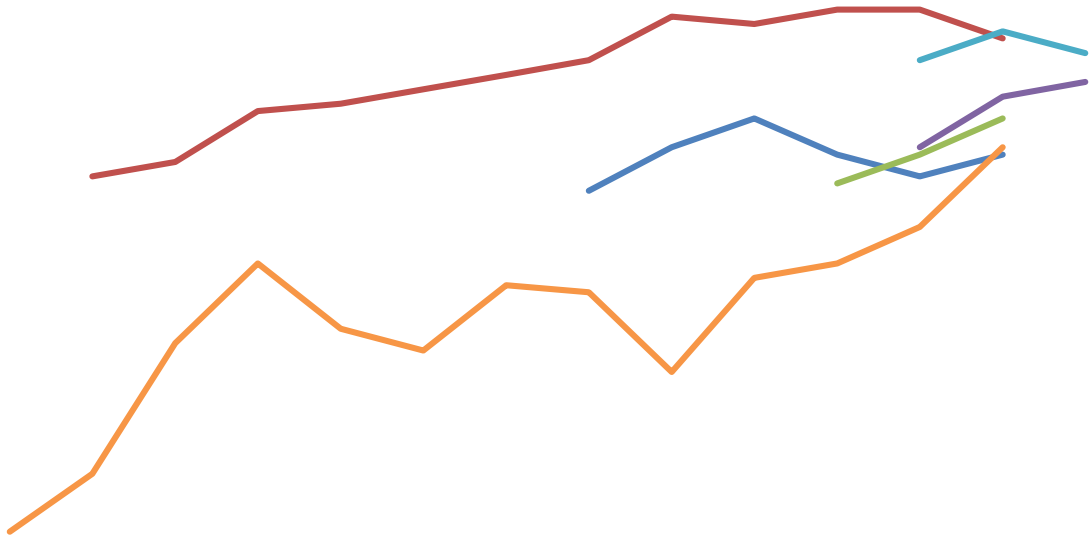
Analysis of Coverage of Fully Immunized Child (FIC), Associated Factors, Outcomes, and Impact Using Routinely Collected Population Cohort Data 2001-2014



April 2015

Analysis of Coverage of Fully Immunized Child (FIC), Associated Factors, Outcomes, and Impact Using Routinely Collected Population Cohort Data 2001-2014

Short title: Analysis of FIC using Routinely Collected Population Cohort Data

Report and analyses by:

Martin Mutua
African Population and Health Research Center
Nairobi, Kenya

Paul Welaga
Navrongo Health Research Centre
Ghana

Charles Zandoh
Kintampo Health Research Centre
Ghana

Moubassira Kagoné,
Nouna Health Research Centre
Burkina Faso

Manzoor Ahmed Hanifi
Chakaria HDSS, icddr,b
Bangladesh

Henrik Ravn, Ane Fisker, Andreas Andersen, Christine Benn, Sanne Thysen, Cesário Martins, Peter Aaby
Bandim Health Project
Guinea-Bissau

CONTENTS

SUMMARY 1

INTRODUCTION AND BACKGROUND 2

OBJECTIVES 3

METHODOLOGY 3

- Definition of FIC by 12 months of age 3
- Study areas and populations 4
- Vaccination data collected 5
- Calculation of coverage of FIC 5
- An important note on “Year of visit” 6
- Data Cleaning 7
- Methods for the Statistical Analyses 7

RESULTS 10

- Objective 1: Coverage of FIC by 12 months of age 10
- Objective 2: Factors associated with FIC by 12 months of age 28
- Objective 3: Impact of FIC on subsequent child survival until 3 years of age 30

DISCUSSION 31

- Main observations 31
- Data coverage and quality 31
- Observations and implications 32

PRIORITY FUTURE TOPICS IDENTIFIED 37

PROBLEMS ENCOUNTERED AND SOLUTIONS DEVISED OR PROPOSED 38

COMMUNICATION STRATEGY AND DISSEMINATION OF RESULTS 39

ACKNOWLEDGEMENTS 39

REFERENCES 40

SUMMARY

Vaccination data collected between 2001-14 from 109,473 12-23 months old children as part of the routine data collection at five African and one Asian INDEPTH health and demographic surveillance system (HDSS) sites was used to analyse the trend over time and determinants of being "fully immunized children" (FIC) and the consequence for subsequent child mortality of being FIC compared to not being FIC. There was an upward trend over time in the proportion being FIC at all centres except one, the coverage in 2013 ranging between 71% and 88%. As expected, cultural and socio-economic factors indicating better conditions were positively associated with FIC. However, encouragingly with increasing coverage the differences in FIC associated with education and wealth tended to disappear. None of the centres found differences in the proportion of being FIC among females and males. While the age of DTP-containing vaccines and OPV went down over time at all centres, the patterns were more variable for BCG and measles vaccine. One centre in Northern Ghana had a major decline in the median age of BCG vaccination from 28 to 3 days but most centres showed little difference. For measles vaccination, several centres showed slight increases in the age of vaccination. This is unfortunate since there is a limited time-window from 274-365 days of age to get measles vaccine and become a FIC. The predominant cause of not being FIC was lack of measles vaccination, explaining from 75% to 100% of not being FIC at the six centres. Controlling for back-ground factors, being FIC was associated with 22% lower mortality (95% confidence interval: 12-31%) than not being FIC. Since the main reason for not being FIC was lack of measles vaccination these results suggest that lack of measles vaccination is associated with 28% (14-45%) higher mortality. None of the centres with mortality data reported measles epidemics, suggesting that the effect of measles vaccination may be non-specific. In conclusion, to improve FIC coverage and child survival a stronger emphasis should be given to ensure that all children are measles vaccinated on time.

Key Messages

- **FIC coverage has increased over time and ranged between 71% and 88% in year 2013**
- **No difference in FIC coverage between boys and girls**
- **Place of residence and delivery, and maternal education are important factors for FIC**
- **Increasing FIC coverage diminishes importance of education and wealth for being FIC**
- **BCG age decreased very significantly in Navrongo but is still a challenge in other sites**
- **Lacking measles vaccination is the main cause for not being FIC**
- **Being FIC is associated with 22% lower mortality**

INTRODUCTION AND BACKGROUND

For the first 40 years of existence of the global immunization program the coverage for DTP3 (the third dose of diphtheria-tetanus-pertussis vaccine) has been the main program indicator. GAVI now wants to have a more embracing target for the post-2015 era and has therefore started to emphasize the "fully immunized child" (FIC) as a key concept and indicator (1).

Though there are many studies of determinants of coverage for specific vaccines, particularly for DTP3, there is little knowledge about the determinants and implications of being FIC. During the scientific conference of the INDEPTH Network of Health and Demographic Surveillance Systems (HDSS) in 2013, GAVI therefore contacted the INDEPTH working group for vaccination and child survival to explore possibilities of collaboration. The present report is the result of this collaboration.

The report has a careful analysis of the usual suspects for being determinants of vaccination status including sex, antenatal care, place of delivery, ethic group, religion, season, marital status, mother's age, maternal education, and wealth. Usually vaccination status is just assessed at 12 months of age. However, we have analyzed the age of vaccination in detail since the actual vaccination age has major implications for how early the vaccine has an effect on the child's health but also on whether there is time to become a fully immunized child. This perspective is particularly important for measles vaccination where there is only a 3-month-window to get the vaccination. Finally, we analyzed the association between vaccination status and subsequent mortality up to three years of age.

OBJECTIVES

The main objective was to measure coverage of FIC using existing prospective data routinely collected by INDEPTH Health and Demographic Surveillance System (HDSS) centres. Three specific objectives were defined:

1. **Estimate the coverage of FIC by 12 months of age**
2. **Analyse the factors associated with FIC by 12 months of age**
3. **Analyse the impact of FIC on subsequent child survival until 3 years of age**

For the first objective, the coverage by sex, place of residence, maternal education, and wealth quintiles was planned. Furthermore, associations between children vaccinated in sequence as well as out of sequence and background factors were studied.

METHODOLOGY

Definition of FIC by 12 months of age

In the present report, the definition of FIC is a child that by 12 months of age has received all recommended doses of the following vaccines when part of the national recommendations:

- BCG 1 dose at birth
- Oral Polio Vaccine (OPV) 3 doses (typically at 6, 10, 14 weeks of age)
- DTP or penta vaccine (DTP/penta) 3 doses (typically at 6, 10, 14 weeks of age)
- Measles-containing vaccine (MCV) 1 dose (at 9 months of age)
- Pneumococcal conjugate vaccine (PCV) 3 doses (typically at 6, 10, 14 weeks of age)

The recommended ages (shown in parentheses) for the vaccines differ slightly for the study areas involved as described in more detail below. OPV at birth is not included here as part of FIC; Rotavirus vaccine, Yellow Fever vaccine, and Rubella vaccine were not included fully in the period covered by this report.

Study areas and populations

Six INDEPTH HDSS centres have contributed data to the present analyses:

- African Population and Health Research Center, Nairobi, Kenya
- Navrongo Health Research Centre, Ghana
- Kintampo Health Research Centre, Ghana
- Nouna Health Research Centre, Burkina Faso
- Chakaria HDSS, Bangladesh
- Bandim Health Project, Guinea-Bissau

Table 1 summarises the 6 HDSS centres and the vaccines included in the analyses. One urban and 5 rural HDSS sites contributed over the period 2001 to 2014; five sites from Africa and one from Asia. Appendices 1-6 present each of the centres with some background information relevant for the present report. Please, not that during the data periods studied here, only two changes happened in the vaccination schedules: Nairobi introduced PCV in early 2011 and Bandim moved from DTP to Penta in 2009. The PCV introduction in Nairobi has not been take into account for the coverages calculated in the present report as the first full birth cohort is 2012.

Table 1 The HDSS centers, period covered, current size and type, and vaccines included in the FIC calculations

HDSS	**Nairobi**	**Navrongo**	**Kintampo**	**Nouna**	**Chakaria**	**Bandim**
Country	Kenya	Ghana	Ghana	Burkina Faso	Bangladesh	Guinea-Bissau
Appendix	1	2	3	4	5	6
Year of visits	2008-13	2002-13	2011-13	2012-14	2012-14	2001-13
Population size of HDSS area	77,000	160,000	143,000	95,000	87,000	27,000 *
Type of area	Urban	Rural	Rural	Rural	Rural	Rural
Interval between HDSS visits (months)	4	12 or 4	4	4	3	6
BCG at birth	X	X	X	X	X	X
DTP (6, 10, 14 w)	-	-	-	-	-	Until 2009
Penta 1-3 (6, 10, 14 w)	X	X	X	(8, 12, 16 w)	X	From 2009
OPV 1-3 (6, 10, 14 w)	X	X	X	(8, 12, 16 w)	X	X
MCV at 9 mo	X	X	X	X	X	X
PCV 1-3 (6, 10, 14 w)	From 2011	-	-	-	-	-

* Number of women currently followed

Vaccination data collected

With regular intervals (3, 4, 6, or 12 months intervals), each HDSS centre visits every household in the HDSS area and standard demographic events (pregnancies, births, deaths, migrations) are recorded for all members of the household. Vaccination dates for children less than 3 years of age are assessed and collected by inspection of vaccination cards (in child health booklets or other documentation) kept by the mothers or guardians. Thus, vaccination data are repeatedly collected during the first 3 years of life. Explicitly, each HDSS collects information on the documentation of vaccinations by asking these questions:

- Does child have a vaccination card? Yes or No
- If Yes, is card seen? Yes or No

When the card is seen, the vaccination dates are recorded to the HDSS files. If the mother is absent the vaccination cards is rarely seen. In most cases the card is not seen if the child is travelling or has died.

Calculation of coverage of FIC

The calculation of FIC was based on vaccinations received before 12 months of age among children visited alive and whose *vaccination card was seen* at a visit between 12 and 23 months of age. The included children fulfilled the following criteria:

a. Age at visit between 12 and 23 months ($365 < \text{Age in days} \leq 730$)
b. Vaccination card was seen
c. Children were alive at the visit (children eligible for analysis of subsequent mortality – aim 3)
d. The first visit between 12-23 months of age was used: if a child had more than one visit fulfilling a. to c. the first visit was used (e.g. if the child was visited at 13 and 19 months of age, the visit at 13 months of age was used).

FIC coverage by 12 month of age was calculated as:

$$\text{FIC} = \frac{\text{number of children from denominator fully immunized} \leq 365 \text{ days of age}}{\text{number of children satisfying points a. to d.}}$$

Only vaccines noted in the vaccination card for the routine vaccines were used. Vaccines given during campaigns (e.g. OPV and MCV) were not included, but routine vaccines provided as part of swap-up

strategies during for example vitamin A campaigns were. Maternal recall of vaccinations was not used since such information would not allow us to assess whether the vaccination contributed to FIC (being delivered before 12 months of age).

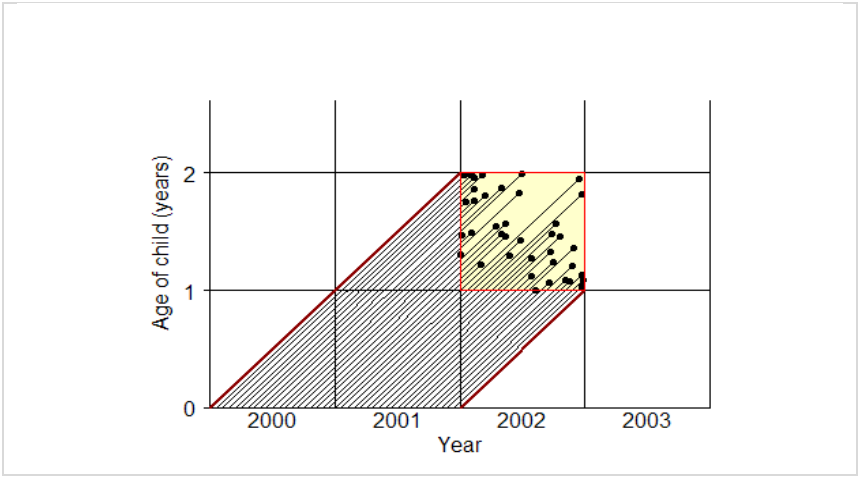
The following classification of children was used in the present report:

FIC	Child who is a FIC
NOTFIC	Child who is not a FIC
FIC-IS	FIC and all vaccines are in the WHO recommended sequence, i.e. BCG < DTP1=OPV1 < DTP2=OPV2 < DTP3=OPV3 < MCV < 12 months of age
FIC-OS	The child is FIC but some of the vaccines are out of the recommended sequence. Categories used: BCG ≥ DTP DTPn ≠ OPVn (n is dose 1, 2, or 3) DTP3 ≥ MCV

An important note on "Year of visit"

FIC coverage was calculated by *year of visit*, i.e. visits within a particular calendar year. This implies children alive and being between 1-2 years of age at the visits in a particular calendar year were eligible. The vaccinations these children had received before 1 year of age (to be able to be FIC) were administered at a maximum 2 years earlier. Thus, a particular FIC coverage in a year reflects vaccinations given 1-2 years earlier. Figure 1 illustrates this by the so-called Lexis diagram. Each sloping line represents a life-line of a child and a bullet (•) illustrates a visit in year 2002. A child between 12 and 23 months of age at a visit in 2002 was born between 2000 and 2001 (but not in 2002). Vaccines given before 1 year of age were thus given in the three years 2000, 2001, or 2002. This must be remembered when interpreting the FIC coverages for a particular year of visit.

Figure 1 Lexis diagram illustrating lifelines of children included in FIC calculations for year of visit 2002



Data Cleaning

Data come from routine collection systems and have not been used for these kinds of analyses before. Therefore, a large amount of data management and cleaning was necessary. A systematic data check was developed to uniform the data check and cleaning. Appendix 7 describes in more detail the data check tool.

Methods for the Statistical Analyses

The Kaplan-Meier method was used to calculate vaccination coverage curves.

The analyses of the potential association between factors and FIC (objective 2) were done using binary regression (FIC: yes vs. no) and risk ratios (RRs) were calculated with corresponding 95% confidence intervals. The potential factors were those listed in Table 2 below.

The analyses of association between FIC and subsequent survival (objective 3) were done using Cox regression. Children entered the analysis at the age of visit (day of visit) and were followed until the first event of death, age 3 years, and out-migration. Age was used as the time-scale, thus age is adjusted for in the analyses. Hazard ratios (HRs) were calculated with corresponding 95% confidence intervals. Adjusting background factors were those in Table 2.

Kintampo HDSS is not included in the survival analyses; there were problems with the mortality data that we were not able to solve during the time available for this report. Chakaria had a very low mortality (13 deaths) and a reliable adjusted analysis was not possible and a preliminary analysis of

hospitalisation was conducted. Therefore the mortality data is presented with and without Chakaria included in the meta-analysis.

A combined hazard ratio estimate of the four site-specific HRs was calculated using meta-analysis. An alternative combined survival analysis was done by merging the four site-specific data and using coarsened exact matching (CEM) (2 and reference therein). Briefly, the CEM method matches FIC and NOT FIC children using all the available factors (including HDSS site) and if a given combination of factors does not include FIC and NOTFIC children it is dropped from further analysis.

The rural Bandim HDSS consists of randomly selected clusters (villages) in rural Guinea-Bissau. The other HDSS's are all following whole populations in well-defined geographical areas and were not based on cluster sampling. The regressions analyses for the Bandim data were adjusted for cluster sampling.

Table 2 Factors (variables) available for each HDSS center
"x" indicates available and "-" indicates not available

Factor (variable)	Nairobi	Navrongo	Kintampo	Nouna	Chakaria	Bandim
Sex	x	x	x	x	x	x
Year of visit	x	x	x	x	x	x
Residence (area/district)	x	x	x	x	x	x
Twinning	x	x	-	x	-	-
Ethnicity	x	x	x	x	-	x
Religion	-	x	x	x	-	-
Parity (birth order)	x	x	x		x	-
Place of delivery	x	x	x	x	x	x
Mother's education	x	x	x	x	x	x
Mother's age	x	x	-	x	x	x
Marital status	x	-	-	x	-	-
Antenatal care	x	-	-	-	x	-
Wealth index	x	x	x	-	x	-
Season of birth	-	x	x	x	x	-
Occupation	-	-	-	x	-	-

A wealth index was calculated for Nairobi, Navrongo, Kintampo, and Chakaria using principal component analysis from household assets as an estimate of household socioeconomic status. The household assets for the site-specific indices are listed in the appendices.

Several of the factors in Table 2 had missing values and only complete records were used in the regression analyses. All statistical tests are two-sided using a 5% statistical significance level. No

adjustments for multiple comparisons have been done. Analyses were conducted using Stata Statistical Software: Release 12. College Station, TX: StataCorp LP.

RESULTS

In Appendices 1-6, the detailed results for each of the six HDSS centres are presented and supplemented by a short summary. Readers interested in more details are referred to these appendices. Each of them has lists of tables and figures and the numbering of the tables and figures are kept the same across appendices. For example Table 4 and Figure 3 in any of the appendices is "FIC coverage by year of visit". These will be cited as Table A4 and Figure A3. What follows is a presentation of the main findings. However, there will be details from the site-specific analyses that are not touched upon.

109,473 children having a total of 186,077 visits between 12-23 months of age were the basis population. Of these children 85,295 (inclusion of 78%) presented a valid vaccination card at one or more visits. Reasons for cards not seen were travel or temporary absence from the home. Only a very small fraction of the children indicated not having a card (Table A2).

Objective 1: Coverage of FIC by 12 months of age

For all HDSS centres and years pooled the FIC coverage was 69% (59,217/85,295). More interesting is to look closer at the FIC coverage by HDSS and year of visit as presented in Table 3 and

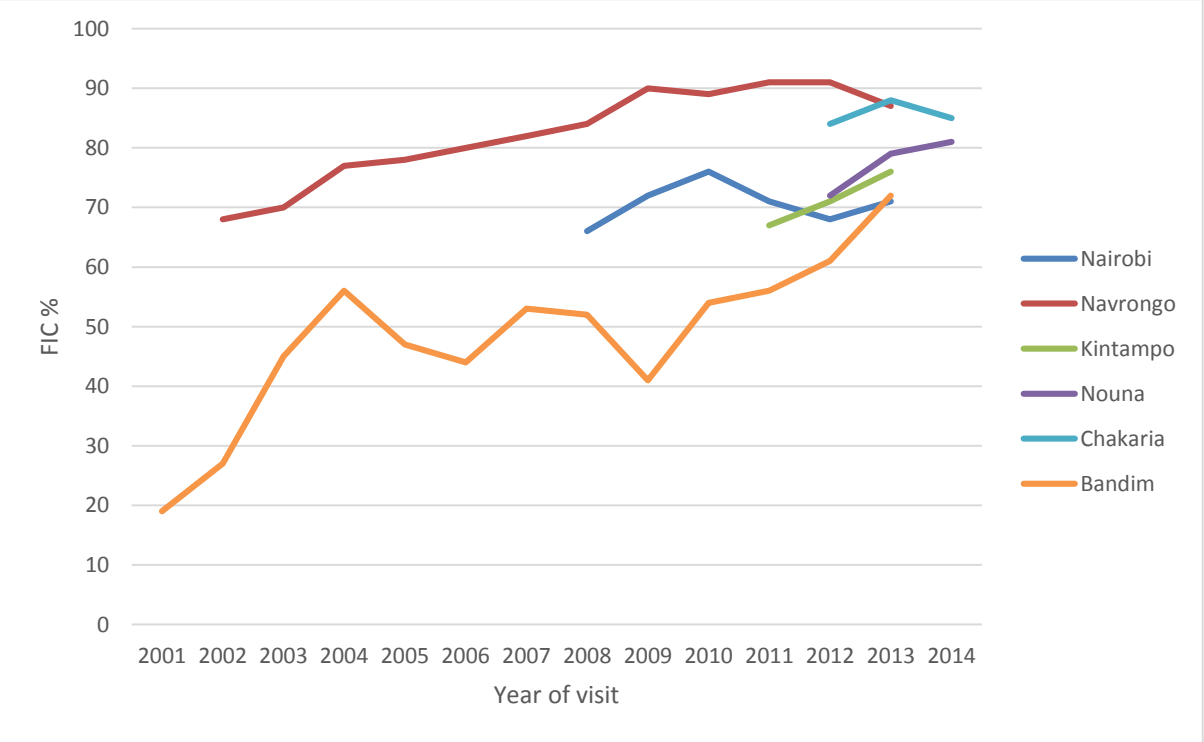
Figure 2. The current level of FIC coverages lies between 70-90%. The urban area of Nairobi has a fairly constant FIC coverage around 70%. For Navrongo, the coverage of FIC increased steadily from 68% in 2002 to around 90% in 2009 and has stayed at this level. Kintampo and Nouna have increased to around 75-80% while Chakaria is constant around 85%. Bandim had a low FIC coverage of only 19% in 2001 (due to a civil war in the period 1998-2000) but had a marked increase during the next 3 years to 56%, stayed relatively constant until 2010 and started to increase above 70% in 2013. Remember, that for a particular year of visit the FIC coverage represents vaccines given during the two previous years (cf. Figure 1).
The site-specific coverage of FIC for the pre-specified factors sex, place of residence, maternal education, and wealth quintiles are found in appendices.

