*

Currently, PNI provides 44 types of immunobiological products, including vaccines, serums and immunoglobulins.[3,4] However, the increase in the complexity of vaccine schedule items in recent decades and the introduction of several vaccines in a short period have brought new challenges to the program, including reaching and maintaining high vaccination coverage in the population.[5] Only for the first year of life, for example, the current vaccination schedule provides an average of eight contacts between the family and health services, so that the child receives a total of 18 doses of vaccines. Nevertheless, researches conducted in specific locations in the country indicated a possible reduction in vaccination coverage, between 1993 and 2015.[6]

The objective of this study was to assess vaccination coverage, based on the National Immunization Program schedule, among children receiving financial support from the Family Income Transfer Program, according to the family socioeconomic status and maternal characteristics.

Methods

These were the first and second stages of the longitudinal study of 'Impact assessment of the Happy Child Program (PCF)', provided by the Ministry of Citizenship (MCid) to children under 3 years old[7] aiming at promoting child development through strengthening family bonds, preventing child neglect and abuse and reducing malnutrition.

The target population of the PCF is comprised of children receiving financial support from Family Income Transfer Program.[8] In order to participate in the program, families must fulfil program conditions in the areas of health and education. These conditions include keeping children and adolescents from 6 to 17 years old in school and complying with basic health care requirement such as taking children under 7 years old to health centers, for immunization and monitoring growth and development, according to the schedule recommended by health teams.

'The Impact Assessment of the Happy Child Program' has been carried out since 2018, a randomized study, aiming to estimate the effect of the program on intellectual stimulation in the home environment and on neurodevelopment of children assisted by Family Income Transfer Program, before they turn one year old.[9] To make up the study, six states were chosen – referred to as Federative Units (FUs) – with a great number of beneficiaries of the Family Income Transfer Program. In each FU, three to six municipalities with excess demand (at least 4:1) of children under 1 year old eligible for the PCF, were selected; they should also have a great number of professionals with the capacity to include and visit weekly ≥80 children. In all, 30 municipalities in the states of Bahia, Ceará, Goiás, Pará, Pernambuco and São Paulo (an average of 109 children per municipality) were selected. Further information on the methodology adopted in the study is available at: https://aplicacoes.mds.gov.br/sagirmps/ferramentas/docs/Caderno%20%20Studies-35-online.pdf; and http://www.epidemio-ufpel.org.br/uploads/downloads/avaliacao-do-impacto-do-programa-crianca-feliz.pdf

The Ministry of Citizenship provided the state team with a list of children and pregnant women eligible for the PCF. When the evaluation team arrived in each municipality, they met with the person in charge of the PCF, at the Social Assistance Reference Center (CRAS), to establish the neighborhoods where the evaluation program would be made available. In most municipalities, PCF is not provided in rural and remote areas or where there are security issues. The researchers, in possession of the list provided by the Ministry of Citizenship to the PCF state team, visited each household to determine whether the family would agree to take part in the program and the study. The inclusion of pregnant women was due to the possibility that these women had given birth after the last update of the list, which usually corresponded to a few months before data collection (Supplementary Material 4).

In this study, 3,242 children evaluated in the first follow-up (baseline - T0), which occurred between August 2018 and July 2019, when they were less than 12 months old, were analyzed; and 3,008 children (93% of the original group) were located and evaluated in the second follow-up (T1), which occurred 9-13 months after the beginning of T0 (median=12 months), according to the FU.

The questionnaires used for data collection, in both stages, had been previously tested in a pilot study conducted in the city of Pelotas, state of Rio Grande do Sul, and are available on the Postgraduate Program in Epidemiology of the Federal University of Pelotas website.[10]

In both evaluations – T0 and T1 – the general questionnaire, applied by trained interviewers, had questions that had already been tested and standardized, extracted from the Multiple Indicator Cluster Survey (MICS),[11] from the instruments used in the 2004 and 2015 Pelotas Birth Cohorts[12,13] and also from the PCF training manuals.[14] The interviewers were selected after taking part in a 40-hour training course held in Brasília, capital of Brazil. The answers to the questions were recorded on tablets, on REDCap platform.[15]

In both visits, the mother was asked to show the Child Health Booklet or any other vaccination record. The interviewer also photographed and recorded the Child Health Booklet, using the tablet; then recorded the vaccines doses the child had already received. For each vaccine, there were five different options to select an answer to complete the multiple choice answer sheet: '1st dose'; '2nd dose'; '3rd dose'; 'did not'; and 'booster shots'. If the child had received the first and second doses of a vaccine, the options '1st dose' and '2nd dose' were selected.

For the analyses, 'adequate vaccination' outcome was operationalized according to the vaccination schedule recommended by the National Immunization Program Information System (PNI)[16] and showed in Figure 1. Children who had received all vaccines recommended for their age (delayed vaccination of up to 15 days was observed for each immunobiological product) were considered to have 'adequate' vaccination. For example, a child aged 6 months and 7 days of life was classified as 'up to date' with the schedule if he or she had received all the vaccines scheduled for children aged 5 months, even if some previous doses had been administered with some delay. Vaccines that are not included in the basic vaccination schedule of PNI[16] (such as influenza), as well as those which are not supplied in the immunization routine in all FUs (e.g., yellow fever),[17] were not included in the construction of the outcome variable.

The independent variables used, were collected in the T0 interview:

a) Family socioeconomic status (divided into quintiles, and established from information on household characteristics and consumer goods, through analysis of main components);
b) Maternal age (years: <20; 20-29; 30-39; ≥40);
c) Maternal schooling (years of study: 0-4; 5-8; ≥9);
d) Self-declared mother's race/skin color (white; brown; Asian; indigenous; and black);
e) Mother living with her husband/partner (yes; no).

As vaccination coverage in T1 was different in the PCF group and in the control group (p=0.032), 'intervention' status or 'control' status of the children was used as a potential confounder in the association between exposures and outcomes.

The random allocation of participants to the control group or to the intervention group and similarity between the groups in T0 and regarding the losses may have prevented selection bias. Information bias was minimized with the standardization of data collection: The teams in the six FUs were trained at the same time, and information about vaccines was obtained directly from the Child Health Booklet.

The sample size required for this "Impact Assessment of the Happy Child Program study" was calculated based on the following parameters: 5% alpha two-tailed error; 10% beta error; 60% program membership (continuity of participation in the PCF for three years); and a 20% increase for follow-up losses. Thus, it would be necessary to check 2,880 children's data in the country.

Statistical analyses were performed using Stata, version 16.0 (StataCorp LLC, College Station, TX, USA). The proportion of children with health booklet or another vaccination record was the first variable to be calculated. Subsequently, the proportion of children with adequate vaccination in T0 and T1 was estimated for the entire sample, with the respective 95% confidence intervals (95%CI). Then, the proportion of children with adequate vaccination was calculated, according to maternal and family characteristics. Next, the proportions were calculated per UF and municipality. In both follow-ups (T0 and T1), multilevel models (level 3, UF; level 2, municipality; level 1, children) were used. Associations were evaluated using the Wald test, and the $p<0.05$ values were considered statistically significant.

The study project was submitted to the Human Research Ethics Committee of the Federal University of Pelotas Faculty of Medicine (CEP/FAMED/UFPel), affiliated to the National Research Ethics Committee (CONEP)/National Health Council (CNS), and approved, CNS Opinion No. 2,148,689, issued on May 13, 2017. The project is available on the Brazilian Clinical Trials Registry (ReBEC) website, identifier: RBR-4x7dny. Mothers or guardians signed a Free and Informed Consent Form, as a condition to participate in the study.

Results

The lists provided by the MCid for 30 municipalities had a total of 8,601 families, with pregnant women or children potentially eligible for inclusion in the PCF. Of the 8,601 families listed, more than half of them were not included in the study because the address was not located by the researchers (28%), the family had moved permanently (15%) or was temporarily absent from home (13.3%) (Supplementary Material 4). In all, 3,242 (37.7%) of the families listed by the MCid were considered eligible for this study.

Among the 3,242 children evaluated in T0, the median age was 7.6 months old; for the 3,008 reassessed in T1, the median age was 18.9 months old. Table 1 shows the sampling distribution according to the characteristics at the baseline (T0). The highest proportion of mothers was between 20-29 years of age (51.5%), had ≥9 years of schooling (60.0%), 75.4% self-declared race/ skin color as brown, and more than 60% reported living with a husband or partner.

There was a loss of 234 children in T1 (7.2% in relation to T0). Among the unaccompanied children in T1, the highest proportion belonged to the poorest quintile (23.5%), mothers were between 20 and 29 years of age (55.2%), had less than nine years of schooling (52.1%), self-declared race/skin color as brown (73.2%), and lived with a husband/partner (66.4%).

A total of 3,133 (96.7%) families in T0 and 2,779 (92.4%) in T1 showed the Child Health Booklet or another record of vaccines received at the time of the interview. In T0, there was no difference between children whose mothers showed the Child Health booklet or another vaccination record, according to any of the independent variables analyzed (Table 2).

Age group	Recommended age (months)	Recommended vaccines
1	0 ≤ age < 2	BCG[a]
		Hepatitis B (at least 1 dose)
2	2 ≤ age < 3	Vaccines for age group 1
		Pentavalent
		IPV[b]
		10-valent pneumococcal
		Human rotavirus
3	3 ≤ age <4	Vaccines for age group 1
		Vaccines for age group 2
		Meningococcal C (at least 1 dose)
4	4 ≤ age < 5	Vaccines for age group 1
		Pentavalent (at least 2 doses)
		IPV[b] (at least 2 doses)
		10-valent pneumococcal (at least 2 doses)
		Human rotavirus (at least 2 doses)
		Meningococcal C (at least 1 dose)
5	5 ≤ age < 6	Vaccines for age group 1
		Pentavalent (at least 2 doses)
		IPV[b] (at least 2 doses)
		10-valent pneumococcal (at least 2 doses)
		Human rotavirus (at least 2 doses)
		Meningococcal C (at least 2 doses)
6	6 ≤ age < 9	Vaccines for age group 1
		Pentavalent (at least 3 doses)
		IPV[b] (at least 3 doses)
		10-valent pneumococcal (at least 2 doses)
		Human rotavirus (at least 2 doses)
		Meningococcal C (at least 2 doses)
7	9 ≤ age < 12	Vaccines for age group 1
		Vaccines for age group 6
8	12 ≤ age < 15	Vaccines for age group 1
		Pentavalent (at least 3 doses)
		IPV[b] (at least 3 doses)
		10-valent pneumococcal (at least 3 doses)
		Human rotavirus (at least 2 doses)
		Meningococcal C (at least 3 doses)
		Triple viral (at least 1 dose)

To be continue

Continuation

Age group	Recommended age (months)	Recommended vaccines
9	15 ≤ age < 48	Vaccines for age group 1
		Vaccines for age group 8
		DTP[c] booster (at least 1 dose)
		OPV[d] booster (at least 1 dose)
		Hepatitis A
		Tetra viral

a) BCG: calmette-Guérin bacillus; b) IPV: poliomyelitis type1, type2 and type 3; c) DTP: diffrhyphthesis, tetanus and *pertussis*; d) OPV: poliomyelitis type 1 and type 3.