Importantly, there was no difference in FIC coverage between male and female children as seen in Figure 3.

Table 3 Coverage of FIC by 12 months of age (in percent) by HDSS and year of visit

HDSS	Nairobi	Navrongo	Kintampo	Nouna	Chakaria	Bandim
Children eligible	5,326	36,638	14,540	6,579	4,467	41,923
Children included (%)	3,541 (66%)	32,678 (89%)	11,705 (81%)	4,016 (61%)	3,714 (83%)	29,641 (71%)
2001	-	-	-	-	-	19
2002	-	68	-	-	-	27
2003	-	70	-	-	-	45
2004	-	77	-	-	-	56
2005	-	78	-	-	-	47
2006	-	80	-	-	-	44
2007	-	82	-	-	-	53
2008	66	84	-	-	-	52
2009	72	90	-	-	-	41
2010	76	89	-	-	-	54
2011	71	91	67	-	-	56
2012	68	91	71	72	84	61
2013	71	87	76	79	88	72
2014	-	-	-	81	85	-
Total	70	82	71	78	86	51

Figure 2 Coverage curves of FIC by 12 months of age (in percent) by HDSS and year of visit



As seen in Figure 4, of the two Nairobi urban informal settlements, Viwandani had a much higher coverage than Korogocho. Fascinatingly in Navrongo, the initially much lower coverage in rural areas has completely disappeared now. In Kintampo, the urban area exhibits higher FIC coverage than rural areas, while the opposite is the case in Nouna. Rather small but a consistent difference is seen between the two areas in Chakaria. For the Bandim HDSS all the areas are rural but the 5 different (administrative) regions show different levels of FIC. A more complete explanation for the difference in FIC coverage by place of residence is clearly a topic for further investigation. As will be seen in the results from objective 2, place of residence was the only factor being statistically significant for all sites when the other factors were adjusted for.

Higher maternal education seems to be associated with higher FIC coverage for all sites, except Nouna, as seen in Figure 5. For Navrongo and Bandim the differences become less when coverage increases.

Wealth quintiles were calculated for Nairobi, Navrongo, Kintampo, and Chakaria and related to coverage of FIC as seen in Figure 6. In general there is trend of higher FIC coverage with better wealth quintile, although it is no so noticeable for Nairobi. For Navrongo, the difference between the wealth quintiles reduced over the years, where the least poor (upper quintile) nearly have the same level of FIC as the other four quintiles.

It is useful to have a closer look at the timing of the different vaccines for FIC and NOTFIC children, how timing may have changed over the years and to compare across HDSS sites. The coverage curves for FIC children are shown in Figure 7 using the most recent year available for each HDSS. The curves for each vaccine will by definition end at 100%. This is not the case for NOTFIC curves as seen in the analogous Figure 8. In the appendices the curves from the first year of each site is also shown (Figure A5). Nairobi and Navrongo have an impressive timing among FIC. The change of timing of the vaccines over the years is also illustrated using median ages in Figure 9 and Figure 10, and details for other vaccines can be found in appendices (Table A9, Table A10 and Figure A6).

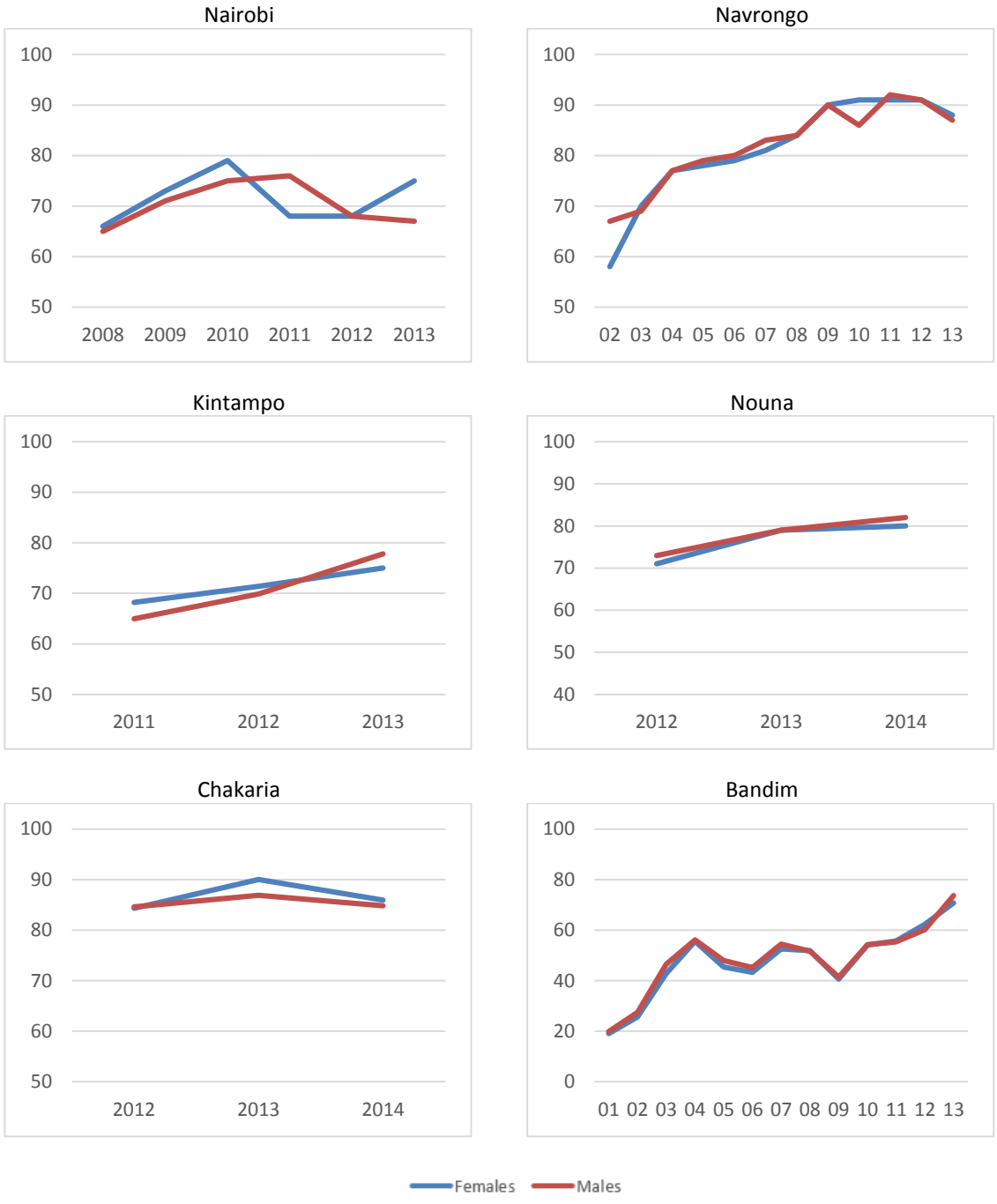
Age of Penta/OPV vaccinations declined with increasing vaccination coverage in the sites with longer follow-up. In Navrongo, the age of BCG vaccination has had an amazing decline from 28 to 3 days over the years covered. A within-country difference of BCG timing is interestingly seen between Navrongo and Kintampo. There seems not to be a particular trend for the age of measles vaccination, except for a worrying increasing trend in Bandim.

Vaccination coverage curves (FIC and NOTFIC children) for all years covered for the sites with longer follow-up are shown in Figure 11, Figure 12, and Figure 13. A few comments on these: In Nairobi 2011 OPV is lower than Penta, which is most likely due to a shortage of OPV in the preceding years. For Bandim 2009 (FIC curves) is seen the transition from DTP to Penta and the curves for these do not separately reach 100% as some will be FIC having DTP while others will be FIC with Penta.

The main reason for a child not to be a FIC is missing measles vaccine, as can be seen from the vaccination curves for NOTFIC children. Also, Figure 14 shows the percentages of children missing a particular vaccine among children being NOTFIC. Lack of measles vaccination ranged from around 75% to 100% between the 6 centres.

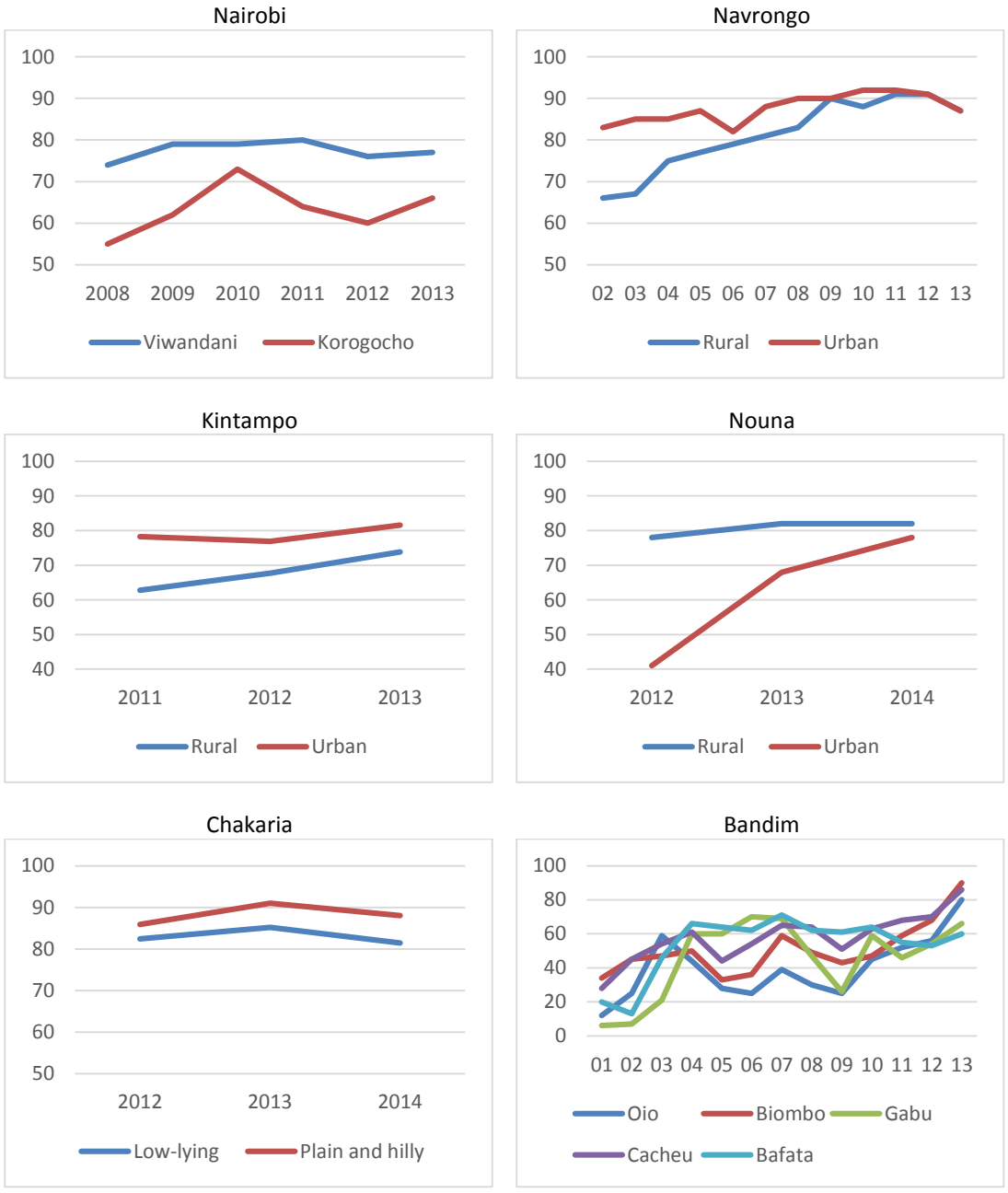
In general, the coverage of children receiving all the vaccines in the recommended sequence, FIC-IS, improved over the years as can be seen in Figure 15. The low figures from Chakaria is because BCG is mostly given with Penta. This is evident when having a closer look at the reasons for out-of-sequence (among children who are FIC), FIC-OS. Figure 16 shows the 3 main reasons for being FIC-OS. Among sites having a high FIC coverage the main reason for FIC-OS is not getting OPV and penta at the same day. For Bandim delayed BCG is a main reason.

Figure 3 FIC coverage (%) by HDSS, year, and sex



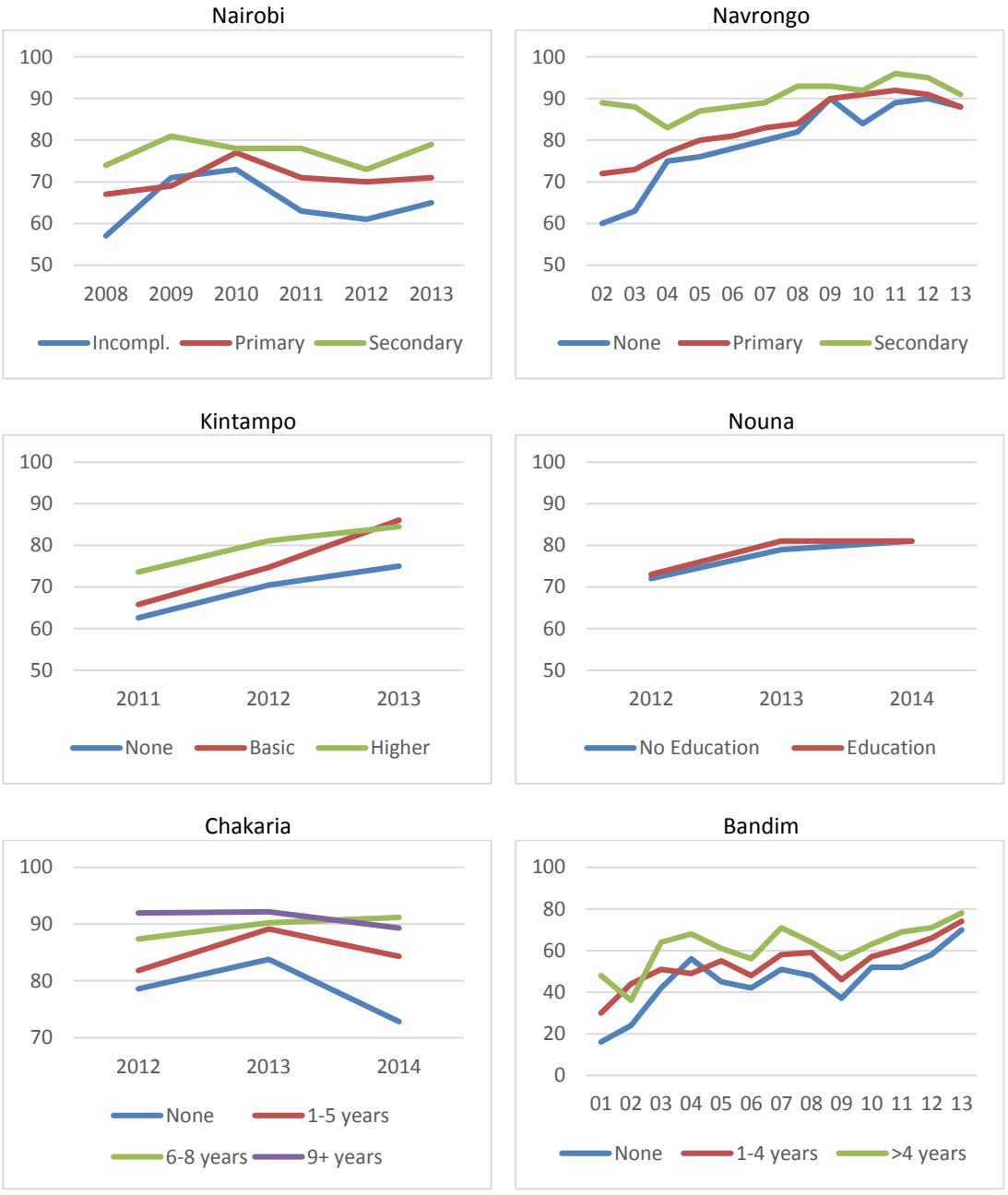
Note: Vertical axes do not have same scale

Figure 4 FIC coverage (%) by HDSS, year, and place of residence



Note: Vertical axes do not have same scale

Figure 5 FIC coverage (%) by HDSS, year, and level of maternal education



Note: Vertical axes do not have same scale

Figure 6 FIC coverage (%) by HDSS, year, and wealth quintiles. Wealth quintiles were not available for Nouna and Bandim HDSS

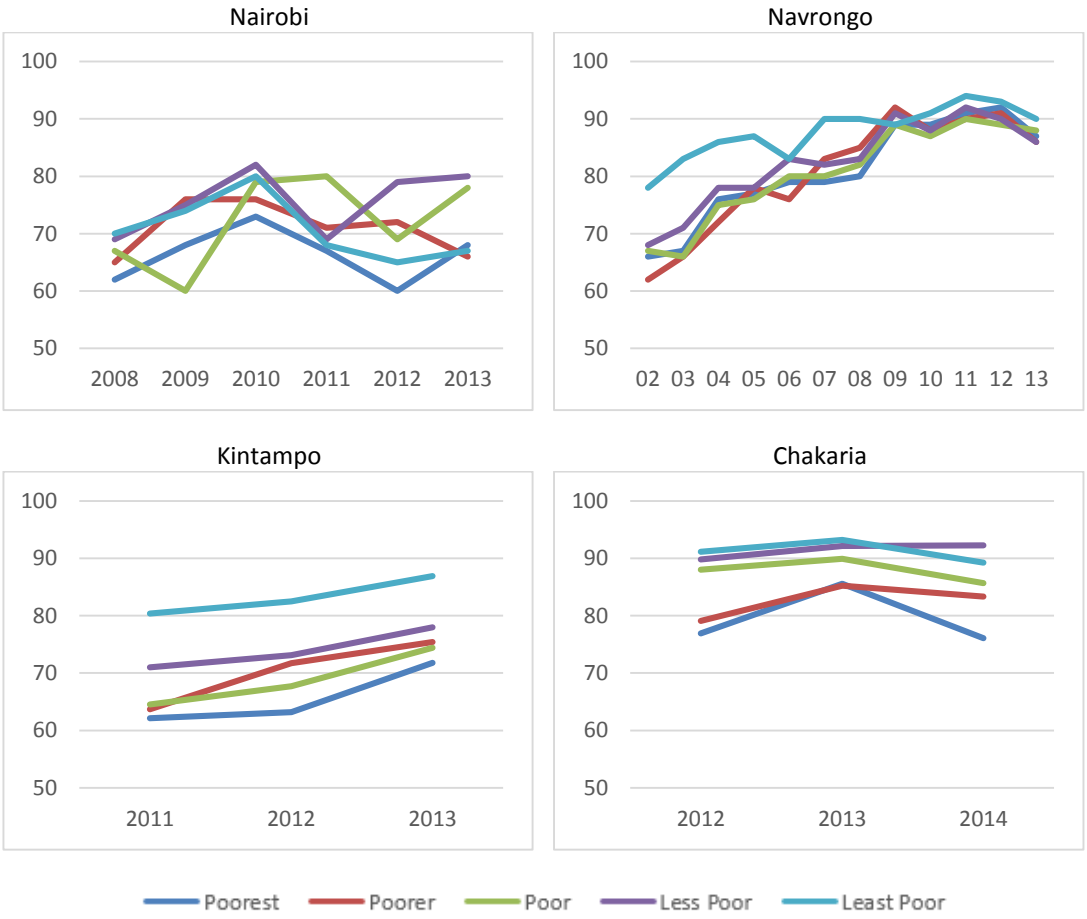


Figure 7 Vaccination coverage curves for children being FIC at 12 months of age

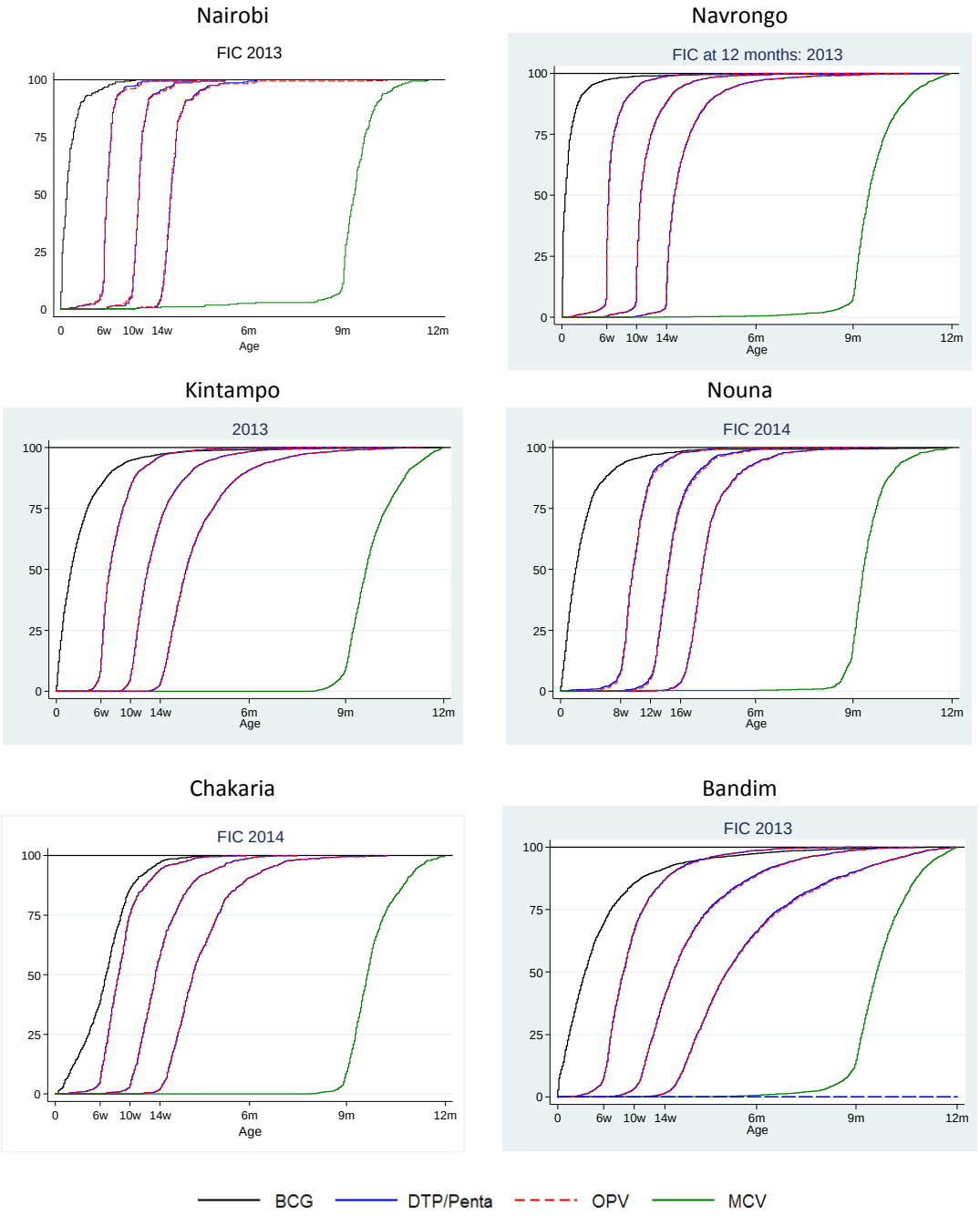


Figure 8 Vaccination coverage curves for children being NOTFIC at 12 months of age