Figure 1 – Vaccination schedule adopted for the construction of 'adequate vaccination variable' according to the vaccination schedule extracted and adapted from the Child Health Booklet

Table 1 – Family and maternal characteristics at baseline (T0) of the 'Impact assessment of Happy Child Program (PCF)' study (n=3,242 children <12 months of life), Brazil, August/2018-April/2019

Family and maternal characteristics	N	%
Family socioeconomic status (quintiles) (n=3.239)		
1º (poorest)	648	20.0
2º	648	20.0
3º	648	20.0
4º	650	20.1
5º (richest)	645	19.9
Maternal age (years) (n=3.199)		
<20	464	14.5
20-29	1,649	51.5
30-39	975	30.5
≥40	111	3.5
Maternal schooling (years) (n=3.004)		
0-4	278	9.3
5-8	924	30.7
≥9	1,802	60.0
Mother's race/skin color (n=3.186)		
White	463	14.5
Brown	2,402	75.4
Black	321	10.1
Mother living with her husband or a partner (n=3.241)		
No	1,198	37.0
Yes	2,043	63.0
Total	**3,242**	**100**

Table 2 – Distribution of children with Child Health Booklet or other vaccination record, at baseline (T0) and in the first follow-up (T1) of the Impact Assessment of the Happy Child Program study, Brazil (T0, August/2018-April/2019; T1, September/2019-January/2020)

Variable	n (%) with a child health booklet[a] or another vaccination recorda (T0)	n (%) with a child health booklet[a] or another vaccination record (T1)
	(n=3,239)	(n=3,008)
Family socioeconomic status (quintiles)	**p=0.420[b]**	**p=0.152[b]**
1º (poorest)	631 (97.5)	554 (91.7)
2º	627 (96.8)	564 (91.6)
3º	629 (97.1)	553 (91.3)
4º	618 (95.4)	568 (94.2)
5º (richest)	625 (96.9)	537 (90.3)
Maternal age (years)	**p=0.257[b]**	**p=0.103[b]**
<20	445 (95.9)	389 (90.6)
20-29	1,596 (96.6)	1,396 (91.1)
30-39	946 (97.1)	854 (93.4)
≥40	110 (99.1)	103 (95.1)
Maternal schooling (years)	**p=0.199[b]**	**p=0.131[b]**
0-4	273 (98.2)	249 (94.8)
5-8	901 (97.5)	772 (92.6)
≥9	1,737 (96.5)	1,557 (91.3)
Mother's race/skin color	**p=0.493[b]**	**p=0.322[b]**
White	447 (96.5)	387 (90.5)
Brown	2,326 (97.0)	2.068 (93.7)
Black	311 (96.9)	275 (91,8)
Mother living with her husband or a partner	**p=0.094[b]**	**p=0.012[b]**
No	1,149 (96,0)	1,016 (90.1)
Yes	1.983 (97,2)	1,762 (92.8)
Total	**3,133 (96.7)**	**2,779 (92.4)**

a) Proportions calculated considering hierarchical levels of multilevel model (level 3, state; level 2, municipality; level 1, children); b) Wald test.

In T1, however, the proportion of children with a health booklet or another vaccination record whose mothers lived with a husband or partner was higher than their counterparts (Table 2).

The proportion of children with adequate vaccination was 2.5 fold greater in T0 (61.0% – 95%CI 59.3;62.6), compared to T1 (24.8% – 95%CI 22.8;25.9) (p<0.001). Table 3 shows the proportions of children with adequate vaccination, according to family and maternal characteristics. In T0, the highest proportion of adequate vaccination occurred among those belonging to the richest quintile (67.9%) and among children whose mothers had ≥9 years of schooling (63.3%) (Table 3). In T1, no differences were observed between the proportions of adequate vaccination, according to the independent variables.

Table 4 shows the percentages of adequate vaccination, according to the vaccination schedule and children's age in months. There was no pattern of increase or decrease in vaccination coverage according to age. In the first follow-up (T0), the age group with the lowest percentage of adequate vaccination corresponded to the stratum from 5.5 to 6.5 months old (53.5%); and the highest percentage, to the stratum from 0.5 to 2.5 months old (93.5%). In the second follow-up (T1), the highest percentage of

Table 3 – Proportion of children with adequate vaccination according to vaccination schedule with delayed vaccination of up to 15 days (T0 and T1), according to family and maternal characteristics in the baseline of the Impact Assessment of the Happy Child Program study, Brazil (T0, August/2018-April/2019; T1, September/2019-January/2020)

Maternal and family characteristics	T0	T1
	Adequate vaccination according to vaccination schedule with delayed vaccination of up to 15 days[a]	Adequate vaccination according to vaccination schedule with delayed vaccination of up to 15 days[a]
	(n=3,205)	(n=3,008)
	n (%)	n (%)
Family socioeconomic status (quintiles)	**p<0.001[b]**	**p=0.557[b]**
1º (poorest)	315 (55.1)	164 (26.6)
2º	396 (57.6)	145 (22.7)
3º	374 (58.4)	149 (24.5)
4º	420 (63.1)	144 (24.3)
5º (richest)	447 (67.9)	143 (26.0)
Maternal age (years)	**p=0.341[b]**	**p=0.474[b]**
<20	273 (61.6)	107 (25.2)
20-29	959 (59.3)	362 (23.6)
30-39	633 (62.4)	238 (26.3)
≥40	71 (63.2)	28 (26.6)
Maternal schooling (years)	**p=0.001[b]**	**p=0.780[b]**
0-4	157 (56.3)	65 (24.1)
5-8	521 (57.2)	202 (24.0)
≥9	1,125 (63.3)	419 (25.2)
Mother's race/skin color	**p=0.573[b]**	**p=0.797[b]**
White	293 (60.2)	95 (23.6)
Brown	1,438 (60.4)	571 (24.1)
Black	196 (63.3)	65 (25.0)
Mother living with her husband or a partner	**p=0.899[b]**	**p=0.092[b]**
No	716 (60,4)	258 (23,1)
Yes	1,238 (60,6)	488 (25,8)
Total	**1,954 (61.0)**	**746 (24.8)**

a) Proportions calculated considering hierarchical levels of multilevel model (level 3, state; level 2, municipality; level 1, children); b) Wald test.

adequate vaccination corresponded to the age group from 12.5 to 15.5 (34.4%) months old, and the lowest, to the age group from 6.5 to 9.5 (12.5%) months old.