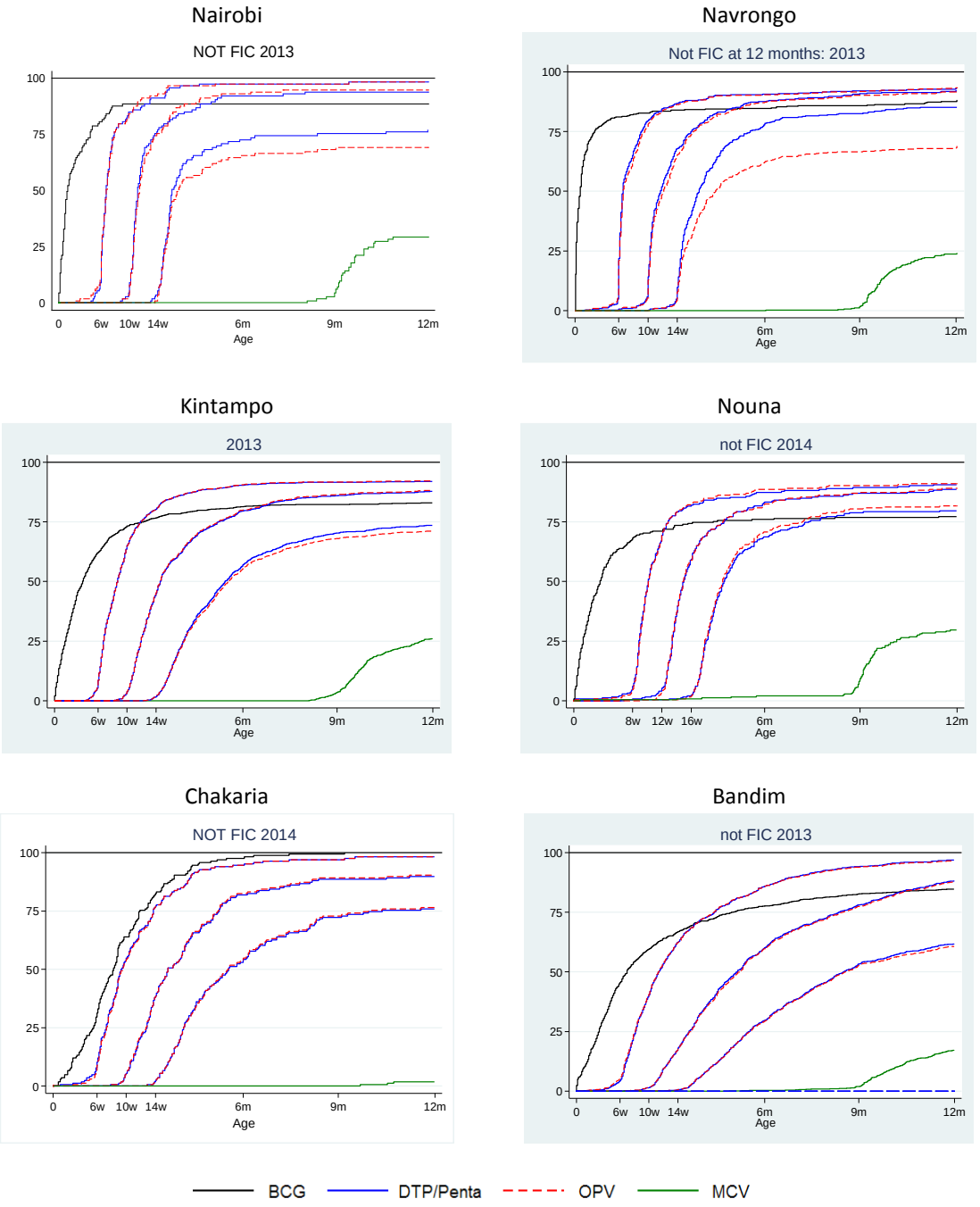
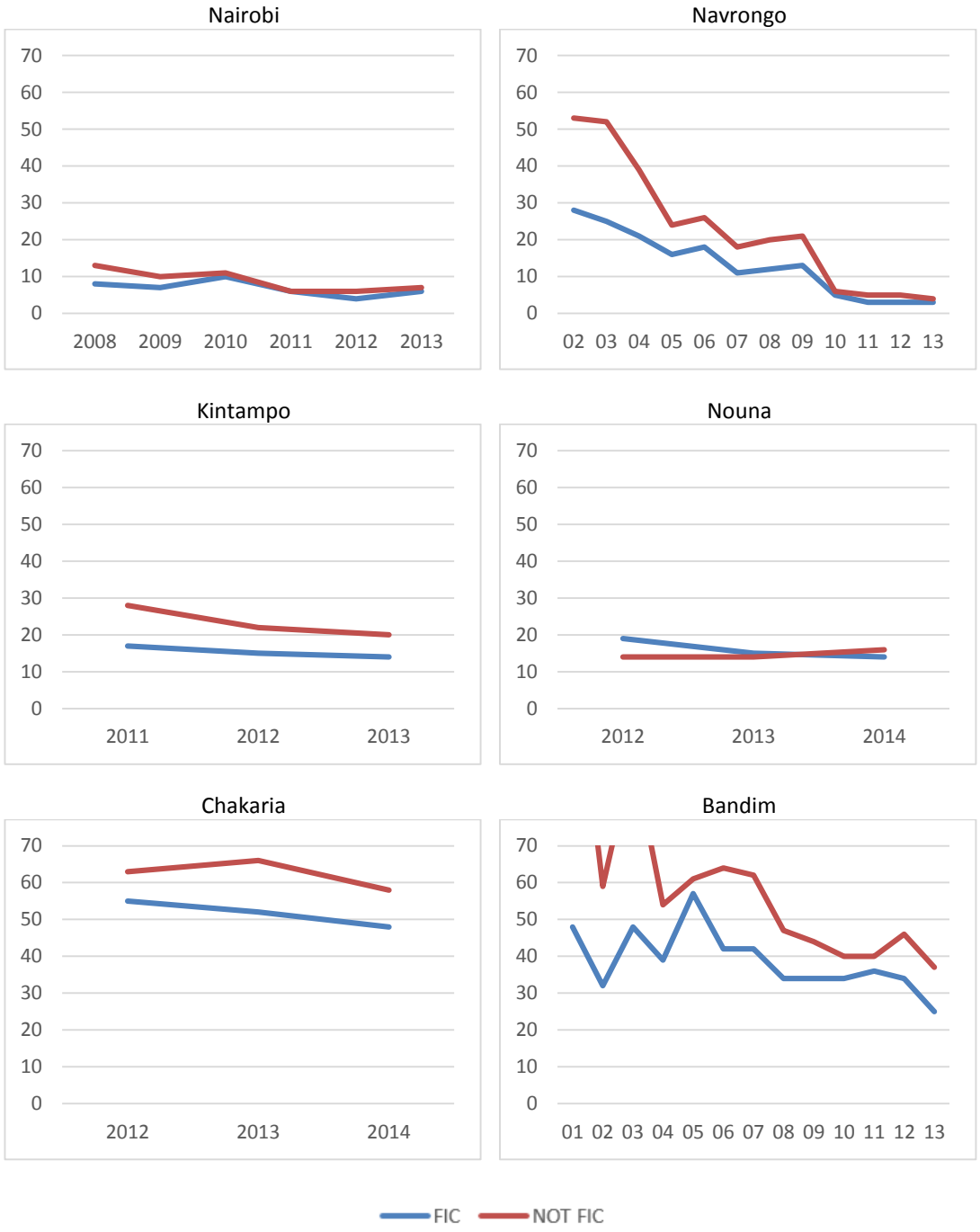


Figure 9 BCG median age in days for FIC and NOTFIC



Note: the curve for Bandim has been cut to obtain same scale on the vertical axes

Figure 10 MCV median age in days for FIC and NOTFIC. Green line indicates the recommended age of 9 months (274 days)

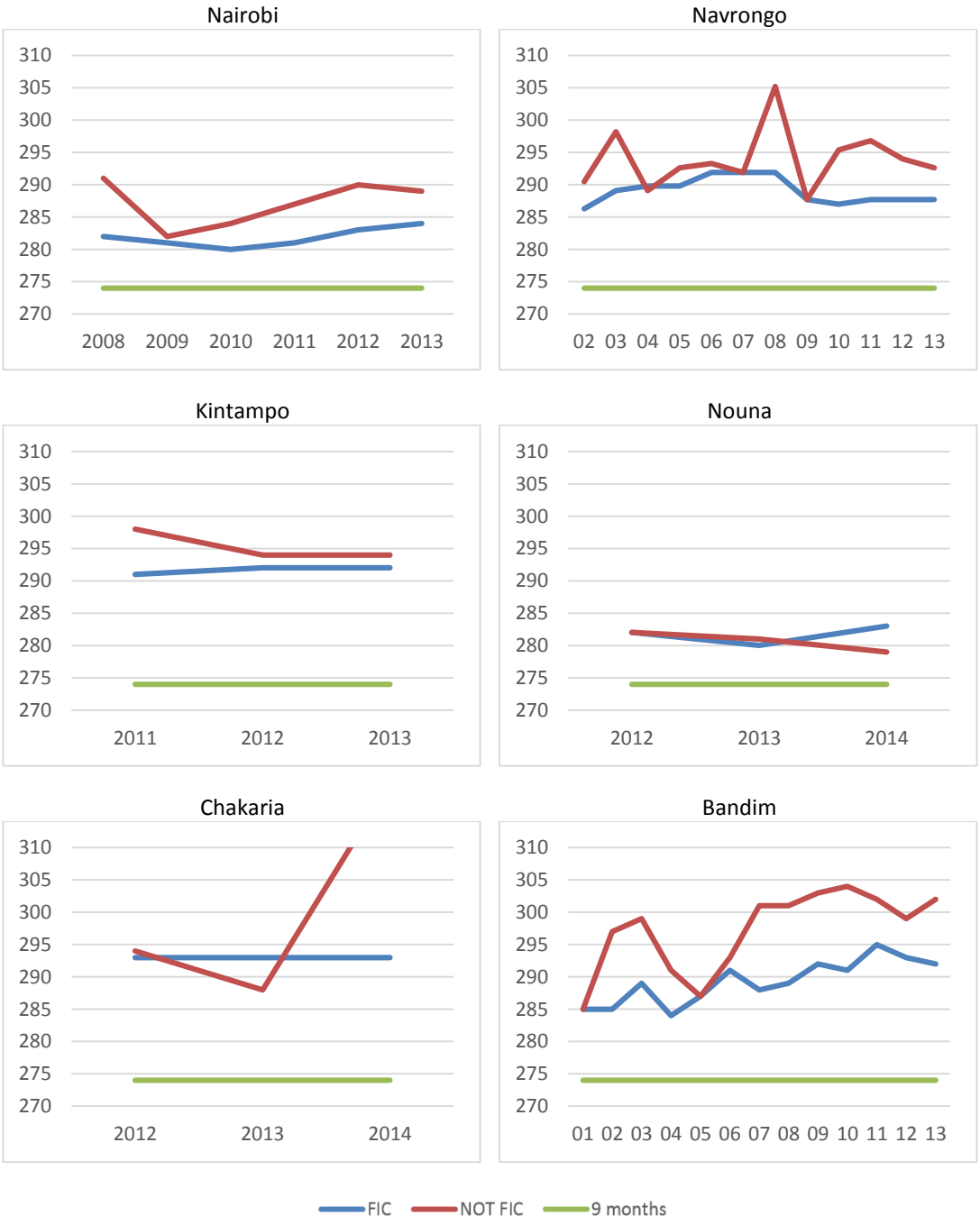


Figure 11 Vaccination coverage curves from Nairobi in the years 2008-13

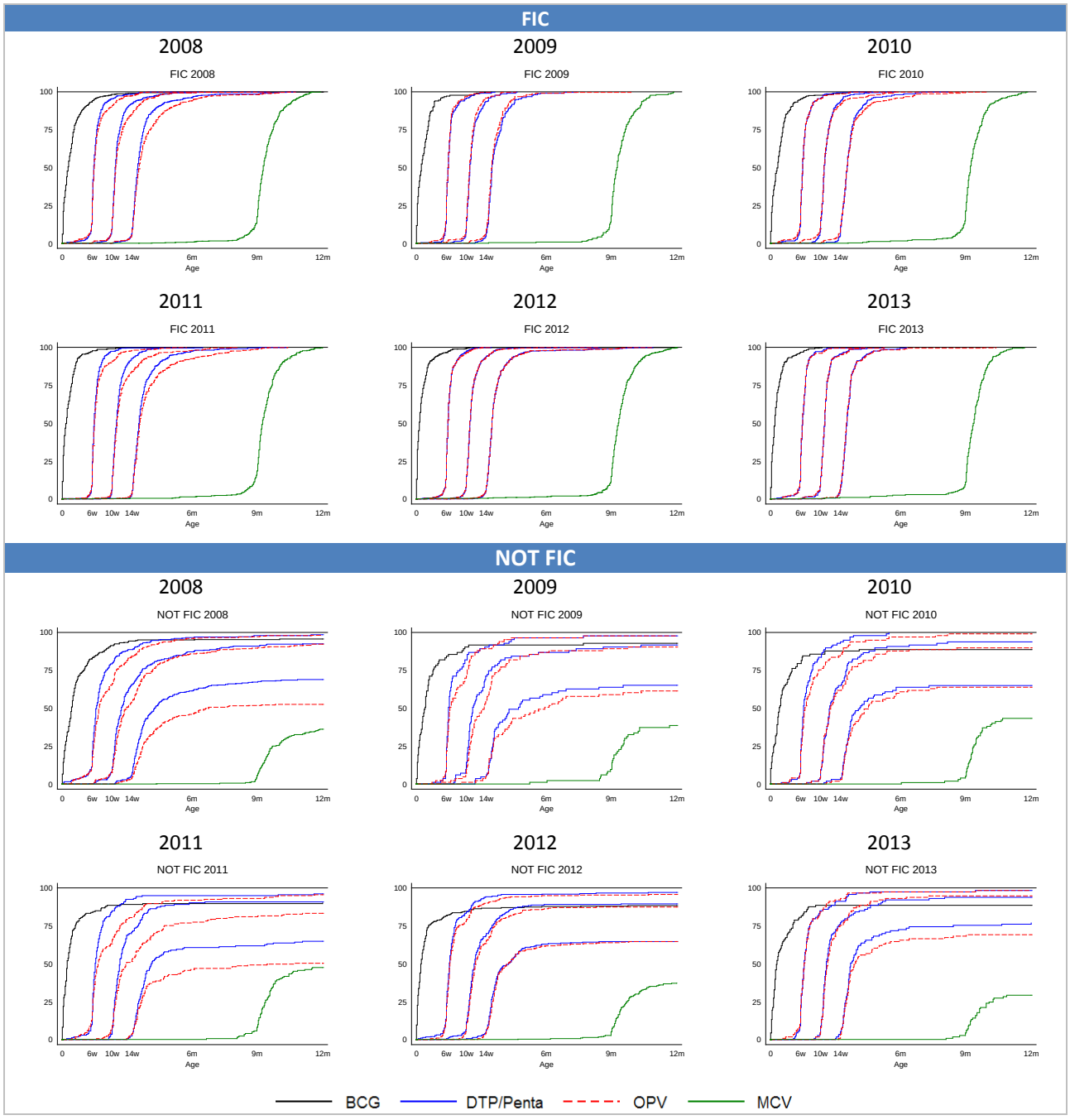


Figure 12 Vaccination coverage curves from Navrongo in the years 2002-13

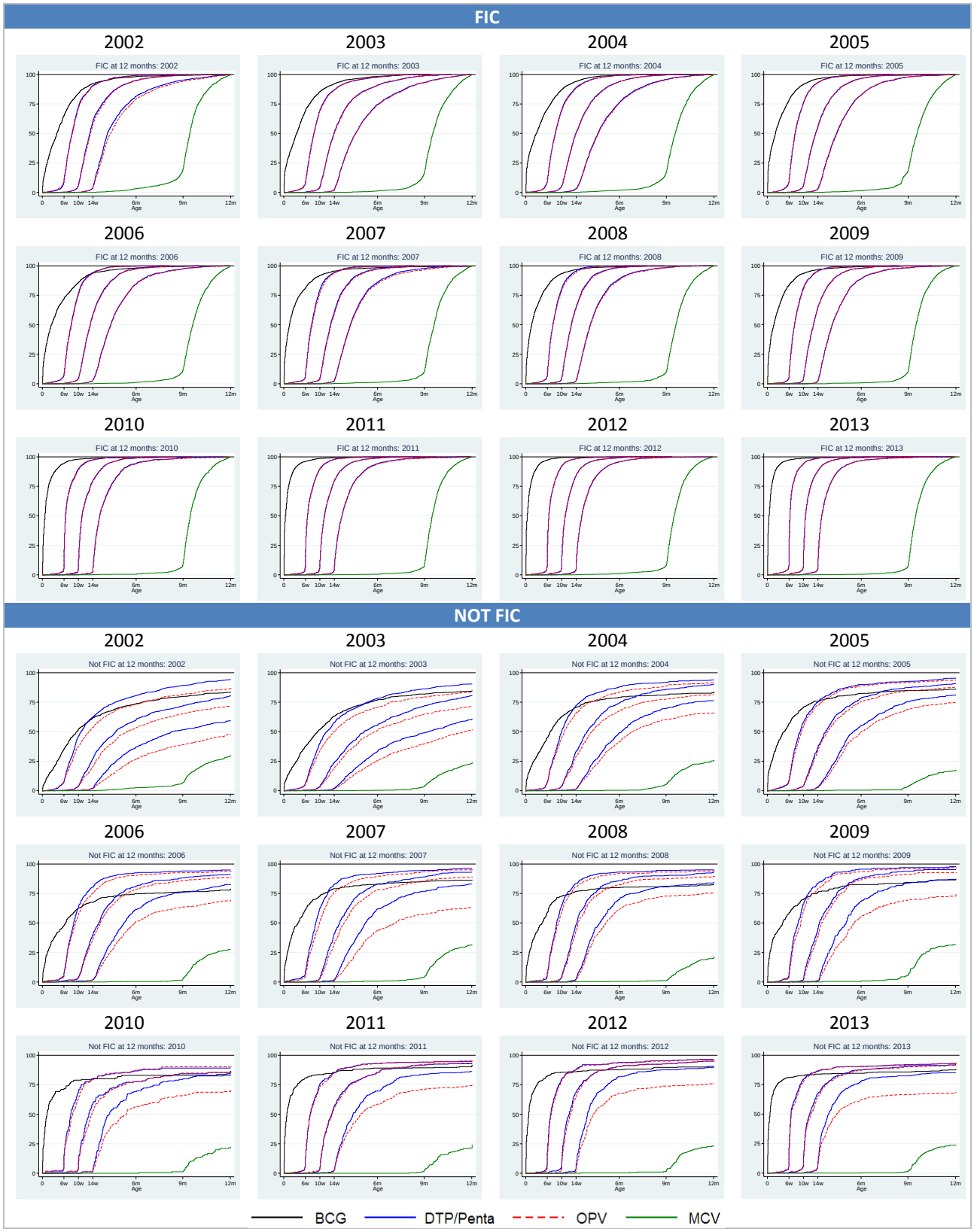


Figure 13 Vaccination coverage curves from Bandim in the years 2001-12 (2013 left out due to space)