Supplementary Materials 1 and 2 show adequate vaccination percentages, respectively for each FU and municipality studied. The highest proportion of adequate vaccination in T0 was observed in the state of Ceará (CE) (78.4%), and the lowest in the state of Pará (PA) (36.1%) (Supplementary Material 1). As observed in T1, no significant differences were observed among the FUs. Among 30 cities studied, Morada Nova, (CE) had the highest vaccination coverage in T0 (89.3%), and São Miguel do Guamá (PA), the highest vaccination coverage in T1 (45.7%) (Supplementary Material 2). The lowest vaccination coverage in T0 was verified in Tailândia (PA), with 10.6%; and in T1, in Paulo Afonso, state of Bahia, (BA), with 7.2%.

According to each FU, among the municipalities studied, the highest percentages of vaccination in T0 were found in Irecê, state of Bahia (BA),

Table 4 – Percentages of adequate vaccination according to vaccination schedule with delayed vaccination of up to 15 days according to the child's age in months, baseline (T0) and first follow-up (T1) of the Impact Assessment of the Happy Child Program study, Brazil (T0, August/2018-April/2019; T1, September/2019-January/2020)

Age in months	Percentage of adequate vaccination in T0	Percentage of adequate vaccination in T1
	n (%)	n (%)
0.5-2.5	188/201 (93.5)	–
2.5-3.5	87/123 (70.7)	–
3.5-4.5	128/194 (66.0)	–
4.5-5.5	146/272 (53.7)	–
5.5-6.5	192/359 (53.5)	–
6.5-9.5	667/1217 (54.8)	1/8 (12.5)
9.5-12.5	546/832 (65.6)	36/122 (29.5)
12.5-15.5	0/7 (0.0)	177/514 (34.4)
15.5-26.5	–	532/2.364 (22.5)

Morada Nova (CE), Novo Gama, state of Goiás (GO), São Miguel do Guamá (PA), Serra Talhada, state of Pernambuco (PE) and Piracicaba, state of São Paulo (SP); and the lowest percentages, in the municipalities of Serrinha (BA), Caucaia (CE), Águas Lindas de Goiás, state of Goiás (GO), Tailândia (PA), Abreu e Lima (PE) and Francisco Morato (SP). In T1, the municipalities with the highest percentages of adequate vaccination were: Irecê and Vitória da Conquista (BA), Sobral (CE), Águas Lindas de Goiás (GO), São Miguel do Guamá (PA), Caruaru (PE) and Piracicaba (SP); and municipalities with the lowest percentages, Paulo Afonso (BA), Caucaia (CE), Novo Gama (GO), Bragança (PA), São Lourenço da Mata (PE) and Limeira (SP) (Supplementary Material 2).

The proportion of children who received all vaccine doses in T0 and T1, based on the vaccination schedule according to their age, is shown in Supplementary Material 3. In T0, the vaccination dose with the lowest coverage was the booster shot of meningococcal vaccine C (14.3%). In T1, the lowest proportion corresponded to the first booster shot of DTP vaccine (6.1%).

Discussion

The results of this study showed a low percentage of children with adequate vaccination, both in the first and second year of life, even taking into account a delayed vaccination of up to 15 days in relation to the age group recommended to receive the vaccine. The percentages of adequate vaccination in the first year of life were higher among children belonging to families of the richest quintile and whose mothers had ≥9 years of schooling. These socioeconomic differences should be interpreted taking into account the sample constitution of the study: families of lower socioeconomic status, beneficiaries of the Family Income Transfer Program. In the second follow-up (T1), there was no relationship between vaccination coverage, socioeconomic status or maternal education, which is possibly a reflection of a decrease in the supply of vaccines in 2019.[18]

A study conducted in the municipality of Volta Redonda, state of Rio de Janeiro (RJ), with children from 2 months to 5 years old receiving care in primary health centers (PHC), found complete vaccination coverage of only 11% in 2012.[19] Another study, conducted under Pelotas Birth Cohorts Study, state of Rio Grande do Sul (RS), showed that at 12 months old, vaccination coverage was 80.9%(95%CI 79.8;82.0), 97.2%(95%CI 96.1;98.0), 87.8%(95%CI 86,7;88.8) and 77.2%(95%CI 75.8;78.4), respectively for those born in the municipality of Pelotas (RS) in 1982, 1993, 2004 and 2015.[6]

Results of population surveys, such as the studies mentioned above in epigraph and in this research, tend to show a vaccination coverage lower than those obtained from the routine health information systems. Data are inserted on these systems through reports of doses received, compiled in health centers.

For coverage calculations, population estimates were used as denominators – which sometimes results in coverage greater than 100%. For example, according to data from the Saúde Brasil series,[20] in 2015, the Bacillus Calmette-Guérin (BCG) vaccine coverage was 105%.[20] In 2016, doses of hepatitis B vaccine (<1 year old), human rotavirus (<1 year old), meningococcal C (12 months old), diphtheria, tetanus and *pertussis* vaccine (DTP) (15 months old), 10-valent pneumococcal (12 months old), poliomyelitis (15 months old) and triple viral (12 months old) administered, were all below the vaccination coverage target. Despite the different calculation methods employed, official data confirm a decline in vaccination coverage at national level.

This study demonstrated that belonging to the richest quintile – within a predominantly poor sample – was a factor associated with higher proportions of adequate vaccination in T0. Two evaluative studies on low-and-middle income countries, found inequalities in vaccination coverage according to socioeconomic status: lower coverage in the poorest quintile, when compared to coverage in the richest quintile.[22,23]

Two Brazilian studies, conducted in Salvador, state capital of Bahia (BA),[24] between 2007 and 2008, and in São Luís, state capital of Maranhão (MA),[25] between 2006 and 2007, showed that children from the poorest social strata had lower vaccination coverage compared to those of the richest strata. On the other hand, studies on Pelotas birth cohorts observed that at 12 months old, there was greater vaccination coverage among children from the wealthiest strata born in 1982, while for those born in 2015, this socioeconomic pattern was the opposite, a fact that the authors attributed to possible vaccine hesitancy among the richest families.[6] According to the authors of historical series, another important reason for the decrease in vaccination coverage is related to the increasing complexity of the Brazilian vaccination schedule, which increased from four types of vaccines in 1982, administered during five visits to the health center in the first year of life, to 18 types of vaccines administered during eight visits. If, on the one hand, the expansion of vaccine supply has been important for the control of vaccine-preventable diseases, on the other hand, the complexity of vaccination schedule has contributed to the decrease in vaccination coverage.