Figure 14 Percentages missing a particular vaccine among children being NOT FIC

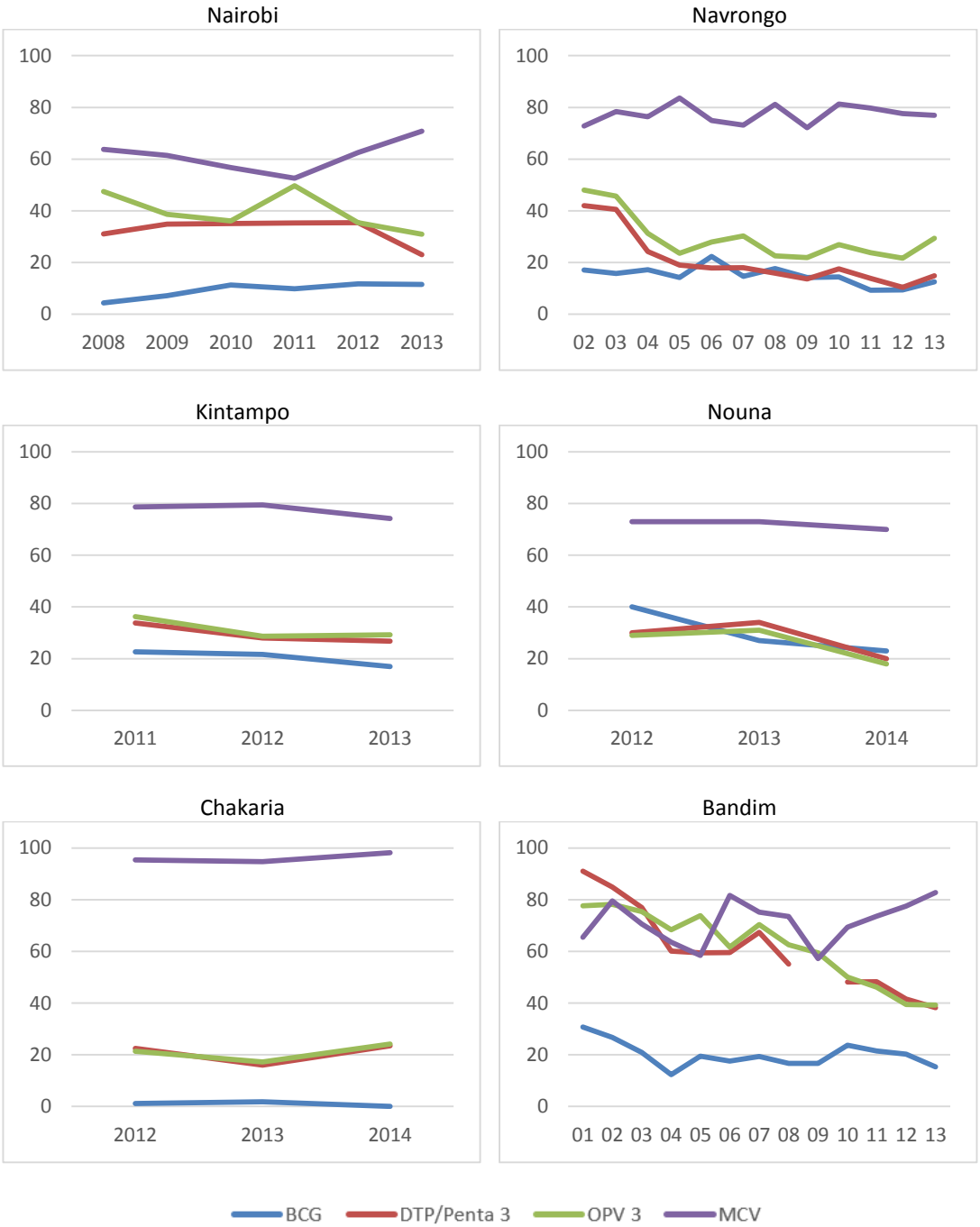


Figure 15 Percent having all the vaccines in sequence (FIC-IS) among children who are FIC

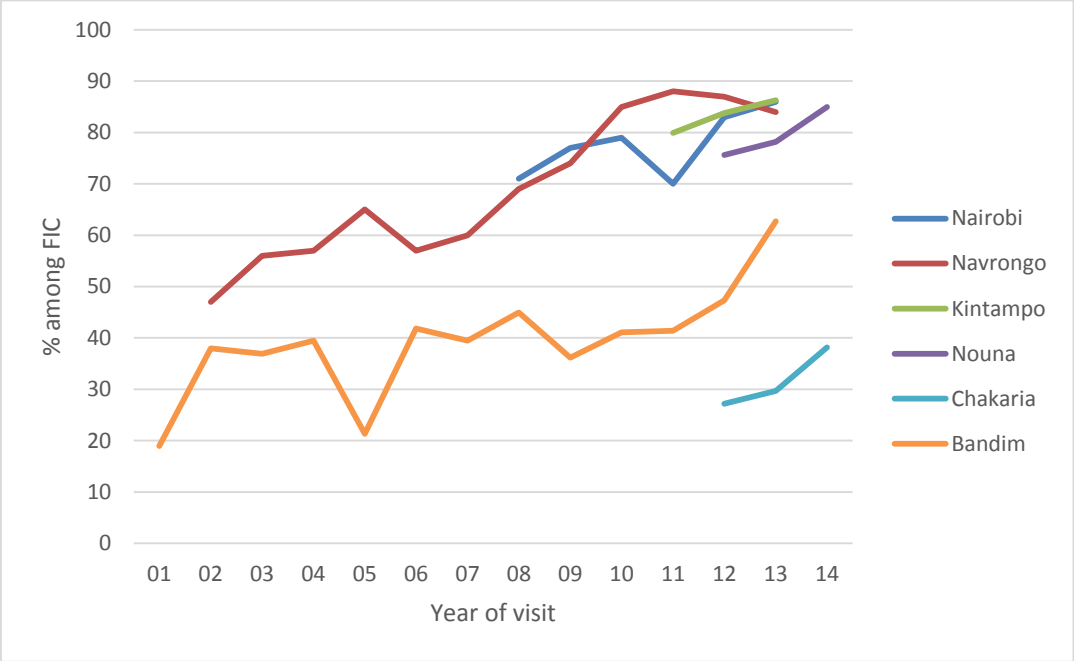
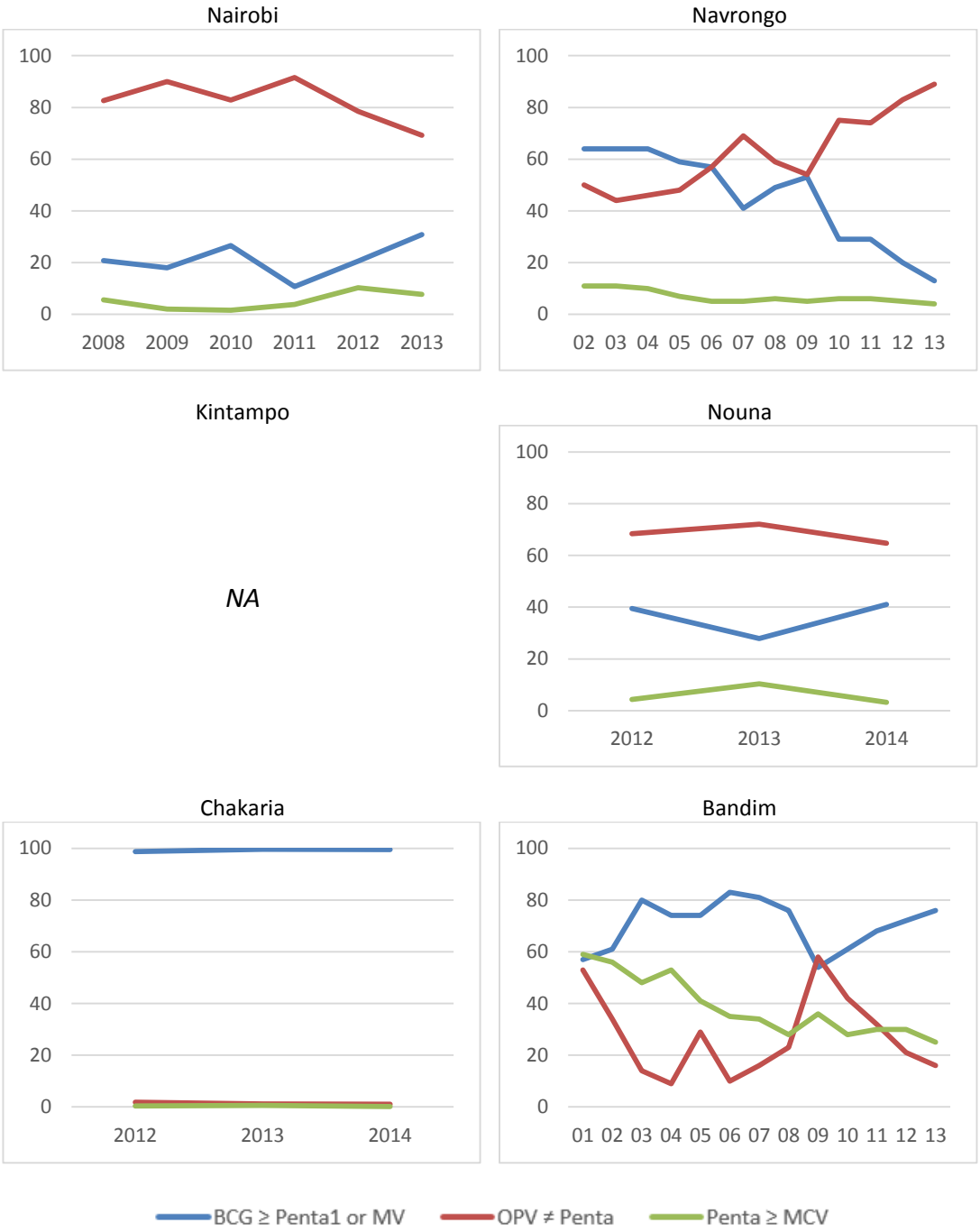


Figure 16 Reason for FIC-OS



Objective 2: Factors associated with FIC by 12 months of age

The tables of detailed results from the site-specific regression analyses are found in the appendices (Table A17). In these analyses the association between a background factor and FIC is adjusted for all the other background factors. Table 4 below summarizes the site-specific analyses. Beside year of visit, residence (area) was the only factor statistically associated with FIC coverage at all HDSS sites. Maternal education was associated with FIC in 5 sites; the highest education level compared with the lowest level had as much as 19% (95%-CI: 13-25%) higher FIC coverage in Bandim and around 5-10% at the other sites. Place of delivery (health facility versus other) was associated (statistically significantly) in 4 sites with around 3-12% higher coverage for the health facility deliveries.

Regression analyses were also conducted on the FIC-in-sequence (FIC-IS) children versus those with FIC but out-of-sequence (i.e. the children NOTFIC were excluded from these analyses). The tables of detailed results from the FIC-IS site-specific regression analyses are found in the appendices (Table A18). Also in these analyses the association between a background factor and FIC is adjusted for all the other background factors. Table 5 below summarizes the site-specific analyses. The common statistically significantly associations were as before place of residence, maternal education, and place of delivery.

Table 4 Summary of the site-specific analyses of the association between background factors and FIC by 12 months of age

Factor (variable)	Nairobi	Navrongo	Kintampo	Nouna	Chakaria	Bandim
Sex	+	+	+	+	+	+
Year of visit	+	+	o	+	+	+
Residence (area/district)	+	+	+	+	+	+
Twinning	+	+	-	o	-	-
Ethnicity	+	+	+	-	-	o
Religion	-	+	+	+	-	-
Parity (birth order)	+	+	+	-	+	-
Place of delivery	+	+	+	+	+	+
Mother's education	+	+	+	+	+	+
Mother's age	+	+	-	+	+	+
Marital status	+	-	-	o	-	-
Antenatal care	+	-	-	-	+	-
Wealth index	+	+	+	-	+	-
Season of birth	-	+	+	o	+	-
Occupation	-	-	-	o	-	-

+	Included in model and adjusted for each other
+	Statistically significant at 5% level
o	Omitted from model
-	Not available

Table 5 Summary of the site-specific analyses of the association between background factors and FIC-in-sequence (FIC-IS) among children FIC by 12 months of age

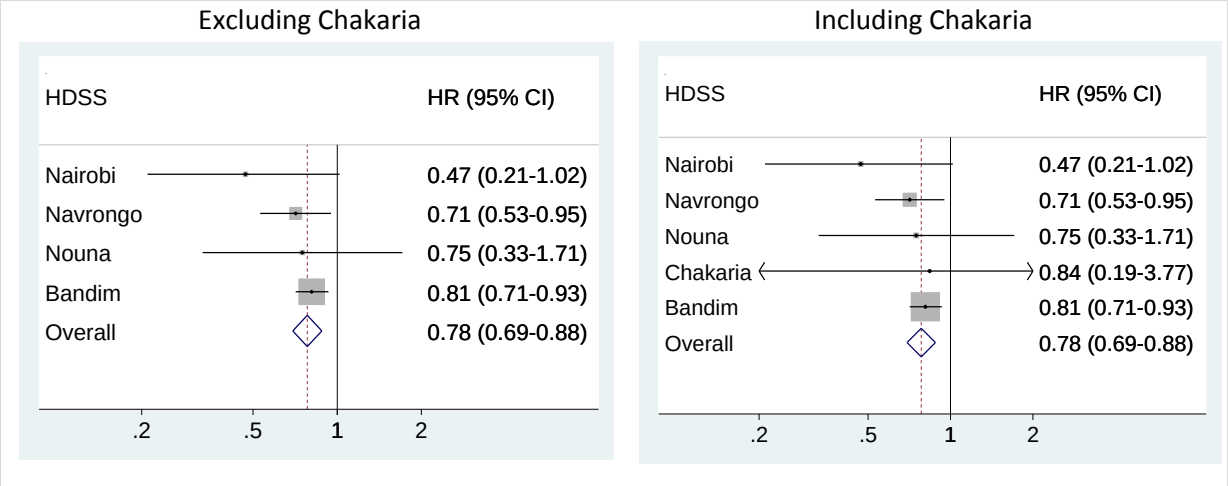
Factor (variable)	Nairobi	Navrongo	Kintampo	Nouna	Chakaria	Bandim
Sex	+	+	+	+	+	+
Year of visit	+	+	o	+	+	+
Residence (area/district)	+	+	+	+	+	+
Twinning	+	+	-	o	-	-
Ethnicity	+	+	+	-	-	o
Religion	-	+	+	+	-	-
Parity (birth order)	+	+	+	-	+	-
Place of delivery	+	+	+	+	+	+
Mother's education	+	+	+	+	+	+
Mother's age	+	+	-	+	+	+
Marital status	+	-	-	+	-	-
Antenatal care	+	-	-	-	+	-
Wealth index	+	+	+	-	+	-
Season of birth	-	+	+	o	+	-
Occupation	-	-	-	o	-	-

+	Included in model and adjusted for each other
+	Statistically significant at 5% level
o	Omitted from model
-	Not available

Objective 3: Impact of FIC on subsequent child survival until 3 years of age

The center-specific survival analyses pointed towards a positive association between FIC and survival. The combined relative estimate of FIC versus NOTFIC was a 22% reduction in mortality (95% CI: 12% to 31%), see Figure 17. We also included the unadjusted estimate from Chakaria which did not change the combined estimate. The detailed site-specific regression analyses can be found in the appendices (Table A19).

Figure 17 Meta analyses of the association between FIC and survival



The result from the alternative approach (CEM) gave a similar estimate of 18% reduction (95% CI: 8% to 28%). Analyses of interaction between sex, place of residence, and year of visit did not show any clear pattern, see appendices (Table A20). We also did a few extra analyses by splitting the FIC group in FIC-IS and FIC-OS which are summarized in Table 6 and detailed in the appendices (Table A21).

Table 6 Site-specific mortality analyses dividing FIC into FIC-IS and FIC-OS.

	NOTFIC	FIC-OS (out-of-sequence) HR (95% CI)	FIC-IS (in-sequence) HR (95% CI)
Nairobi	Ref	0.70 (0.26-1.89)	0.38 (0.15-0.92)
Navrongo	Ref	0.69 (0.49-0.97)	0.72 (0.53-0.98)
Nouna	Ref	0.58 (0.15-2.21)	0.79 (0.34-1.82)
Bandim	Ref	0.77 (0.63-0.93)	0.83 (0.72-0.96)

DISCUSSION

Main observations

In data sets of this size many associations will become statistically significant but we will emphasise the observations which may have the largest implications from a policy implementation perspective. First, though the expected socio-economic factors were positively associated with being FIC, there are clear signs that the relative importance of these factors is diminishing as the coverage goes up. Hence, if the vaccination programmes get better organised it should be possible to make sure that all children are fully immunized. Second, while all centres showed the expected downward trend in age of DTP/OPV vaccinations, the patterns were more variable for BCG and measles vaccinations even though we should expect similar improvements for the other vaccines when the program is improving the coverage. This suggests that there are contrary practices in some centres which may become a stumbling block for reaching all children. Third, the key factor in not being fully immunized is the lack of measles vaccination. Fourth, not being FIC (i.e. not measles vaccinated) by 12 months of age is associated with considerable excess mortality through childhood. For each of these observations we will briefly discuss whether there are data issues which may question the conclusion, and we will discuss the possible implications.

Data coverage and quality

The data from INDEPTH sites are not necessarily representative of specific countries but are suitable to detect patterns in vaccination practises and show how they may relate to subsequent mortality. The data presented depended on the vaccination card being seen. Hence, there are issues of whether the children with “card seen” would be representative of the total population. As seen in Table A2 of the appendices very few children had no vaccination card; in Navrongo, Bandim, and Nairobi less than 1% had no card in recent years. Hence, the data presented do indeed cover the total population except for the possibility that those not home to present their vaccination card may have had lower vaccination coverage. This could in fact be explored by examining the vaccination status of absent children at later visits but there has been no time to do so. Based on previous experiences we think that we may only have overestimated FIC slightly.

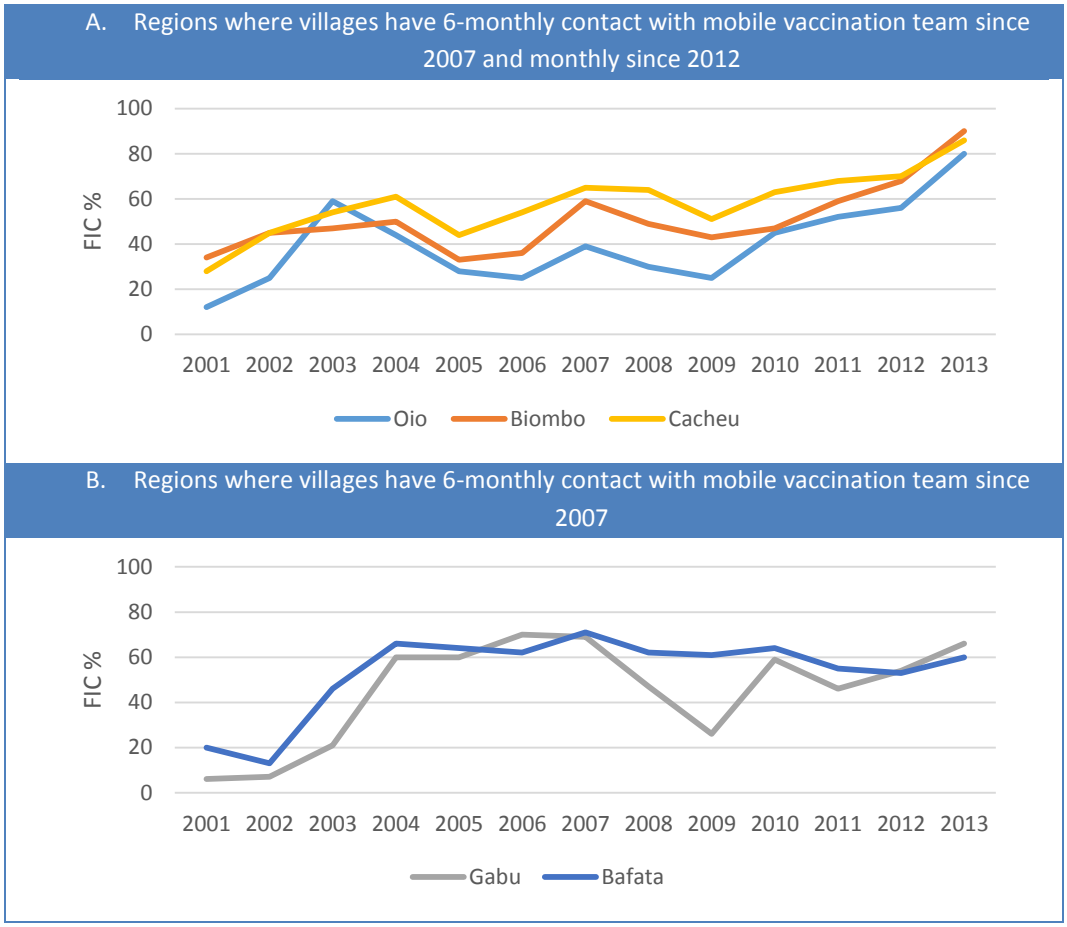
If the assessment of FIC is fairly complete, bias and confounding are only likely to be issues in relation to the link between FIC-status and subsequent mortality which is discussed in greater detail below.

Observations and implications

First, all children can be reached. In the two centres with more than 10 years of data – Navrongo and Bandim – maternal education, which "determine" most things in health, clearly has a diminishing importance as the coverage increased (Figure 5). A similar trend is seen for the wealth index in Navrongo (not studied in Bandim) (Figure 6). The Navrongo HDSS has not managed the vaccination program in their study area so the pattern seen for both maternal education and wealth index are likely to reflect that with a good program with close contact with the population (through community-based nurses) the barriers to vaccination can be overcome. In the Bandim study areas vaccinations are provided by the national health services and EPI. However, since 2007, the Bandim HDSS has offered routine vaccinations at the 6-monthly routine home visits. Since 2012 Bandim HDSS have had mobile teams visiting the villages monthly in three regions (Oio, Biombo, Cacheu) but only 6-monthly in the other two regions (Bafata, Gabu). It will be seen (Figure 18 A) that the FIC coverage has increased more in those regions with monthly contacts (introduced in 2012); the increase is from around 40% to more than 80%. In the other two regions (Figure 18 B) which are those which have received most donor support for health programmes, the proportion being FIC has remained stable around 60%. Maternal education is becoming a minor problem (Figure 5). In Nouna in Burkina Faso, where health services runs a system with monthly contact between health centres and all villages, there is increasing FIC coverage and no impact of maternal education. Hence, to increase the proportion with FIC in rural areas with little infrastructure some form of regular contact or outreach services is needed. Encouragingly the data suggest that there is no difference in FIC by sex (Figure 3).

Second, as expected the age of DTP/Penta/OPV vaccinations declined with increasing vaccination coverage in the sites with longer follow-up (Navrongo, Bandim). The median age of vaccination is probably a good indicator of the degree of contact between the population and the health services. For example, there are major differences in the age of vaccination between Navrongo and Bandim. However, the age patterns for BCG and measles vaccinations are inconsistent. Navrongo has experienced a major decline in age of BCG vaccination from 28 to 3 days (Table 9, Appendix 2). However, in Kintampo also in Ghana there has been little change and it is considerably higher compared to Navrongo (Figure A6, Table A9 in Appendix 3). A well implemented Community-based Health Planning Services (CHPS) system which was initially piloted in Navrongo and later scaled to the entire nation as a national primary health care policy might have contributed to the decline in BCG vaccination age in Navrongo.

Figure 18 The proportion being FIC by region in Bandim HDSS and intensity of contact



Note: Limited to regions on follow-up since 1990

In addition, the change in Navrongo seems to be linked to a clear decision by local health authorities that all newborns should be BCG vaccinated at the first contact with the health care system and a decision that a multi-dose vial should be opened even if only one child was present for vaccination (3). Interestingly, there has been a major decline in neonatal mortality from 3 to 1 % synchronic with the drop in the age of BCG vaccination (3). Chakaria in Bangladesh usually administer BCG together with Penta/OPV and the median age is therefore more than 50 days. In Bandim the BCG age has been above 30 days over most of the period with no real indication of improvement. However, in the last two years of surveillance the age has declined linked to the HDSS's monthly visits in 3 regions (4). With the monthly contacts in Nouna there has been a stable median age of BCG vaccination of around 15 days. Since BCG seems to have beneficial non-specific effects also reducing neonatal mortality (5, 6), there are good reasons to ensure that BCG is given much earlier than happens currently.

For measles vaccine there is actually a worrying indication of increasing age of vaccination in both Nairobi and Bandim. There is no real change in Navrongo, the other site with longer follow-up. The Bandim HDSS team has previously shown that the increase in age of measles vaccination is linked to a national policy of not opening a 10-dose vial of measles vaccine unless there are at least 6 eligible children (i.e. unvaccinated children <12 months) present for vaccination (7). Hence, it becomes more difficult to get vaccinated, the age of vaccination increases and the measles vaccination coverage by 12 months actually declined (7). As seen in the site report, similar restrictive policies are also implement in Nairobi by only vaccinating once a week in some institutions. The restrictive vial opening policies are not endorsed by WHO but they keep being implemented presumably advocated to national EPI programs by consultants or agencies concerned by the wastage of vaccines. These policies are a clear danger to a FIC-program and should be actively discouraged.

Third, lack of measles vaccination is clearly the major cause of NOTFIC. This pattern is seen at all sites. In a sense this is not surprising since the way the FIC coverage is calculated there is only 90 days between 9 and 11 months of age to get measles vaccinated. So in rural areas with poor infrastructure the children have much fewer chances of getting vaccinated. However, this pattern is particularly regrettable because measles vaccine more than any other vaccine has been linked to better child survival (8-11). Unfortunately the way the EPI coverage is calculated could suggest that vaccinations after 12 months of age are not important. Therefore, some programs have started not giving measles vaccine after 12 months of age; e.g. this has happened in Guinea-Bissau. It will be seen in Table A16 of the appendices that there were major difference in terms of the proportion of NOTFIC-at-12 months who became FIC by 24 months and low vaccination incidence between 12 and 15 months (Figure A12). The best performing sites were Navrongo and Chakaria where 70-80% of the children were fully vaccinated during the second year of life. In contrast, only 20-40% of NOTFIC-at-12-month children were fully vaccinated by 24 months of age at the other sites.

Given the importance of measles vaccination for child mortality (see point 4) there are reasons to emphasize much more strongly that children should receive measles vaccine before 12 months of age. As measles infection is becoming increasing less of a problem, mothers may forget the importance of measles vaccination and new systems of communication should be developed to remind mothers to get their children vaccinated at 9 months of age, e.g. with mobile-phone based text messages or direct phone calls.

Fourth, not being FIC – i.e. not being measles vaccinated before 12 months of age - is linked to a considerable excess mortality through childhood. There were no measles epidemics of importance during the conduct of these studies and very few measles deaths were included in the analysis. Hence, the result may be interpreted as due to confounding. However, the estimated hazard ratio was adjusted for the usual determinants of vaccination. As discussed below, a frailty bias implying that frail children are vaccinated later or not at all could explain some of the effect. But it should also be considered that there are several reasons that the estimate (Figure 17) will be conservative.

In Figure 17 we compared the mortality of children being FIC vs NOTFIC by 12 months of age but their mortality could only be compared from the day they were actually seen after 12 months. Hence, some of the NOTFIC children will in fact have received the missing vaccines before they were actually seen at the visit and their mortality profile is likely to be more like the mortality profile of the FIC children; these children will have blurred the mortality difference between the groups. In the two larger studies we have adjusted for this comparing FIC versus NOTFIC at both 12 months of age and at the HDSS visit where vaccination status information was collected. It will be seen in Table 7 that the differential effect increased in both studies. In this sense the estimates we have presented are conservative. Furthermore, even after the HDSS visit some of the NOTFIC-at-visit children may receive further vaccinations and become more like the FIC children and the estimate will presumably be further conservative. [The impact of this could be further estimated by using all the follow-information available from the routine HDDSS data collection but there has been no time for this.]

Table 7 Mortality Hazard Ratio for FIC vs NOTFIC at 12 months and at-visit

	FIC-at 12 months	FIC-at-visit
Navrongo	0.71 (0.53-0.95)	0.67 (0.46-0.96)
Bandim	0.81 (0.71-0.93)	0.78 (0.69-0.89)
Combined	0.79 (0.70-0.90)	0.77 (0.68-0.87)

All studies which have examined the sequence of DTP and measles vaccinations have found that DTP administered with or after MV – i.e. out-of-sequence vaccinations - are associated with considerably higher mortality than receiving MV alone after DTP3. For example, in an analysis of data from Navrongo for the period 1996-2012 the children having DTP ≥ MV had 45% (95% CI: 10-92%) higher mortality than the children who had MV after DTP3 and these out-of-sequence vaccinated children had higher mortality than measles unvaccinated children (12). Since there will be more of the out-of-sequence vaccinated children in the FIC-group than in the NOTFIC groups this would have diminished

the mortality differential estimated for FIC versus NOTFIC children. This is supported by the fact that the mortality differentials for FIC versus NOTFIC is stronger in the years 2001-5 and after 2008 but not in 2006-7 where all children would receive a campaign measles vaccine. [The impact of this could be further estimated by using all the follow-up information but there has been no time for this.]

Both OPV and measles vaccine have been shown in randomized trials to be associated with beneficial non-specific effects, i.e. reducing mortality more than can be explained by prevention of polio or measles infections (9, 13). In our experience, the campaigns with these vaccines (OPV, measles vaccine) which have been implemented in the last 15 years in most low-income countries have also reduced the mortality rate and have therefore also diminished the difference between groups with different vaccination status. Hence, it is likely the campaigns will also have reduced the difference between FIC and NOTFIC. [The impact of this could be further estimated by using all the follow-up information but there has been no time for this.]

Many observational and randomised studies have now documented non-specific beneficial immune-training effects of measles vaccination (8-12). WHO's SAGE review found that measles vaccination was associated with almost a halving of mortality and little of this effect could be explained by prevention of measles infection. The committee recommended further research of the non-specific effects of vaccines (14, 15). The effect found in the SAGE review is quite consistent with the difference found between FIC and NOTFIC without prevention of measles infection being an important component of this effect. That being said it cannot be excluded that part of the effect could be due to frail children being less likely to receive measles vaccination. We applied a statistical method (CEM), which tried to estimate a causal effect of FIC by reducing imbalance in background factors between FIC and NOTFIC using matching. The method did not remove the association and the association was almost the same as for the standard analysis. However, it should be remembered that information on additional background factors could be important. For example, the impact of frailty could be further estimated by using the information on previous nutritional status which is available in part of the data sets from Navrongo and Bandim but there has been no time to explore these analyses.

In conclusion, it would seem important to clarify this issue further because GAVI would have a much stronger case for promoting FIC if it can be shown beyond doubt that FIC is associated with lower mortality than NOTFIC.

PRIORITY FUTURE TOPICS IDENTIFIED

With a data set this size there are numerous studies which can be made, and we have not been able to comment on all the site-specific analyses within the time frame of the present report. We are only going to mention the topics most closely linked to the key issues emphasized in the discussion. Assuming that resources can be obtained we will undertake the following studies:

- WHO/GAVI should strengthen the focus on MCV coverage as the missing vaccine to reach FIC. We will explore what works or does not work in terms of getting a higher coverage for measles vaccination between 9 and 11 months of age. Potential new strategies could be used at different centres to increase MCV coverage, for example mHealth with SMS reminders (PhD-study in Bandim is currently being planned).
- Since the possible effect of being FIC for subsequent mortality might be a key argument for GAVI's promotion of FIC, we will explore whether the effect can be explained by frailty bias and whether the effect is only linked to measles vaccination or whether there are similar different effects when DTP or OPV are missing.
- There is clear variation in the extent to which children are vaccinated after 12 months of age between the different centres. We will examine how this might be linked to subsequent morbidity and mortality.
- With the huge variation in age of BCG vaccination also within the same country we will explore the effects of different policies like getting rid of multi-dose vial policies, and more frequent contacts as in Nouna and Bandim. We will also explore how the change in age of BCG vaccination is possibly linked to changes in neonatal mortality (3)
- We will explore how variation in the organisation of vaccination services within and between countries contribute to reduce the impact of the usual inequality factors like maternal education and wealth.
- Since gender based inequalities plays a large role in the global conscience and the shaping of policies we will explore whether the apparent equality of vaccination for girls and boys are linked to certain ways of organising vaccination services.
- WHO has recently acknowledged that vaccines may have non-specific immune training effects and recommended further research into the non-specific effects of vaccines (14,15). We will explore how variation in vaccination practises may affect child mortality and whether they should be taken into consideration in the planning of programmes; hence, we will look at the

age of vaccination since there are clear indications that earlier priming may have stronger immune training effects (11, 13); it will be examined whether co-administration of vaccines like BCG and Penta or measles vaccine and Penta has consequences for child survival; as mentioned above it will also be examined whether getting Penta/DTP after measles vaccine has implications for child survival (12).

- Partly to their own surprise several of the INDEPTH sites have reached MDG4 (at least Navrongo, Nouna, and Bandim). We will explore the variation within some of the sites (different regions in Bandim; Navrongo and Kintampo in Ghana) to examine how much variation in vaccination practices may have contributed to reaching MDG4.

PROBLEMS ENCOUNTERED AND SOLUTIONS DEVISED OR PROPOSED

It was a much larger work to get data cleaned and ready for the analyses than first anticipated; we needed to get back to original data several times to get data checked and updated.

Kintampo mortality data did not become available within the time frame of the analysis.

Ideas planned but not able to do within the time frame of the project.

- FIC-IS-valid: FIC-IS and satisfying minimum 24 days (≥ 24) between doses of same vaccine The minimum age and intervals are used to determine if a dose is valid (i.e. physiologically efficacious)
- Calculation of missed opportunities. We did start on this e.g. by calculating number of children not vaccinated with BCG at birth if they were born in a health facility providing BCG.
- Morbidity analyse (data not cleaned for this – it would have been a major effort to get ready within the project period). Chakaria HDSS performed preliminary analyse which are reported in Appendix 5. We did not comment on these and will be part of future work.
- Site-specific summaries of the findings would have been natural to include in the appendices.

COMMUNICATION STRATEGY AND DISSEMINATION OF RESULTS

The researchers will publish at least one paper per site partly based on the data presented to GAVI. The specific focus may vary by site but is likely to focus on timeliness of vaccinations, out-of-sequence-vaccinations and the low MCV coverage. We envisage writing at least two cross-site papers or meta-analyses focusing on common features of the determinants for FIC and out-of-sequence vaccinations, the lack of measles vaccination, and the analyses of survival in relation to vaccination status. These analyses will address the issues raised in the discussion above. The papers will be written by the researchers, and under the full responsibility of the researchers. Under acknowledgements, it will be stated that "Part of the data analysis was funded by GAVI, but GAVI had no role in the study design, data collection, data analysis, data interpretation, or in the preparation, review, or approval of the manuscript".

ACKNOWLEDGEMENTS

The routine data collection was funded by the centres. In 2010 DANIDA (DANISH AID) gave a grant to the 6 sites to monitor childhood interventions as part of the HDSS activities entitled "Monitoring and assessing the impact of vaccinations and other childhood interventions for both boys and girls" (DANIDA grant: 104.Dan.8-920). Subsequently European Union FP7 supported similar activities in the three centres: Navrongo, Nouna and Bandim (OPTIMUNISE (grant: Health-F3-2011-261375)). The Bandim scientists involved in the work (Henrik Ravn, Ane Fisker, Andreas Andersen, Sanne Thysen, Peter Aaby, and Christine Benn) were funded by a "Center of Excellence" grant from the Danish National Research Foundation (DNRF-108) and a postdoc grant from the Danish Council for Independent Research (1333-00192) to Ane Fisker, an ERC starting grant (ERC-2009-StG-243149) to Christine Benn, and a research professorship grant from Novo Nordisk Foundation to Peter Aaby. Without the support from DANIDA and EU there would have been no data to analyse. GAVI supported data cleaning and analysis workshops leading to the present report.

We are grateful to the INDEPTH secretariat which organised the first workshop in Accra, Ghana, in March 2014. We would also like to thank Professor David Canning, Harvard University, who worked as an external consultant to advice on the analysis.

We would also like to thanks George Pariyo, GAVI, who has been a valuable and patience help during the whole project. His knowledge and insightful understanding of HDSS data has been most helpful.

REFERENCES

1. GAVI. Report of the Chief Executive Officer. Report to the GAVI Alliance Board 4-5 December 2012
2. Blackwell, Matthew, Stefano Iacus, Gary King, and Giuseppe Porro. 2009. "Cem: Coarsened Exact Matching In Stata." The Stata Journal 9: 524–546
3. Welaga P. Determinants and consequences of delayed BCG vaccinations on child survival in Northern Ghana. MPhil thesis, Ghana School of Public Health 2013
4. Thysen SM, Byberg S, Pedersen M, Rodrigues A, Ravn H, Martins C, Benn CS, Aaby P, Fisker AB. BCG coverage and barriers to BCG vaccination in Guinea-Bissau: an observational study. BMC Public Health 2014, 14:1037.
5. Aaby P, Roth A, Ravn H, Napirna BM, Rodrigues A, Lisse IM, Stensballe L, Diness BR, Lausch KR, Lund N, Biering-Sørensen S, Whittle H, Benn CS. Randomized trial of BCG vaccination at birth to low-birth-weight children: beneficial nonspecific effects in the neonatal period? JID 2011;204:245-52
6. Biering-Sørensen S, Aaby P, Napirna BM, Roth A, Ravn H, Rodrigues A, Whittle H, Benn CS. Small randomised trial among low-birth-weight children of Bacillus Calmette-Guérin vaccination at first health center contact. Pediatr Inf Dis J 2012;31:306-8
7. Fisker AB, Hornshøj L, Rodrigues A, Balde I, Fernandes M, Benn CS, Aaby P. Effects of the introduction of new vaccines in Guinea-Bissau on vaccine coverage, vaccine timeliness, and child survival: an observational study. Lancet Global Health 2014;2:e478-87
8. Aaby P, Samb B, Simondon F, Coll Seck AM, Knudsen K, Whittle H. Non-specific beneficial effect of measles immunisation: analysis of mortality studies from developing countries.Br Med J 1995;311:481-485
9. Aaby P, Martins CL, Garly ML, Bale C, Andersen A, Rodrigues A, Ravn H, Lisse IM, Benn CS, Whittle H. Non-specific effects of standard measles vaccine at 4.5 and 9 months of age on childhood mortality: Randomised controlled trial. BMJ 2010
10. Aaby P, Whittle HC, Benn CS. Vaccine programmes must consider their effect on general resistance. BMJ. 2012;344:e3769. doi: 10.1136/bmj.e3769.
11. Aaby P, Martins CL, Ravn H, Rodrigues A, Whittle HC, Benn CS. Is early measles vaccination better than later measles vaccination? A review Trans Roy Soc Trop Med Hyg 2015;109:16-28
12. Welaga P et al. Measles vaccination and MDG4: Reducing out-of-sequence vaccinations and reducing child mortality in Northern Ghana (submitted)
13. Lund N, Andersen A, Hansen AS, Jepsen FS, Barbosa AG, Biering-Sørensen S, Ravn H, Aaby P, Benn CS. The Effect of Oral Polio Vaccine at Birth on Mortality. A Randomized Trial. CID (In revision). 2015
14. Higgins JPT, Soares-Weiser K, Reingold A. Systematic review of the non-specific effects of BCG, DTP and measles containing vaccines. http://www.who.int/immunization/sage/meetings/2014/april - accessed April 13, 2015
15. Strategic Advisory Group of Experts on Immunization. Week Epidemiol Rec 2014;89: 233-235

Appendix 1: Nairobi 2008-13

List of Tables

Table 1 Inclusion per year of visit 5
Table 2 Percent of children per year having no vaccination card 5
Table 3 Representativeness – comparison children included and excluded from the analyses 7
Table 4 FIC coverage by year of visit 8
Table 5 Coverage of FIC by year of visit and sex 9
Table 6 Coverage of FIC by year and Place of residence 9
Table 7 Coverage of FIC by year of visit and Socio-economic status (wealth index) 9
Table 8 Coverage of FIC by year of visit and maternal education 9
Table 9 Median vaccination age (days) and lower and upper quartiles for FIC 12
Table 10 Median vaccination age (days) and lower and upper quartiles for NOT FIC with a vaccine 12
Table 11 Among children NOT FIC, missing a specific vaccine 14
Table 12 Among children NOT FIC, missing only the particular vaccine 15
Table 13 Among children NOT FIC, number of vaccines missing 15
Table 14 Full immunization coverage (FIC) in sequence (FICIS) and out of sequence (FICOS) 16
Table 15 Main reasons for out-of-sequence for FIC who are out-of-sequence (FICOS) 18
Table 16 Fully Vaccination coverage at 24 months (FIC24) for NOT FIC at 12 months of age 20
Table 17 Analyses of association between background factors and FIC 21
Table 18 Analyses of association between background factors and FICIS among FIC 22
Table 19 Survival analysis of FIC vs NOT FIC, Children followed to 3 years of age 23
Table 20 Interactions 24
Table 21 Survival analysis – splitting FIC into FICIS and FICOS 24
Table 22 Survival analysis – NOT FIC split into “FIC without MCV” and otherwise 25

List of Figures

Figure 1 Flow chart of inclusion for Nairobi 2008-13 5
Figure 2 Histogram of visits from flow chart 6
Figure 3 FIC coverage by year of visit 8
Figure 4 FIC Coverage by key factors 10
Figure 5 Coverage curves for each vaccine among FIC, NOT FIC, and combined 11
Figure 6 Comparison of median vaccination age of FIC and NOT FIC 13
Figure 7 Among NOT FIC percent of missing a particular vaccine 14
Figure 8 Coverage of FIC-in-sequence among FIC 16
Figure 9 Coverage of FIC-in-sequence among FIC for key factors 17
Figure 10 Reason for out-of-sequence among FICOS 18
Figure 11 FIC15 Coverage curves for each vaccine among FIC, NOT FIC, and combined 19
Figure 12 Coverage of FIC24 among NOT FIC at 12 months 20
Figure 13 Vaccination card used in Nairobi 26

Nairobi Urban Health Demographic Surveillance System (NUHDSS)

Description of site

The Nairobi Urban Health Demographic Surveillance System (NUHDSS) is located in two Nairobi urban informal settlements of Korogocho and Viwandani located about 7 kilometers from each other. The NUHDSS started as a pilot study in 2000 covering four slum settlements but was subsequently scaled-down in August 2002 to cover only Korogocho and Viwandani. The baseline census of all residents conducted in August 2002 indicated that about 60,000 people were living in about 23,000 households in the DSA. As of 31st December 2013, the study population across the year stood at 77,016 individuals living in 30,635 households, with Viwandani having a higher share of the population (57 percent vs. 43 percent). It was established by the African Population and Health Research Center (APHRC).

The main goal of the NUHDSS is to provide a platform to investigate the long-term social, economic and health consequences of urban residence, and serve as a primary research tool for intervention and impact evaluation studies focusing on the needs of the urban poor in sub-Saharan Africa (1). The surveillance involves visits to all households in the study sites three times a year and the continuous update on information on pregnancy and pregnancy outcomes, births, migration, episodes of morbidity, health-seeking behavior, mortality and causes of death. The surveillance system also collects data on livelihood sources, vaccination status for under five children, marital status, and school attendance, but only on an annual basis. Initially vaccination information was collected at the first contact with an under five child (birth registration or in migration) and updated yearly as part of the DSS visits. However, in 2007 a separate dedicated field team was established to collect and update all maternal and child health information every four months.

National immunization schedule

The immunization programme in Kenya is managed by the division of vaccines and immunization (DVI). The goal of the Division of Vaccine and Immunization is to reduce morbidity, mortality and disability due to life threatening infections due to vaccine preventable diseases. The division has been in existence since 1980 when it was established as Kenya Expanded Programme on Immunization (KEPI) under the Ministry of Health. It was renamed as DVI in 2008 in order to focus on handling of vaccines and immunization services in Kenya. The Government of Kenya provides vaccines for the vaccine preventable diseases free of charge through DVI.

Initially the DVI was mandated to coordinate immunization against the six common childhood killer diseases namely: Tuberculosis, poliomyelitis, diphtheria, pertussis, tetanus and Measles. This was

expanded in 2002 to include hepatitis B and Haemophilus influenza type b with the introduction of the pentavalent vaccine. Yellow fever was later introduced in four endemic districts. In 2011, the program expanded to cover pneumococcal disease and rota virus vaccine later in 2014. The table below summarises the most current childhood routine immunization schedule in Kenya.

Vaccine	Schedule	Comments
BCG	At birth	
OPV	At birth, 6, 10 and 14wk	Also given during immunization campaigns
DPT-HepB-Hib	6, 10 and 14wk	Introduced in 2002
Pneumococcal vaccine	6, 10 and 14wk	Introduced in 2011
Measles	9 months	Also given during immunization campaigns
Yellow Fever	9 months	Given in 4 districts at high risk
Vitamin A	6m, 12m, 18m, 24m, 30m, 36m, 42m, 48m, 54m and 60m	Given during measles/OPV immunization campaigns
Rota virus vaccine	6 and 10 wk	Introduced in July 2014

The routine vaccines are mainly provided by different levels of public and government health facilities across the country. In addition, selected private health facilities offer vaccination services with approval from the government. In total, EPI services are provided in 5,800 of 7500 health facilities – Public, Private, Faith based, and NGOs are all supported by DVI (2).