The Lowest maternal schooling was associated with the lowest vaccination coverage levels in T0. The study conducted at a PHC in Volta Redonda, (RJ), found higher prevalence of delayed vaccination among children whose mothers had less than eight years of schooling.[19] Another study, conducted in the state of Maranhão, between 2006 and 2007, with children aged 12 to 59 months, showed higher prevalence of incomplete vaccination among families whose head of the family had less than five years of schooling.[25]

In general, (i) the sample size and scope stood out in this study, involving more than 3 million children from six Federative Units and 30 municipalities in four of the five macro-regions of Brazil, and (ii) the strategy adopted to collect information about the outcome, including photographs of Child Health Booklets and data extracted from the vaccination record. Many studies have used only the information reported by mothers or guardians about the vaccines received by the child. Analysis of data obtained from two follow-ups – T0 and T1 – enabled comparing vaccination coverage in the same population, within a period of one year.

However, this study presents a limitation: the fact of having used data from a predominantly poor population, and that it had been originated from a study designed to answer another research question, has limited the generalization of its results. Information on the use of health services by children and availability of vaccines for them at the primary health centers of the Brazilian National Health System (SUS) could not be evaluated.

The differences in the prevalence of vaccination coverage between the first and second follow-ups allow us to consider the following hypothesis: the decrease in vaccination coverage in the period, in part, may be a reflection of lack of vaccines, especially pentavalent immunization coverage in 2019.[18] The wide difference in vaccination coverage between FUs and municipalities is also a fact that stands out. This difference is due to, on the one hand, the local characteristics of implementation of the PNI (vaccine supply, access to health services and record data regularity in the Children's Health Booklet), and on the other hand, the dependence on the families' support to vaccinate their children. As vaccination is one of the conditionalities for receiving the benefits from the Family Income Transfer Program, there is a stronger hypothesis that this difference is attributed to local characteristics of implementation of the program.

Similar difference was identified in 2017, when the percentage of children up to 2 years old vaccinated was 24.7% in the state of Bahia, 25.7% in the state of Ceará, 23.4% in the state of Goiás, 42.1% in the state of Pará, 33% in the state of Pernambuco and 15.8% in the state of São Paulo.[26]

It was also noteworthy low vaccination coverage, even if a delayed vaccination of up to 15 days for each vaccine had been taken into account. Thus, it is worrying the fact that all the children assessed belonged to families that received financial support from the Family Income Transfer Program, whose access is conditioned to the fulfillment of some requirements such as complying with the vaccination schedule of all children under 7 years of age, in the family.[27] The findings of the study suggested the need for a detailed assessment of the family's compliance with the conditionality of maintaining the vaccination schedule of their children updated.

Home visiting programs may increase vaccination coverage in children.[28] In this study, in T1, vaccination coverage in the PCF group was higher than in the control group, even after adjusting for the 'intervention' or 'control' status, indicating that the Happy Child Program (PCF) can contribute to the improvement of vaccination rates.

The Ministry of Health, as the body responsible, has shown concern about the decline in vaccination coverage in the country. The World Health Organization recommends coverage of 90% for BCG and human rotavirus, and 95% for other immunizers. Measures to be taken to promote vaccination include (i) extending time of vaccination sites, (ii) avoiding access barriers, (iii) taking advantage of the opportunity for vaccination (consultations or other procedures at health centers), (iv) identifying children's delayed vaccination and, through active search and community strategies, (v) promoting collective health education actions, together with the community, for vaccine-preventable diseases, and (vi) fighting vaccine misinformation, always extolling the safety and benefits of vaccines.[29]

It should be noted that, soon after the study on screen had been concluded, the COVID-19 pandemic emerged in the country and, most likely, more recent reports, that preventive actions that had been carried out in the primary health care network and were severely affected by the pandemic, indicated a vaccination coverage – by the end of 2020 – however lower than that showed in this analysis.

Authors' contribution

Barcelos RS, Santos IS, Munhoz TN, Blumenberg C, Bortolotto CC, Matijasevich A, Salum C, Santos Júnior HG, Marques L, Correia L, Souza MR, Lira PIC, Altafim E, Macana EC and Victora CG collaborated with the concept and design of the study, data collection, analysis and interpretation, drafting and critical reviewing of the intellectual content of the manuscript. All authors have approved the final version of the manuscript and have declared themselves to be responsible for all aspects of the work, including ensuring its accuracy and integrity.

References

1. Andre FE, Booy R, Bock HL, Clemens J, Datta SK, John TJ, et al. Vaccination greatly reduces disease, disability, death and inequity worldwide. Bull World Health Organ. 2008;86(2):81-160. doi: https://doi.org/10.2471/blt.07.040089.
2. World Health Organization. Immunization [Internet]. [Geneva]: World Health Organization; 2019 [acesso 20 jul. 2020]. Disponível em: https://www.who.int/news-room/facts-in-pictures/detail/immunization
3. Ministério da Saúde (BR). Manual de normas e procedimentos para vacinação [Internet]. Brasília, DF: MS; 2014 [acesso 17 jun. 2020]. Disponível em: https://bvsms.saude.gov.br/bvs/publicacoes/manual_procedimentos_vacinacao.pdf
4. Ministério da Saúde (BR). Programa Nacional de Imunização: coberturas vacinais no Brasil, período: 2010 – 2014 [Internet]. Brasília, DF: MS; 2015 [acesso 17 jun. 2020]. Disponível em: https://portalarquivos2.saude.gov.br/images/pdf/2017/agosto/17/AACOBERTURAS-VACINAIS-NO-BRASIL---2010-2014.pdf
5. Domingues CMAS, Teixeira AMS. Coberturas vacinais e doenças imunopreveníveis no Brasil

no período 1982-2012: avanços e desafios do Programa Nacional de Imunizações. Epidemiol Serv Saude. 2013;22(1):9-27. doi: http://dx.doi.org/10.5123/S1679-49742013000100002.

6. Silveira MF, Buffarini R, Bertoldi AD, Santos IS, Barros AJD, Matijasevich A, et al. The emergence of vaccine hesitancy among upper-class Brazilians: results from four birth cohorts, 1982-2015. Vaccine. 2020 jan 16;38(3):482-8. doi: http://dx.doi.org/10.1016/j.vaccine.2019.10.070.

7. Ministério do Desenvolvimento Social e Agrário (BR). A intersetoralidade na visita domiciliar [Internet]. Brasília, DF: MDS; 2017 [acesso 23 dez. 2020]. (Programa criança feliz). Disponível em: http://www.mds.gov.br/webarquivos/publicacao/crianca_feliz/A_intersetorialidade_na_visita_domiciliar_2.pdf

8. Ministério da Cidadania (BR). Criança feliz: quanto mais cuidado, mais futuro [Internet]. Brasília DF; 2017 [acesso 23 dez. 2020]. Disponível em: http://cidadania.gov.br/criancafeliz/campanha/

9. Santos IS, Munhoz TN, Barcelos RS, Blumenberg C, Bortolotto CC, Matijasevich A, et al. Estudo de Linha de Base da Avaliação de Impacto do Programa Criança Feliz. Cad Estud. 2020;(35):13-31.

10. Victora C, Santos I, Munhoz T. Avaliação do Programa Criança Feliz: projeto de pesquisa [Internet]. Pelotas, RS: Programa de Pós-graduação em Epidemiologia; 2020 [acesso 21 jun. 2020]. Disponível em: http://www.epidemio-ufpel.org.br/uploads/downloads/avaliacao-do-impacto-do-programa-crianca-feliz.pdf Disponível

11. Multiple Indicator Cluster Surveys. MICS6 Questionnaires [Internet]. UNICEF; 2017 [acesso 05 mai. 2020]. Disponível em: http://mics.unicef.org/tools

12. Santos IS, Barros AJD, Matijasevich A, Domingues MR, Barros FC, Victora CG. Cohort profile: the 2004 Pelotas (Brazil) birth cohort study. Int J Epidemiol. 2011;40(6):1461-8. doi: http://dx.doi.org/10.1093/ije/dyq130.

13. Hallal PC, Bertoldi AD, Domingues MR, Silveira MF, Demarco FF, Silva ICM, et al. Cohort Profile: The 2015 Pelotas (Brazil) Birth Cohort Study. Int J Epidemiol. 2018 Aug 1;47(4):1048-1048h. doi: http://dx.doi.org/10.1093/ije/dyx219.

14. Ministério do Desenvolvimento Social (BR). Guia para visita domiciliar [Internet]. Brasília, DF: MDS; 2020 [acesso 10 mar. 2020]. (Programa crianca feliz). Disponível em: http://www.mds.gov.br/webarquivos/arquivo/crianca_feliz/Guia%20para%20Visita%20Domiciliar%20-%20Programa%20Crian%C3%A7a%20Feliz%20-%2021-06-2017.pdf

15. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)-- a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform. 2009;42(2):377-81.

16. Ministério da Saúde (BR). Vacinação [Internet]. Brasília, DF: MS; 2020 [acesso 23 mai. 2020]. Disponível em: http://www.saude.gov.br/saude-de-a-z/vacinacao

17. Ministério da Saúde (BR). Municípios conforme áreas de recomendação para vacinação contra febre amarela [Internet]. Brasília, DF: MS; 2017 [acesso 20 jun. 2020]. Disponível em: http://portalarquivos.saude.gov.br/images/pdf/2017/abril/07/Municipios-conforme-Areas-de-recomendacao-para-vacinacao-contra-febre-amarela.pdf

18. Brasil. Postos de saúde são reabastecidos com vacina pentavalente 2020 [Internet]. Brasília, DF; 2020 [acesso 27 dez. 2020]. Disponível em: https://www.gov.br/pt-br/noticias/saude-e-vigilancia-sanitaria/2020/01/postos-de-saude-sao-reabatecidos-com-vacina-pentavalente

19. Cardoso MDT, Carneiro SG, Ribeiro TT, Strapasson JF, Carneiro RG. Avaliação da cobertura vacinal em crianças de 2 meses a 5 anos na estratégia saúde da família. Rev APS. 2015;18(3):273-80.

20. Ministério da Saúde (BR). Saúde Brasil, 2019: Uma análise da situação de saúde com enfoque nas doenças imunopreveníveis e na imunização [Internet]. Brasília, DF: MS; 2019 [acesso 02 jul. 2020]. Disponível em: https://www.saude.gov.br/images/pdf/2019/dezembro/05/Saude-Brasil-2019-imunizacao.pdf

21. Cruz A. A queda da imunização no Brasil. Rev Consensus [Internet]. 2017 [acesso 6 jun. 2020];(25):20-9. Disponível em: https://portal.fiocruz.br/sites/portal.fiocruz.br/files/documentos/revistaconsensus_25_a_queda_da_imunizacao.pdf

22. Restrepo-Méndez MC, Barros AJD, Wong KL, Johnson HL, Pariyo G, França G, et al. Inequalities in full immunization coverage: trends in low- and middleincome countries. Bull World Health Organ. 2016 nov 1;94(11):794-805B. doi: http://dx.doi.org/10.2471/BLT.15.162172.

23. Hosseinpoor AR, Bergen N, Schlotheuber A, Gacic-Dobo M, Hansen PM, Senouci K, et al. State of inequality in

diphtheria-tetanus-pertussis immunisation coverage in low-income and middle-income countries: a multicountry study of household health surveys. Lancet Glob Health. 2016;4(9):e617-26. doi: http://dx.doi.org/10.1016/S2214-109X(16)30141-3

24. Barata RB, Pereira SM. Desigualdades sociais e cobertura vacinal na cidade de Salvador, Bahia. Rev Bras Epidemiol. 2013;16(2):266-77. doi: http://dx.doi.org/10.1590/S1415-790X2013000200004.