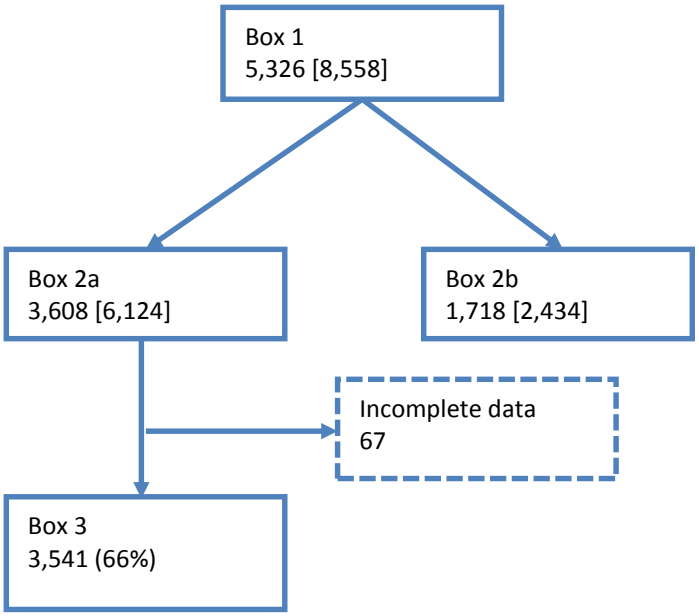
Organization of immunization in the area

There are no public health facilities within the two NUHDSS study sites. Vaccinations services are provided through Public health facilities located in the neighboring communities where residents of the two sites can have access: Four health facilities are located in the neighborhood of Korogocho and two are close to Viwandani. Vaccination services are also offered in private and non-governmental health facilities within or near the slums. There are no particular vaccinations days in the Government facilities. Vaccines are administered throughout the months. However, for private health facilities vaccination services are available on particular days of the week. For instance; Marura Nursing Home and Provide International, BCG and Measles vaccines can only be administered on Fridays and Wednesdays respectively. This is because BCG and Measles Vaccine come in multi-dose vial and requires many patients getting the dose hence the vial dose has to be administered the same day once opened. Vaccination campaigns are conducted by the Government health facilities with assistance from the Community Health Workers (CHWs). Nurses from government health facilities train CHWs and other health care workers to administer vaccines such

as polio but the trained nurses are responsible for vaccines which are not easy to administer such as measles.

1. Emina J, Beguy D, Zulu E, Ezeh A, Muindi K, Elung'ata P, Otsola J, Yé Y: Monitoring of Health and Demographic Outcomes in Poor Urban Settlements: Evidence from the Nairobi Urban Health and Demographic Surveillance System. *Journal of Urban Health* 2011, 88(2):200-218.
2. DVI: **Comprehensive Multi-Year Plan 2011-2015**. In. Edited by Immunization DoVa; 2011

Figure 1 Flow chart of inclusion for Nairobi 2008-13



Box 1
Number of children alive at an HDSS home visit between 12 and 23 months of age
[Number of visits asking for vaccine card]

Box 2a
Number of children from box 1 having at least one visit with card seen
[Number of visits for these children including those where card not seen]

Box 2b
Number of children from box 1 having no seen card at any visit between 12 and 23 months of age
[Number of visits]

Box 3
Number of children included in analyses

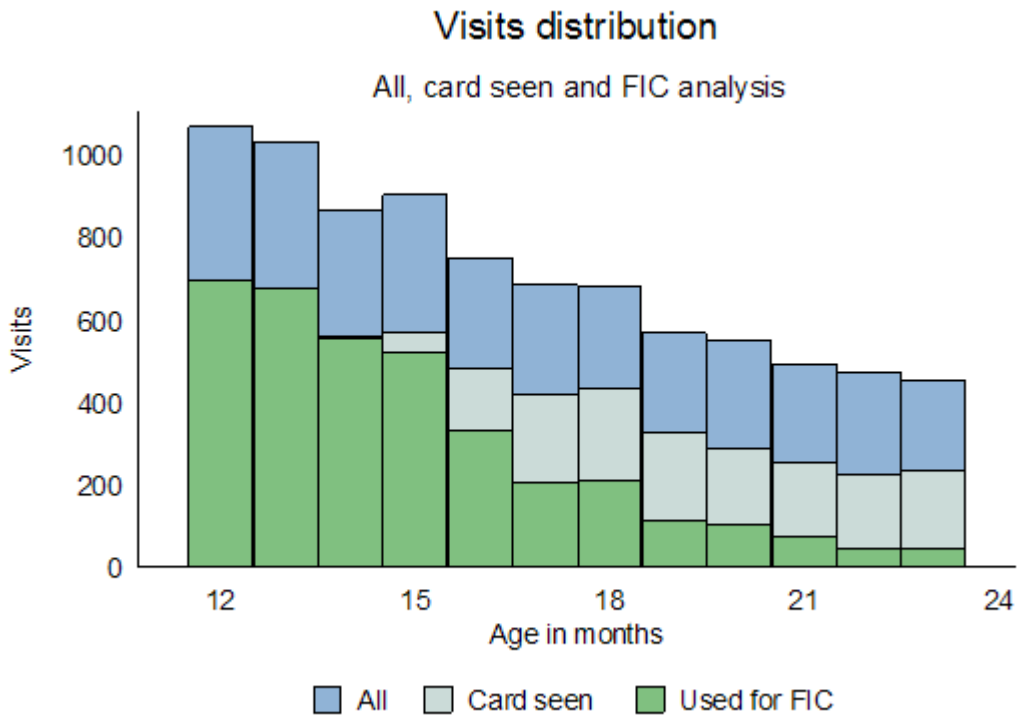
Table 1 Inclusion per year of visit

Year of Visit	Inclusion % (n/total)
2008	68 (926/1365)
2009	61 (297/484)
2010	56 (407/726)
2011	72 (604/843)
2012	74 (916/1238)
2013	58 (391/670)
Total	66 (3541/5326)

Table 2 Percent of children per year having no vaccination card

Year of Visit	No card % (n/total)
2008	1.5 (20/1365)
2009	0.6 (3/484)
2010	1.5 (11/726)
2011	0.5 (4/843)
2012	0.7 (9/1238)
2013	0.6 (4/670)
Total	1.0 (51/5326)

Figure 2 Histogram of visits from flow chart



All = Visits from Box 1
Card seen = Visits from Box 2a
Used for FIC = Visits fromBox 3

Table 3 Representativeness – comparison children included and excluded from the analyses

Variable	Included n (%)	Excluded n (%)	P-value
Sex			
Male	1763 (50)	908 (51)	0.045
Female	1778 (50)	877 (49)	
Year of visit			
2008	926 (26)	430 (24)	< 0.001
2009	297 (8)	192 (11)	
2010	407 (11)	312 (17)	
2011	604 (17)	206 (12)	
2012	916 (26)	339 (19)	
2013	391 (11)	306 (17)	
Study site			
Korogocho	1682 (48)	1081 (61)	< 0.001
Viwandani	1859 (52)	704 (39)	
Twins			
Not twin	3401 (96)	1752 (98)	< 0.001
Twin	140 (4)	33 (2)	
Ethnicity			
kikuyu	916 (26)	469 (26)	< 0.001
luhya	643 (18)	277 (16)	
Luo	583 (16)	297 (17)	
Kamba	771 (22)	277 (16)	
Others	564 (16)	407 (23)	
Missing	64 (2)	58 (3)	
Parity			
1	1144 (32)	441 (25)	< 0.001
2	1080 (30)	497 (28)	
3+	1306 (37)	840 (47)	
Missing	11 (0)	7 (0)	
Place of delivery			
non HF	713 (20)	385 (22)	0.443
HF	2818 (80)	1394 (78)	
Missing	10 (0)	6 (0)	
Mother's education			
No/incomplete	969 (27)	658 (37)	< 0.001
complete	1638 (46)	711 (40)	
secondary+	909 (26)	389 (22)	
Missing	25 (1)	27 (2)	
Mother's age			
<20	583 (16)	277 (16)	< 0.001
20-24	1372 (39)	579 (32)	
25-29	873 (25)	447 (25)	
30+	646 (18)	424 (24)	
Missing	67 (2)	58 (3)	
Marital status			
Not union	485 (14)	362 (20)	< 0.001
Union	2986 (84)	1337 (75)	
Missing	70 (2)	86 (5)	
Recommended antenatal care			
<4 ANC	1696 (48)	947 (53)	< 0.001
4+ ANC	1772 (50)	788 (44)	
Missing	73 (2)	50 (3)	
Wealth status – Quintiles *			
Poorest	781 (22)	469 (26)	< 0.001
Poorer	719 (20)	300 (17)	
Poor	621 (18)	273 (15)	
Less poor	603 (17)	269 (15)	
Least poor	499 (14)	226 (13)	
Missing	318 (9)	248 (14)	

* The assets used for the wealth index is found in the next table

Table of assets for wealth index

Vehicle	Sewing machine	Torch
Motorcycle	Electric iron	Kerosene lamp with glass
Bicycle	Fan	Kerosene stove
Refrigerator	Telephone/mobile phone	wall clock
Television	Electric/gas stove	Mattress
Radio/stereo	Sofa set	Blankets
DVD/VCD/VCR	Table	Bed

Table 4 FIC coverage by year of visit

Year of Visit	FIC coverage % (n/total)
2008	66 (608/926)
2009	72 (214/297)
2010	76 (310/407)
2011	71 (431/604)
2012	68 (625/916)
2013	71 (278/391)
Total	70 (2466/3541)

Figure 3 FIC coverage by year of visit

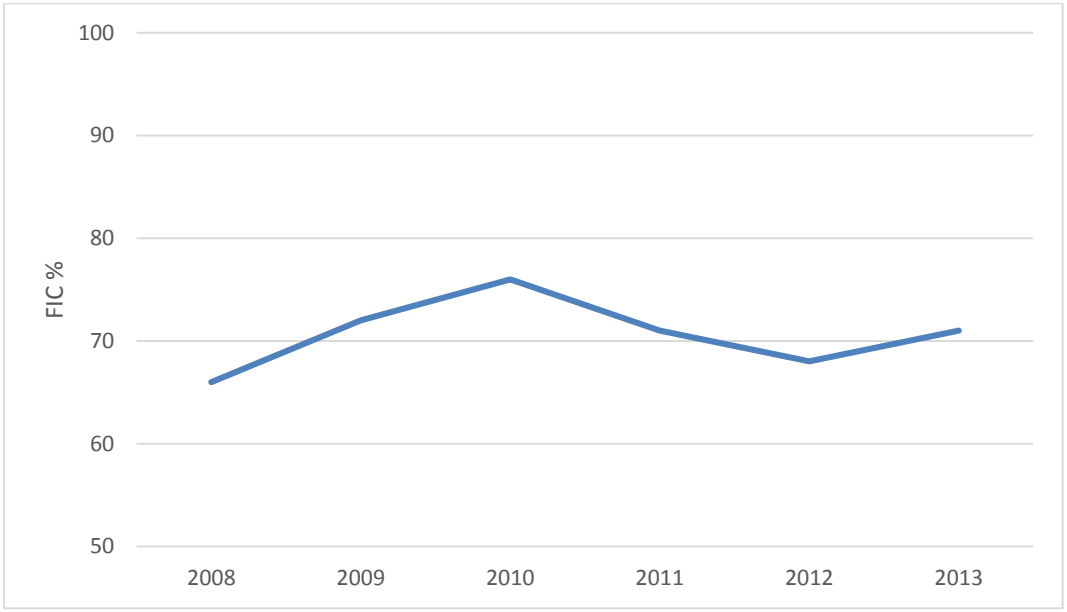


Table 5 Coverage of FIC by year of visit and sex

Year of Visit	Sex		
	Females	Males	Total
2008	66 (295/447)	65 (313/479)	66 (608/926)
2009	73 (117/160)	71 (97/137)	72 (214/297)
2010	79 (166/211)	74 (144/196)	76 (310/407)
2011	68 (215/318)	76 (216/286)	71 (431/604)
2012	68 (299/437)	68 (326/479)	68 (625/916)
2013	75 (153/205)	67 (125/186)	71 (278/391)
Total	70 (1245/1778)	69 (1221/1763)	70 (2466/3541)

Table 6 Coverage of FIC by year and Place of residence

Year of Visit	Place of residence		
	Viwandani	Korogocho	Total
2008	74 (117/521)	55 (221/405)	66 (608/926)
2009	79 (166/180)	62 (72/117)	72 (214/297)
2010	79 (215/208)	73 (146/199)	76 (310/407)
2011	80 (299/297)	64 (195/307)	71 (431/604)
2012	76 (153/468)	60 (269/448)	68 (625/916)
2013	77 (1245/185)	66 (136/206)	71 (278/391)
Total	77 (0/1859)	62 (1039/1682)	70 (2466/3541)

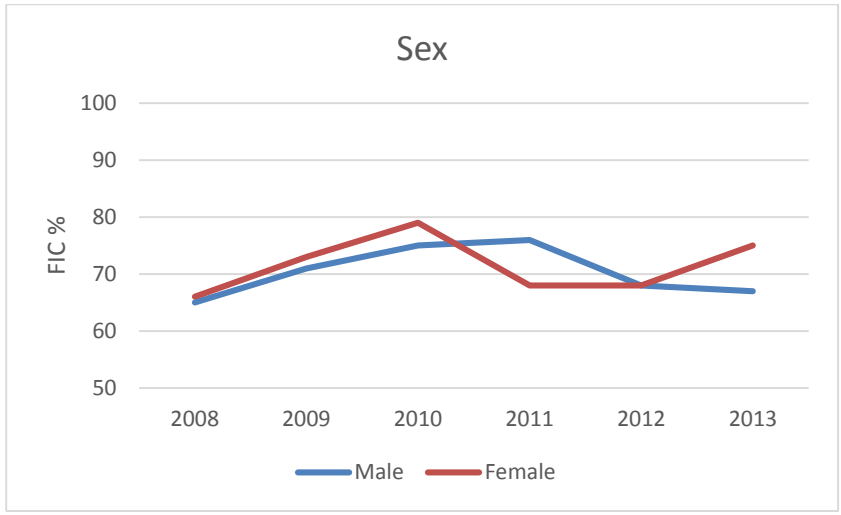
Table 7 Coverage of FIC by year of visit and Socio-economic status (wealth index)

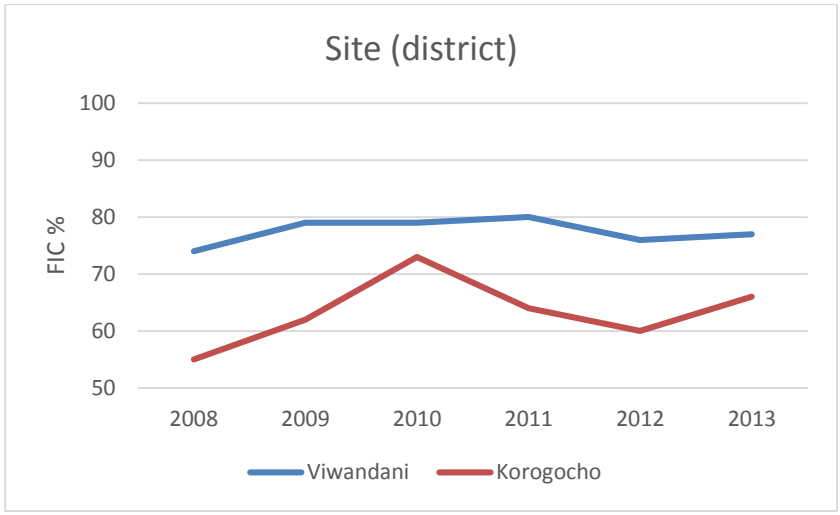
Year of Visit	Wealth index				
	Poorest	Poorer	Poor	Less poor	Least poor
2008	62 (38/61)	65 (80/124)	67 (105/158)	69 (115/168)	70 (167/240)
2009	68 (15/22)	76 (42/55)	60 (22/37)	75 (58/77)	74 (56/76)
2010	73 (86/118)	76 (71/93)	79 (54/68)	82 (53/65)	80 (28/35)
2011	67 (119/179)	71 (95/133)	80 (95/119)	69 (59/85)	68 (21/31)
2012	60 (159/267)	72 (151/211)	69 (103/152)	79 (107/135)	65 (48/74)
2013	68 (83/123)	66 (61/92)	78 (56/72)	80 (43/54)	67 (16/24)
Total	65 (500/770)	71 (500/708)	72 (435/606)	75 (435/584)	70 (336/480)

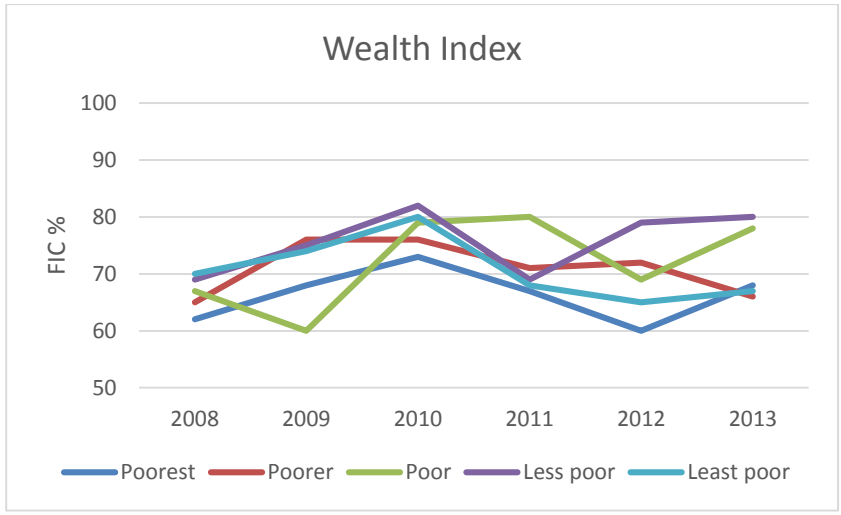
Table 8 Coverage of FIC by year of visit and maternal education

Year of Visit	Maternal education			
	Incomplete Primary	Complete Primary	Secondary or more	Total
2008	57 (165/291)	67 (280/416)	74 (162/218)	66 (608/926)
2009	71 (49/69)	69 (98/143)	81 (67/83)	72 (214/297)
2010	73 (82/112)	77 (153/198)	78 (74/95)	76 (310/407)
2011	63 (87/139)	71 (199/279)	78 (141/180)	71 (431/604)
2012	61 (133/219)	70 (320/456)	73 (168/231)	68 (625/916)
2013	65 (80/123)	71 (110/155)	79 (87/110)	71 (278/391)
Total	63 (596/953)	70 (1160/1647)	76 (699/917)	70 (2466/3541)

Figure 4 FIC Coverage by key factors







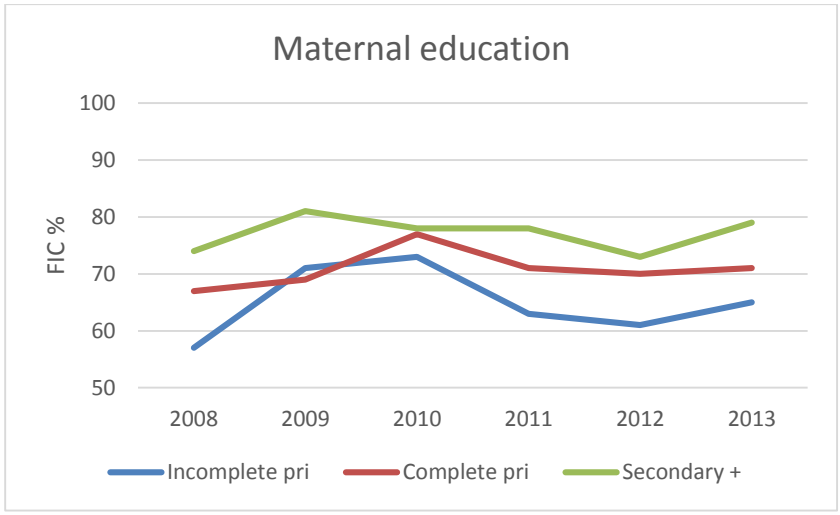
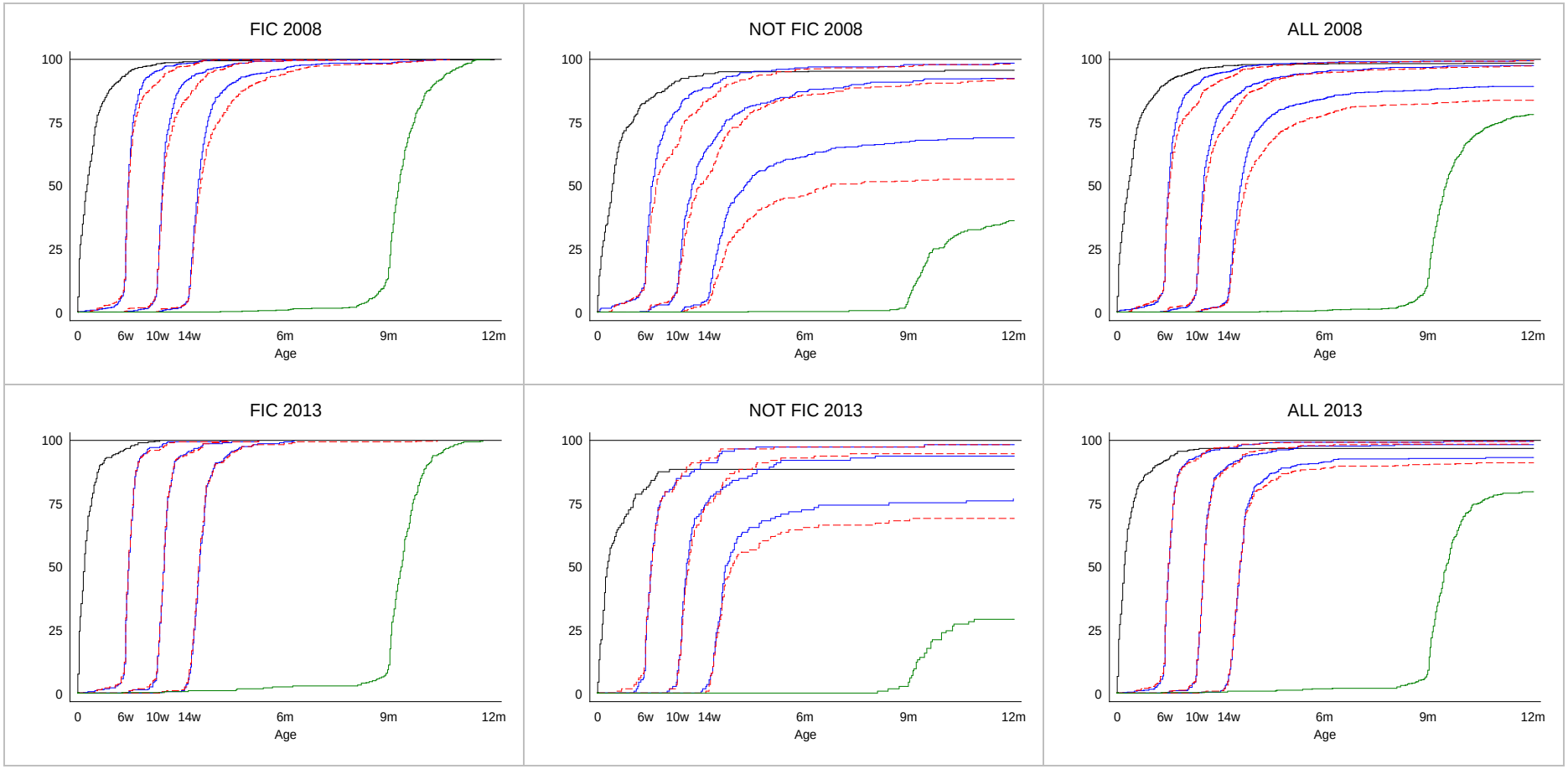


Figure 5 Coverage curves for each vaccine among FIC, NOT FIC, and combined



BCG is black; Penta is blue; OPV is dashed and red; MCV is green

Table 9 Median vaccination age (days) and lower and upper quartiles for FIC

Year of visit	BCG			Penta 1			Penta 2			Penta 3			OPV 1			OPV 2			OPV 3			MCV		
	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
2008	2	8	16	42	44	48	71	74	81	101	106	114	42	45	50	71	75	84	102	108	123	275	282	295
2009	1	7	16	42	45	48	72	75	81	102	106	119	42	44	48	71	75	80	102	106	114	274	281	293
2010	3	10	17	42	45	49	72	75	81	102	107	114	42	45	48	72	75	82	102	107	115	274	280	293
2011	1	6	13	43	45	49	72	76	81	102	108	116	43	45	50	72	77	86	103	109	124	275	281	294
2012	1	4	10	42	44	48	72	75	80	102	106	113	42	44	47	72	75	80	102	106	113	276	283	294
2013	2	6	12	42	45	49	72	76	79	102	107	112	42	45	49	72	76	79	102	106	112	276	284	294
Total	**1**	**6**	**14**	**42**	**45**	**48**	**72**	**75**	**81**	**102**	**106**	**114**	**42**	**45**	**49**	**72**	**75**	**82**	**102**	**107**	**116**	**275**	**282**	**294**

Table 10 Median vaccination age (days) and lower and upper quartiles for NOT FIC with a vaccine

Year of visit	BCG			Penta 1			Penta 2			Penta 3			OPV 1			OPV 2			OPV 3			MCV		
	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
2008	3	10	19	42	45	52	72	76	86	102	108	129	42	46	57	72	77	98	103	113	159	277	289	337
2009	2	8	17	42	45	48	72	76	84	103	108	126	42	45	49	72	77	85	102	108	126	275	286	314
2010	3	10	18	43	45	50	73	76	84	103	108	119	42	45	51	73	76	85	103	108	125	275	283	302
2011	1	6	14	43	45	50	72	77	85	103	109	126	43	46	54	73	78	98	104	112	150	276	285	307
2012	1	5	12	42	45	49	73	76	85	103	107	123	42	45	49	73	76	86	103	108	124	277	289	322
2013	2	6	14	42	45	50	73	76	81	103	108	116	42	45	50	73	76	82	103	108	117	278	289	317
Total	**2**	**7**	**16**	**42**	**45**	**50**	**72**	**76**	**85**	**103**	**108**	**124**	**42**	**45**	**52**	**72**	**77**	**88**	**103**	**110**	**134**	**277**	**287**	**317**

Figure 6 Comparison of median vaccination age of FIC and NOT FIC

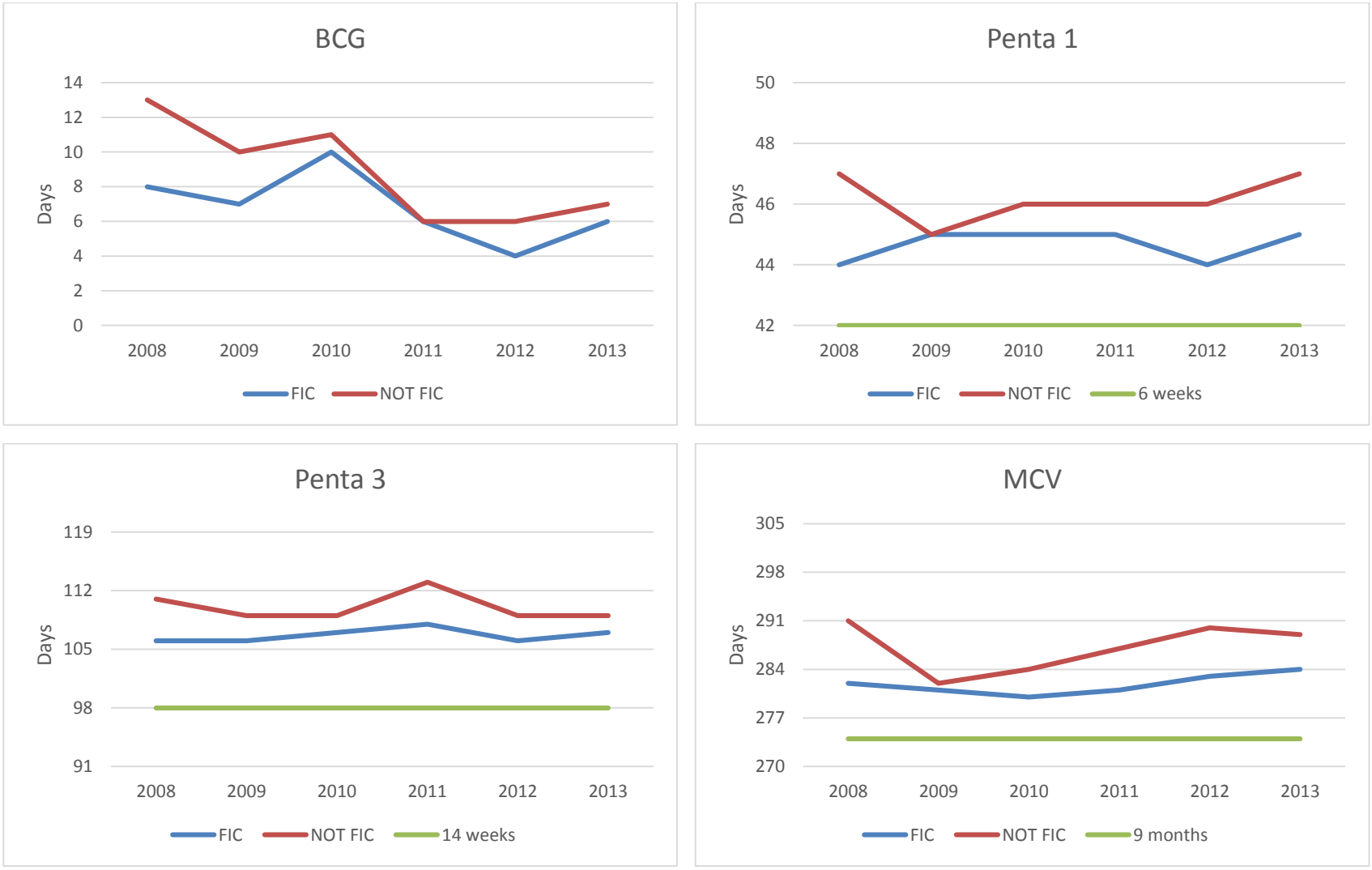


Table 11 Among children NOT FIC, missing a specific vaccine

Year of visit	BCG	Penta 1	Penta 2	Penta 3	OPV 1	OPV 2	OPV 3	MCV	Number NOT FIC
2008	4.4 (14)	1.6 (5)	7.5 (24)	31.1 (99)	1.9 (6)	7.9 (25)	47.5 (151)	63.8 (203)	318
2009	7.2 (6)	2.4 (2)	8.4 (7)	34.9 (29)	2.4 (2)	9.6 (8)	38.6 (32)	61.4 (51)	83
2010	11.3 (11)	0.0 (0)	6.2 (6)	35.1 (34)	1.0 (1)	10.3 (10)	36.1 (35)	56.7 (55)	97
2011	9.8 (17)	4.0 (7)	9.2 (16)	35.3 (61)	4.6 (8)	16.8 (29)	49.7 (86)	52.6 (91)	173
2012	11.7 (34)	3.1 (9)	10.7 (31)	35.4 (103)	4.5 (13)	12.7 (37)	35.4 (103)	62.5 (182)	291
2013	11.5 (13)	1.8 (2)	6.2 (7)	23.0 (26)	1.8 (2)	5.3 (6)	31.0 (35)	70.8 (80)	113
Total	8.8 (95)	2.3 (25)	8.5 (91)	32.7 (352)	3.0 (32)	10.7 (115)	41.1 (442)	61.6 (662)	1075

Figure 7 Among NOT FIC percent of missing a particular vaccine

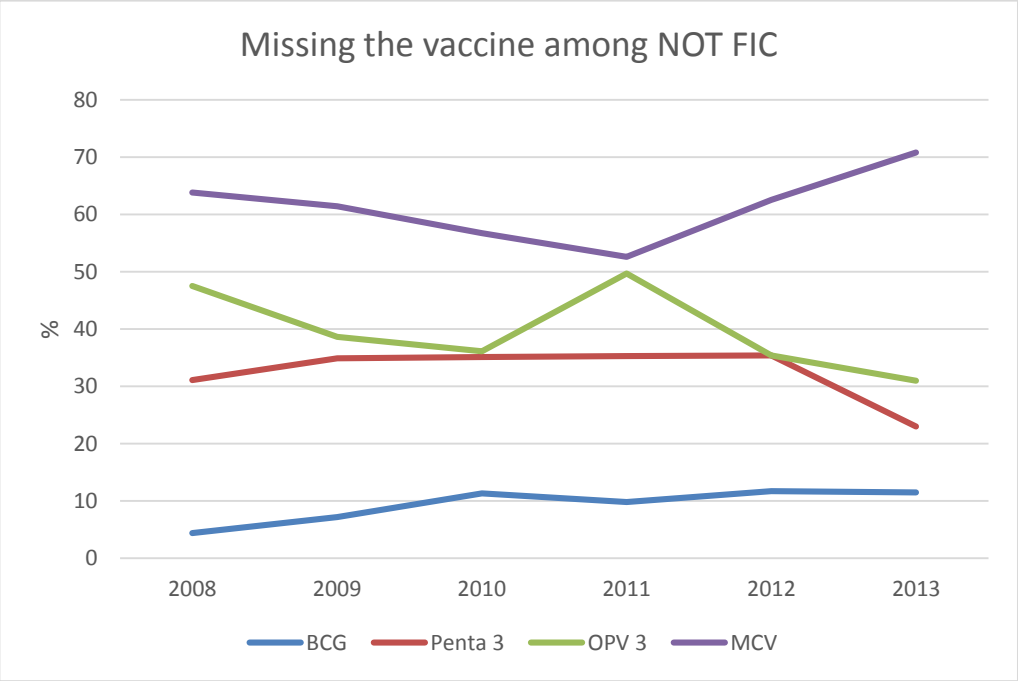


Table 12 Among children NOT FIC, missing only the particular vaccine

Year of visit	BCG	Penta 3	OPV 3	MCV
2008	1.3 (4)	5.4 (17)	18.6 (59)	39.0 (124)
2009	1.2 (1)	12.1 (10)	16.9 (14)	41.0 (34)
2010	9.3 (9)	11.3 (11)	10.3 (10)	37.1 (36)
2011	4.1 (7)	9.8 (17)	18.5 (32)	33.0 (57)
2012	6.5 (19)	9.3 (27)	11.0 (32)	40.9 (119)
2013	3.5 (4)	4.4 (5)	10.6 (12)	55.8 (63)
Total	4.1 (44)	8.1 (87)	14.8 (159)	40.3 (433)

Table 13 Among children NOT FIC, number of vaccines missing

	Number of vaccines missing							
Year of visit	1	2	3	4	5	6	7	8
2008	64.1 (204)	19.5 (62)	8.8 (28)	3.1 (10)	3.1 (10)	0.9 (3)	0.3 (1)	0 (0)
2009	71.1 (59)	14.5 (12)	3.6 (3)	2.4 (4)	3.6 (3)	0 (0)	2.4 (2)	0 (0)
2010	68.0 (66)	16.5 (16)	10.3 (10)	2.1 (2)	2.1 (2)	1.0 (1)	0 (0)	0 (0)
2011	65.3 (113)	13.3 (23)	9.3 (16)	5.8 (10)	2.3 (4)	1.2 (2)	2.3 (4)	0.6 (1)
2012	67.7 (197)	15.1 (44)	6.2 (18)	3.8 (11)	2.8 (8)	1.7 (5)	1.7 (5)	1.0 (3)
2013	74.3 (84)	15.0 (17)	5.3 (6)	0 (0)	3.5 (4)	0 (0)	0.9 (1)	0.9 (1)
Total	67.3 (723)	16.2 (174)	7.5 (81)	3.4 (37)	2.9 (31)	1 (11)	1.2 (13)	0.5 (5)

Table 14 Full immunization coverage (FIC) in sequence (FICIS) and out of sequence (FICOS)

Year of visit	FICIS % (n/FIC)
2008	71 (430/608)
2009	77 (164/214)
2010	79 (246/310)
2011	70 (300/431)
2012	83 (518/625)
2013	86 (239/278)
Total	77 (1897/2466)

FICIS is defined as the WHO recommended sequence of vaccinations, i.e. BCG before OPV1, OPV1=Penta1, OPV2=Penta2, OPV3=Penta3 and Penta3 before MCV.

Figure 8 Coverage of FIC-in-sequence among FIC

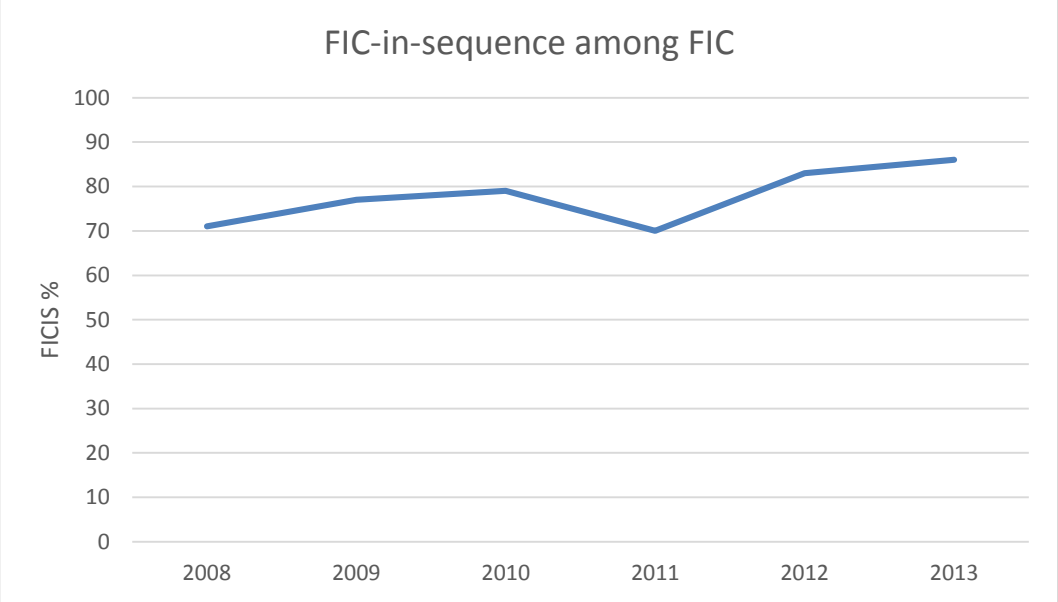
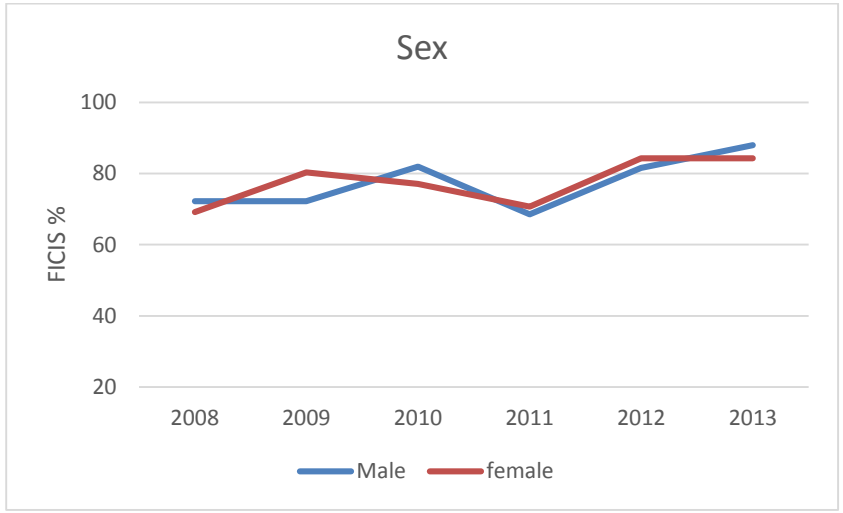
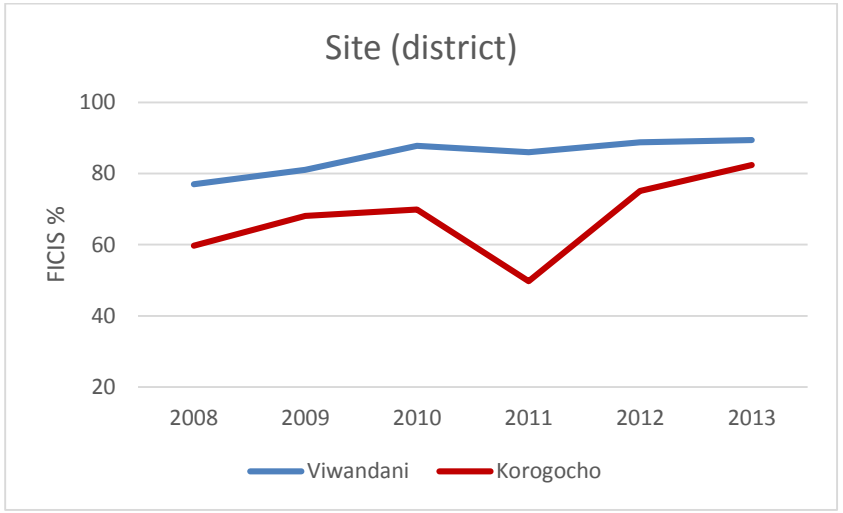
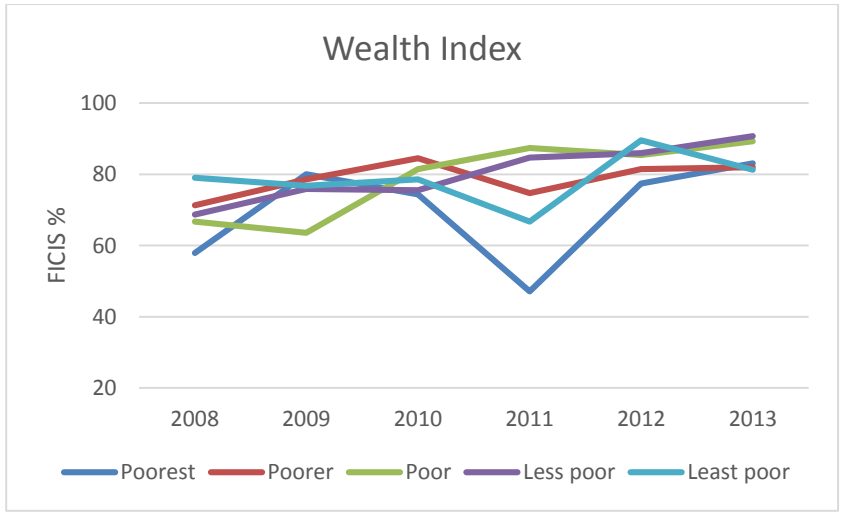


Figure 9 Coverage of FIC-in-sequence among FIC for key factors







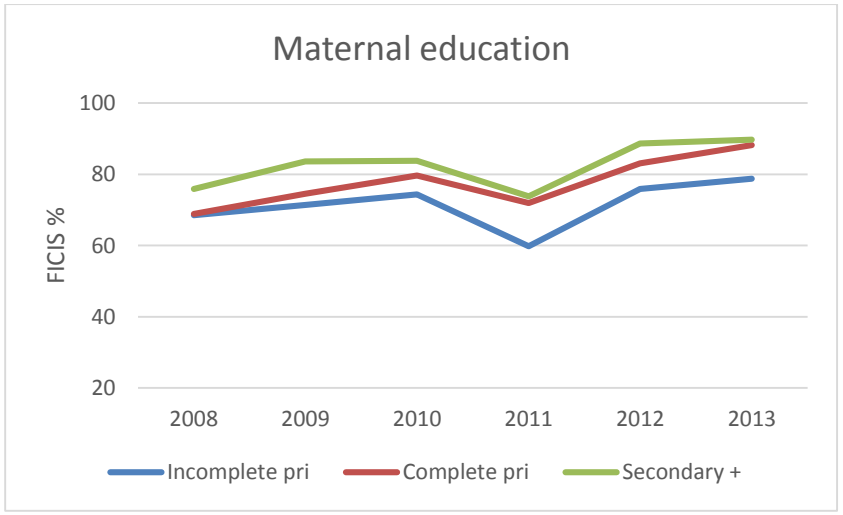


Table 15 Main reasons for out-of-sequence for FIC who are out-of-sequence (FICOS)