25. Yokokura AVCP, Silva AAM, Bernardes ACF, Lamy FF, Alves MTSSB, Cabral NAL, et al. Cobertura vacinal e fatores assovciados ao esquema vacinal básico incompleto aos 12 meses de idade, São Luís, Maranhão, Brasil, 2006. Cad Saude Publica. 2006;29(3):522-34. doi: http://dx.doi.org/10.1590/S0102-311X2013000300010.

26. Ministério da Saúde (BR). Sistema de Informação do Programa Nacional de Imunizações: 2020 [Internet]. Brasília, DF; 2020 [acesso 22 dez. 2020]. Disponível em: http://sipni.datasus.gov.br/si-pni-web/faces/inicio.jsf

27. Ministério da Cidadania (BR). Bolsa família e cadastro único no seu município: informações detalhadas sobre todos os municípios do país [Internet]. Brasília, DF: Ministério da Cidadania; 2019 [acesso 02 jul. 2020]. Disponível em: https://www.gov.br/cidadania/pt-br/acoes-e-programas/bolsa-familia

28. Isaac MR, Chartier M, Brownell M, Chateau D, Nickel NC, Martens P, et al. Can opportunities be enhanced for vaccinating children in home visiting programs? A population-based cohort study. BMC Public Health. 2015 jul 7;15:620. doi: http://dx.doi.org/10.1186/s12889-015-1926-8.

29. Conselho Nacional de Secretarias Municipais de Saúde (BR). Dez passos para ampliar a cobertura vacinal [Internet]. Brasília, DF: CONASEMS; 8 out. 2019 [acesso 04 jun 2020]. Disponível em: https://www.conasems.org.br/dez-passos-para-ampliar-cobertura-vacinal/

Received on 06/11/2020
Approved on 01/03/2021

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Supplementary Material 1 - Proportion of children with adequate vaccination, per state, according to vaccination schedule with delayed vaccination of up to 15 days, at baseline (T0) and in the first follow-up (T1) of the Impact Assessment of the Happy Child Program study, Brazil (T0, August/2018-April/2019; T1, September/2019-January/2020)

Federative Unit	T0	T1
	Adequate vaccination according to vaccination schedule with delayed vaccination of up to 15 days[a]	Adequate vaccination according to vaccination schedule with delayed vaccination of up to 15 days[a]
	(n=3,205)	(n=3,008)
	n (%)	n (%)
	p=0.001[b]	p=0.549[b]
Bahia	297 (59.4)	80 (19.4)
Ceará	662 (78.4)	237 (28.0)
Goiás	176 (57.6)	79 (28.8)
Pará	200 (36.1)	138 (27.1)
Pernambuco	351 (62.6)	136 (24.5)
São Paulo	268 (67.8)	76 (21.8)
Total	**1,954 (61.0)**	**746 (24.8)**

a) Proportions calculated considering hierarchical levels of multilevel model (level 3, state; level 2, municipality; level 1, children); b) Wald test.

Supplementary Material 2 - Proportion of children with complete vaccination for age up to 15 days after the exact age, per municipality, at baseline (T0) and in the first follow-up (T1) of the Impact Assessment of the Happy Child Program study, Brazil (T0, August/2018-April/2019; T1, September/2019-January/2020)

Federative Unit/Municipality	T0	T1
	Adequate vaccination according to vaccination schedule with delayed vaccination of up to 15 days	Adequate vaccination according to vaccination schedule with delayed vaccination of up to 15 days
	(n=3,205)	(n=3,008)
	n (%)	n (%)
Bahia		
Casa Nova	22 (53.7)	10 (25.0)
Feira de Santana	122 (55.5)	22 (10.9)
Irecê	40 (88.9)	13 (28.9)
Paulo Afonso	52 (46.0)	7 (7.2)
Serrinha	20 (34.5)	13 (25.0)
Vitória da Conquista	41 (77.4)	15 (28.9)
Ceará		
Caucaia	83 (60.1)	23 (15.9)
Crato	121 (84.0)	45 (31.0)
Itapipoca	112 (75.7)	34 (22.7)
Juazeiro do Norte	127 (82.5)	49 (31.2)
Morada Nova	100 (89.3)	30 (27.3)
Sobral	119 (83.2)	56 (38.4)

To be continue

Continuation

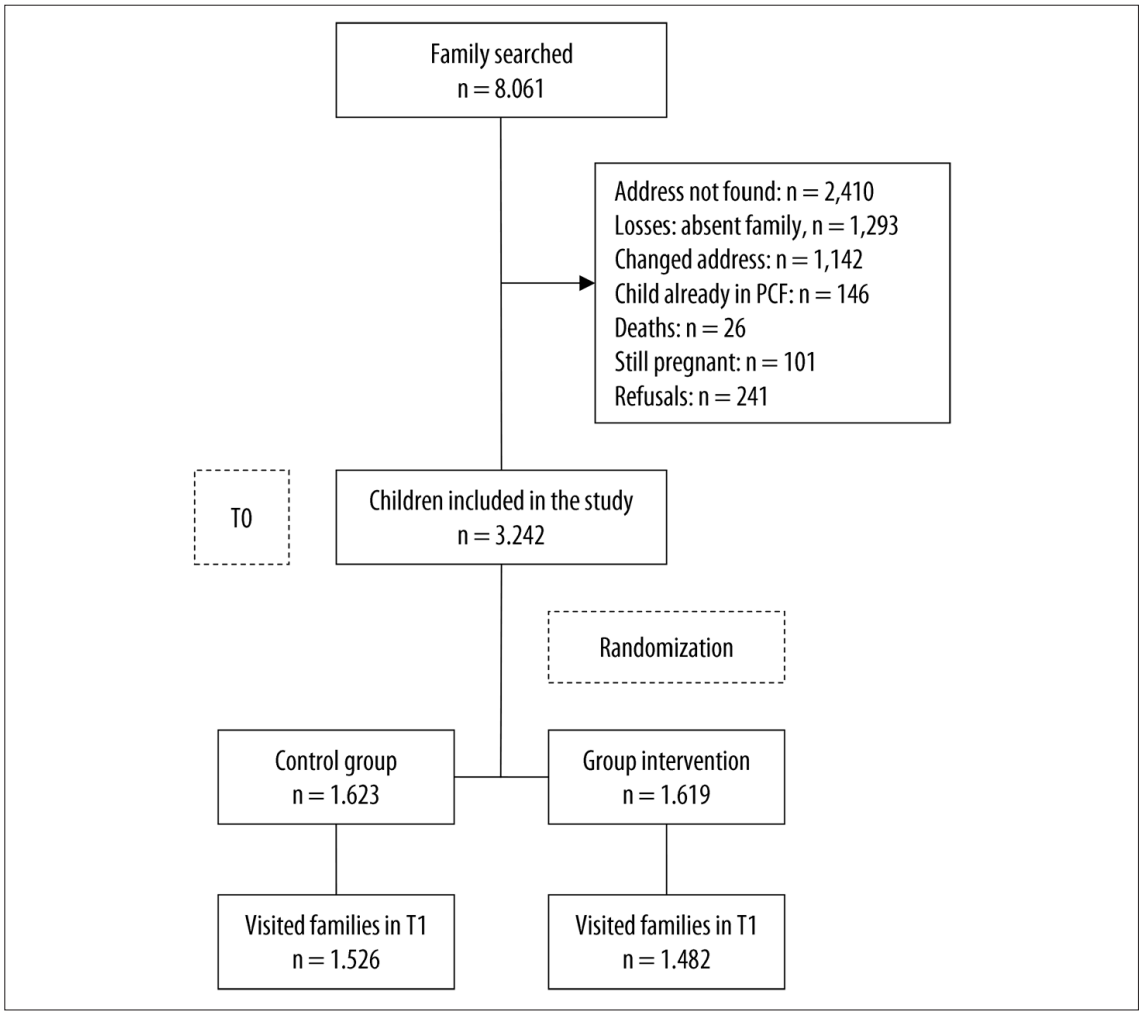
Material Suplementar 2 – Proporção de crianças com vacinas completas para idade até 15 dias após a idade exata, por município, na linha de base (T0) e no primeiro acompanhamento (T1) do estudo de Avaliação do Impacto do Programa Criança Feliz, Brasil (T0, agosto/2018-abril/2019; T1, setembro/2019-janeiro/2020)

Federative Unit/Municipality	T0	T1
	Adequate vaccination according to vaccination schedule with delayed vaccination of up to 15 days	Adequate vaccination according to vaccination schedule with delayed vaccination of up to 15 days
	(n=3,205)	(n=3,008)
	n (%)	n (%)
Goiás		
Águas Lindas de Goiás	56 (45.9)	36 (34.6)
Luziânia	69 (53.1)	29 (26.9)
Novo Gama	51 (75.0)	14 (23.0)
Pará		
Altamira	82 (55.8)	47 (36.4)
Bragança	38 (41.3)	10 (11.9)
Breu Branco	22 (21.2)	12 (14.3)
São Miguel do Guamá	43 (58.9)	32 (45.7)
Tailândia	15 (10.6)	37 (29.4)
Pernambuco		
Abreu e Lima	38 (34.2)	14 (13.9)
Camaragibe	69 (67.7)	31 (32.0)
Caruaru	94 (79.0)	44 (37.9)
São Lourenço da Mata	53 (52.0)	9 (9.0)
Serra Talhada	97 (79.5)	38 (31.9)
São Paulo		
Francisco Morato	69 (57.5)	23 (20.2)
Limeira	76 (69.1)	17 (16.8)
Piracicaba	34 (82.9)	11 (28.2)
Sumaré	29 (67.4)	7 (21.2)
Taboão da Serra	60 (68.2)	18 (22.2)
Total	**1,954 (61.0)**	**746 (24.8)**

Supplementary Material 3 - Percentage of adequate vaccine doses in baseline study (T0) and first year of follow-up (T1) according to the vaccination schedule and recommended age, considering delayed vaccination of up to 15 days, Brazil (T0, August/2018-April/2019; T1, September/2019-January/2020)

Vaccines	T0 (n=3,242)	T1 (n=3,008)
	n (%)	n (%)
BCG[a] (single dose)	189 (94.0)	189 (94.0)
Hepatitis B (single dose)	191 (95.0)	191 (95.0)
Pentavalent (1st dose)	99 (80.5)	99 (80.5)
IPV[b] (1st dose)	113 (91.9)	113 (91.9)
10-valent Pneumococcal (1st dose)	108 (87.8)	108 (87.8)
Human rotavirus (1st dose)	108 (87.8)	108 (87.8)
Meningococcal C (1st dose)	132 (68.0)	132 (68.0)
Pentavalent (2nd dose)	173 (63.6)	173 (63.6)
IPV[b] (2nd dose)	201 (73.9)	201 (73.9)
10-valent Pneumococcal (2nd dose)	194 (71.3)	194 (71.3)
Human rotavirus (2nd dose)	205 (75.4)	205 (75.4)
Meningococcal C (2nd dose)	209 (58.2)	209 (58.2)
Pentavalent (3rd dose)	173 (44.3)	173 (44.3)
IPVb (3rd dose)	202 (51.7)	202 (51.7)
Pneumococcal 10-valente (booster shot)	3 (42.9)	71 (59.7)
Meningococcal C (booster shot)	1 (14.3)	65 (54.6)
Triple viral (1st dose)	3 (42.9)	71 (58.2)
DTP[c] (1st booster shot)	–	12 (6.1)
OPV[d] (1st booster shot)	–	71 (36.0)
Hepatitis A (single dose)	–	71 (36.0)
Tetra viral (single dose)	–	74 (38.1)

a) BCG: Calmette-Guérin bacillus; b) IPV: poliomyelitis type 1, type 2, type 3; c) DTP: diphtheria, tetanus and *pertussis*.



Supplementary Material 4 - Number of families sought and children included in the study