Year of Visit	Type of out-of-sequence % (n)			
	BCG ≥ Penta1 or MCV	OPV ≠ Penta	Penta ≥ MCV	Total FICOS
2008	21 (37)	83 (147)	5 (10)	178
2009	18 (9)	90 (45)	2 (1)	50
2010	27 (17)	83 (53)	26 (1)	64
2011	11 (14)	92 (120)	4 (5)	131
2012	21 (22)	79 (84)	10 (11)	107
2013	31 (12)	69 (27)	8 (3)	39
Total	20 (111)	84 (476)	5 (31)	569

Note: Percentages do not sum to 100 as children may contribute to more than one type of out-of-sequence

Figure 10 Reason for out-of-sequence among FICOS

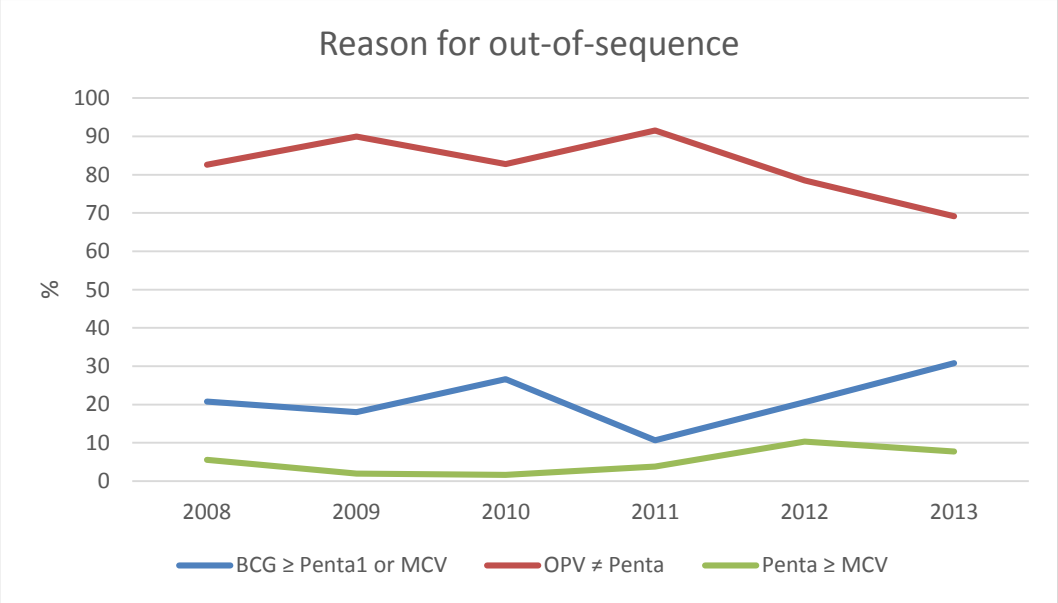
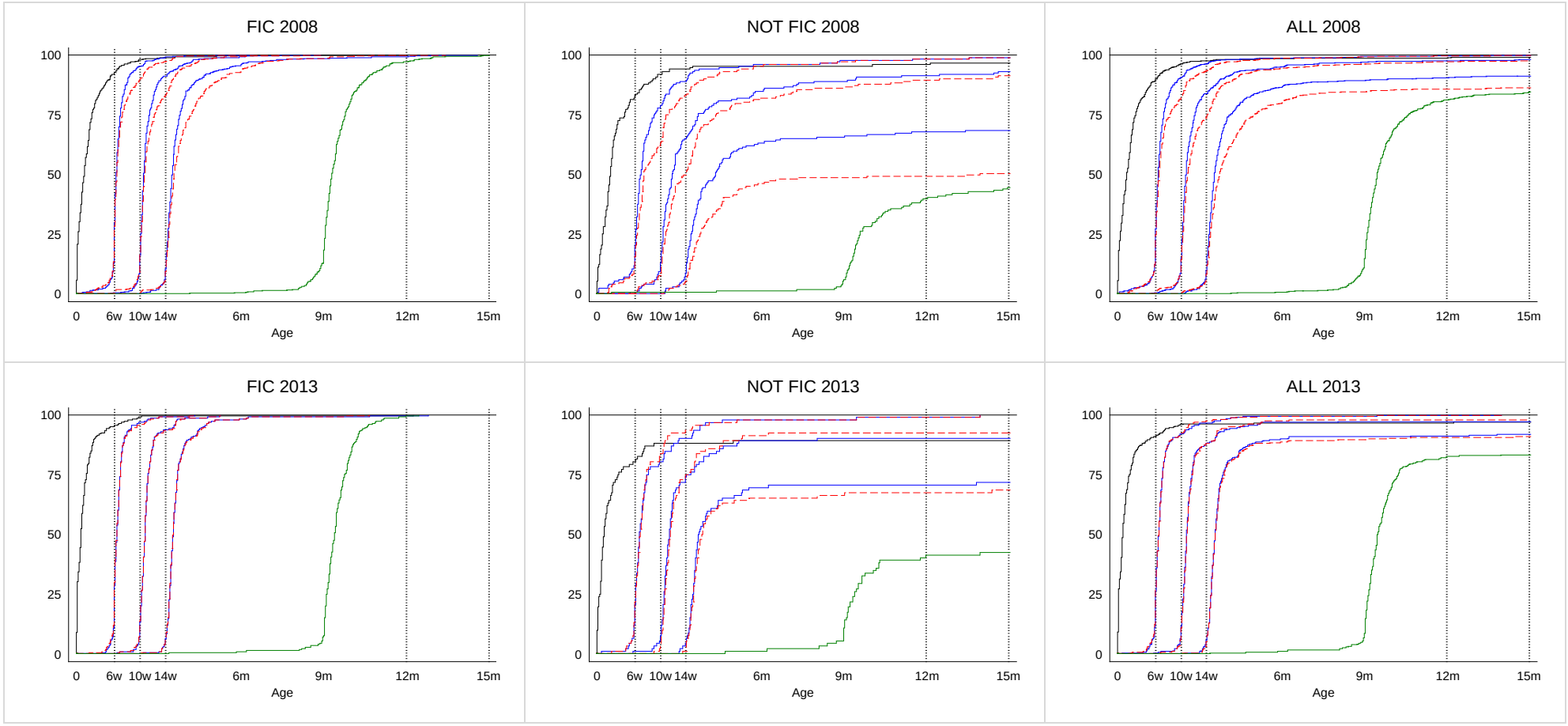


Figure 11 FIC15 Coverage curves for each vaccine among FIC, NOT FIC, and combined



N=2,474 children included, i.e. 70% (2,474/3,541) of the children in the overall FIC analyses (see Figure 1)

Table 16 Fully Vaccination coverage at 24 months (FIC24) for NOT FIC at 12 months of age

Year of visit for FIC12	Percent (FIC24/N)
2008	50 (1/2)
2009	64 (7/11)
2010	0 (0/3)
2011	13 (4/30)
2012	19 (20/107)
2013	22 (13/58)
Total	21 (45/211)

Figure 12 Coverage of FIC24 among NOT FIC at 12 months

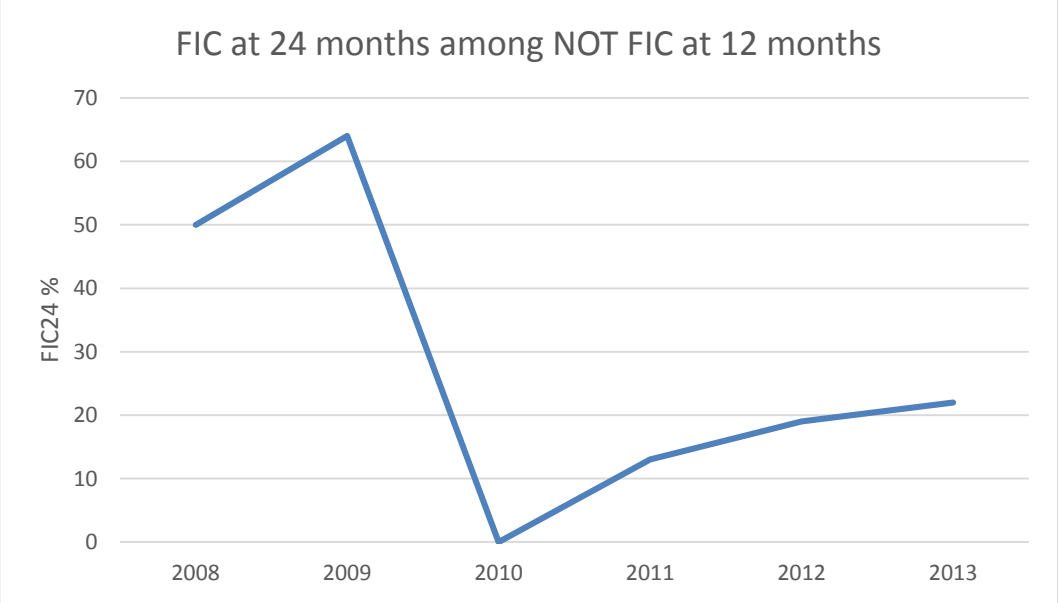


Table 17 Analyses of association between background factors and FIC

Factor	N	%	FIC %	Unadjusted P-value PR (95% CI)	Adjusted P-value aPR (95% CI)
Sex				0.620	0.668
Male	1763	50	69	Ref	Ref
Female	1778	50	70	1.01 (0.97-1.06)	1.01 (0.96-1.06)
Year of visit				0.002	0.014
2008	926	26	66	Ref	Ref
2009	297	8	72	1.10 (1.01-1.19)	1.06 (0.96-1.16)
2010	407	11	76	1.16 (1.08-1.25)	1.13 (1.04-1.22)
2011	604	17	71	1.09 (1.01-1.16)	1.04 (0.96-1.13)
2012	916	26	68	1.04 (0.97-1.11)	0.99 (0.92-1.07)
2013	391	11	71	1.08 (1.00-1.17)	1.08 (0.99-1.18)
Study site				<0.001	<0.001
Korogocho	1682	48	62	Ref	Ref
Viwandani	1859	52	77	1.24 (1.19-1.30)	1.18 (1.11-1.25)
Twins				0.008	0.053
Not twin	3401	96	70	Ref	Ref
Twin	140	4	58	0.83 (0.72-0.95)	0.88 (0.77-1.02)
Ethnicity				0.001	0.070
kikuyu	919	26	73	Ref	Ref
luhya	646	18	65	0.89 (0.83-0.95)	0.91 (0.85-0.98)
Luo	580	16	64	0.88 (0.82-0.95)	0.93 (0.86-1.00)
Kamba	778	22	78	1.06 (1.01-1.12)	0.97 (0.91-1.04)
Others	564	16	66	0.91 (0.85-0.98)	0.92 (0.85-0.99)
Missing	54	2	57		
Parity				<0.001	<0.001
1	1144	32	75	Ref	Ref
2	1080	30	70	0.93 (0.89-0.98)	0.92 (0.87-0.97)
3+	1306	37	64	0.85 (0.81-0.90)	0.84 (0.78-0.91)
Missing	11	0	64		
Place of delivery				0.046	0.195
non HF	713	20	66	Ref	Ref
HF	2818	80	70	1.06 (1.00-1.12)	1.04 (0.97-1.11)
Missing	10	0	60		
Education				0.001	0.436
No/incomplete	953	27	63	Ref	Ref
complete	1647	47	70	1.13 (1.06-1.19)	1.03 (0.96-1.09)
secondary+	917	26	76	1.22 (1.15-1.30)	1.05 (0.97-1.12)
Missing	24	1	46		
Mother age (years)				0.046	0.033
<20	586	17	66	Ref	Ref
20-24	1389	39	72	1.09 (1.02-1.16)	1.10 (1.01-1.20)
25-29	871	25	71	1.08 (1.00-1.16)	1.15 (1.04-1.27)
30+	636	18	68	1.04 (0.96-1.13)	1.16 (1.04-1.29)
Missing	59	2	58		
Marital status				0.250	0.514
Not union	485	14	68	Ref	Ref
Union	2986	84	70	1.04 (0.97-1.11)	1.02 (0.95-1.11)
Missing	70	2	56		
Recommended antenatal care				0.120	0.907
<4 ANC	1696	48	69	Ref	Ref
4+ ANC	1772	50	71	1.04 (0.99-1.08)	1.00 (0.95-1.05)
Missing	73	2	64		
Wealth status - Quintiles				0.004	0.630
Poorest	770	22	65	Ref	Ref
Poorer	708	20	71	1.09 (1.01-1.17)	1.00 (0.93-1.07)
Poor	606	17	72	1.11 (1.03-1.19)	0.98 (0.90-1.06)
Less poor	584	16	74	1.15 (1.07-1.23)	1.01 (0.93-1.09)
Least poor	480	14	70	1.08 (1.00-1.17)	0.95 (0.86-1.04)
Missing	393	11	66		
Child age				0.075	0.342
12-17 months	2948	83	70	Ref	Ref
18-24 months	593	17	66	0.95 (0.89-1.01)	0.97 (0.90-1.03)

Table 18 Analyses of association between background factors and FICIS among FIC

Factor	N	%	FICIS %	Unadjusted P-value PR (95% CI)	Adjusted P-value aPR (95% CI)
Sex				0.903	0.756
Male	1221	50	77	Ref	Ref
Female	1245	50	77	1.00 (0.96-1.05)	0.99 (0.94-1.04)
Year of visit				<0.001	<0.001
2008	608	25	71	Ref	Ref
2009	214	9	77	1.08 (0.99-1.19)	1.06 (0.95-1.19)
2010	310	13	79	1.12 (1.04-1.21)	1.16 (1.06-1.27)
2011	431	17	70	0.98 (0.91-1.07)	1.03 (0.94-1.14)
2012	625	25	83	1.17 (1.10-1.25)	1.19 (1.10-1.29)
2013	278	11	86	1.22 (1.13-1.30)	1.24 (1.13-1.35)
Study site				<0.001	<0.001
Korogocho	1039	42	67	Ref	Ref
Viwandani	1427	58	84	1.26 (1.20-1.32)	1.25 (1.17-1.34)
Twins				0.558	0.887
Not twin	2385	97	77	Ref	Ref
Twin	81	3	74	0.96 (0.84-1.10)	0.99 (0.86-1.14)
Ethnicity				<0.001	0.749
kikuyu	665	27	76	Ref	Ref
luhya	417	17	73	0.95 (0.89-1.02)	0.96 (0.89-1.04)
luo	374	15	71	0.93 (0.86-1.01)	1.00 (0.92-1.08)
kamba	599	24	82	1.07 (1.01-1.14)	0.99 (0.92-1.07)
others	376	15	80	1.05 (0.99-1.12)	1.02 (0.94-1.10)
Missing	35	1	83		
Parity				0.333	0.734
1	861	35	78	Ref	Ref
2	758	31	78	1.00 (0.95-1.05)	0.97 (0.91-1.04)
3+	840	34	75	0.97 (0.92-1.02)	0.99 (0.91-1.07)
Missing	7	0	86		
Place of delivery				<0.001	0.001
non HF	474	19	70	Ref	Ref
HF	1986	81	79	1.12 (1.05-1.19)	1.14 (1.05-1.23)
Missing	6	0	83		
Education				0.001	0.076
No/incomplete	607	25	71	Ref	Ref
complete	1152	47	77	1.08 (1.02-1.15)	1.07 (1.01-1.15)
secondary+	695	28	82	1.15 (1.08-1.22)	1.08 (1.00-1.16)
Missing	12	0	50		
Mother age (years)				0.020	0.423
<20	383	16	70	Ref	Ref
20-24	984	40	78	1.11 (1.03-1.19)	1.07 (0.98-1.16)
25-29	619	25	79	1.13 (1.04-1.21)	1.08 (0.98.1.19)
30+	443	18	76	1.08 (1.00-1.18)	1.06 (0.95.1.18)
Missing	37	2	84		
Marital status				0.048	0.427
Not union	328	13	72	Ref	Ref
union	2099	85	78	1.07 (1.00-1.15)	0.97 (0.91-1.04)
Missing	39	2	79		
Recommended antenatal care				0.194	0.872
<4 ANC	1162	47	76	Ref	Ref
4+ ANC	1257	51	78	1.03 (0.99-1.08)	1.00 (0.96-1.06)
Missing	47	2	83		
Wealth status - Quintiles				0.001	0.462
Poorest	500	20	69	Ref	Ref
Poorer	500	20	79	1.14 (1.06-1.23)	1.07 (0.99-1.15)
Poor	435	18	80	1.16 (1.08-1.25)	1.04 (0.95-1.14)
Less poor	435	18	79	1.14 (1.06-1.23)	1.05 (0.96-1.15)
Least poor	336	14	79	1.15 (1.06-1.24)	1.07 (0.98-1.18)
Missing	260	11	76		
Child age				0.021	0.202
12-17 months	2072	84	78	Ref	Ref
18-24 months	394	16	72	0.93 (0.87-0.99)	0.95 (0.89-1.03)

Table 19 Survival analysis of FIC vs NOT FIC, Children followed to 3 years of age

Factor [no. of missing]	**Rate**	**D**	**Pyrs**	**N**	**Crude P-value HR (95%-CI)**	**Adjusted P-value HR (95%-CI)**
FIC					0.018	0.055
No	12.8	16	1248.1	941	Ref	Ref
Yes	5.5	16	2901.5	2188	0.43 (0.22-0.86)	0.47 (0.21-1.02)
Sex					0.745	0.597
Male	8.2	17	2082.2	1567	Ref	Ref
Female	7.3	15	2067.4	1562	0.89 (0.45-1.78)	0.82 (0.39-1.73)
Year of visit					0.049	0.093
2008	10.2	13	1268.9	853	Ref	Ref
2009	15.5	6	386.5	266	1.46 (0.55-3.84)	1.61 (0.57-4.57)
2010	1.9	1	529.8	347	0.18 (0.02-1.36)	0.19 (0.02-1.54)
2011	12	9	751.8	522	1.17 (0.50-2.74)	1.33 (0.48-3.69)
2012	2.9	3	1042.2	846	0.26 (0.07-0.90)	0.27 (0.07-1.06)
2013	0	0	170.4	295		
Study site					0.082	0.933
Korogocho	10.3	20	1944.3	1483	Ref	Ref
Viwandani	5.4	12	2205.6	1646	0.53 (0.26-1.08)	1.04 (0.42-2.58)
Twins					0.503	0.91
Not twin	7.5	30	3986.8	3005	Ref	Ref
Twin	12.3	2	162.8	124	1.63 (0.39-6.83)	0.89 (0.11-7.02)
Ethnicity [35]					0.263	0.573
Kikuyu	9.9	11	1110.6	819	Ref	Ref
Luhya	10.8	8	741.1	561	1.08 (0.43-2.69)	1.22 (0.43-3.43)
Luo	10.9	7	640.5	509	1.08 (0.42-2.80)	1.07 (0.36-3.20)
Kamba	4.3	4	922.2	692	0.43 (0.14-1.36)	0.55 (0.15-1.95)
Others	2.9	2	700	513	0.29 (0.06-1.32)	0.39 (0.08-1.89)
Parity [9]					0.952	0.805
1	8.4	11	1312.5	998	Ref	Ref
2	7.4	9	1216.5	937	0.88 (0.37-2.13)	0.92 (0.33-2.56)
3+	7.5	12	1609.2	1185	0.90 (0.40-2.03)	0.69 (0.20-2.31)
Place of delivery [8]					0.785	0.789
Non HF	8.3	7	838.6	616	Ref	Ref
HF	7.6	25	3301	2505	0.89 (0.38-2.06)	1.16 (0.44-3.08)
Education [19]					0.115	0.207
No/incomplete	8.1	9	1116.9	847	Ref	Ref
Complete	10.3	20	1951.1	1467	1.26 (0.58-2.78)	1.46 (0.58-3.65)
Secondary+	2.8	3	1057.4	796	0.35 (0.09-1.29)	0.49 (0.12-2.02)
Mother age [37]					0.346	0.465
<20	10.5	7	669.8	513	Ref	Ref
20_24	7.1	11	1559	1192	0.67 (0.26-1.74)	0.96 (0.29-3.15)
25_29	10.4	11	1056.9	792	1.01 (0.39-2.61)	1.64 (0.43-6.28)
30+	3.6	3	826.3	595	0.35 (0.09-1.35)	0.64 (0.11-3.56)
Marital status [62]					0.512	0.809
Not union	10	6	602.9	442	Ref	Ref
Union	7.5	26	3477.9	2625	0.74 (0.31-1.81)	0.88 (0.31-2.48)
Recommended antenatal care [68]					0.091	0.238
<4 ANC	10	20	1998.6	1497	Ref	Ref
4+ ANC	5.3	11	2062.7	1564	0.53 (0.25-1.11)	0.63 (0.29-1.36)
Wealth status - Quintiles [307]					0.109	0.168
Poorest	7	6	859.6	678	Ref	Ref
Poorer	6.1	5	821.7	639	0.88 (0.27-2.89)	0.88 (0.25-3.05)
Poor	4.2	3	711.2	539	0.62 (0.15-2.46)	0.64 (0.14-2.90)
Less poor	15.7	11	702.4	512	2.29 (0.85-6.19)	2.00 (0.63-6.32)
Least poor	4.5	3	663.9	454	0.68 (0.17-2.70)	0.52 (0.11-2.42)
Child age					0.976	0.677
12-17 months	7.8	28	3566.9	2606	Ref	Ref
18-24 months	6.9	4	582.7	523	0.98 (0.33-2.90)	0.76 (0.22-2.71)

Table 20 Interactions

	Adjusted HR (95%-CI)	Test of no interaction p-value
Males	0.78 (0.26-2.34)	0.181
Females	0.26 (0.08-0.84)	
Korogocho	0.57 (0.21-1.58)	0.538
Viwandani	0.35 (0.11-1.13)	
2008-10	0.35(0.13-0.94)	0.347
2011-13	0.74(0.21-2.57)	

Table 21 Survival analysis – splitting FIC into FICIS and FICOS

Factor	Rate	D	Pyrs	N	Crude HR (95%-CI)	Adjusted HR (95%-CI)
FIC					p=0.021	p=0.100
NOTFIC	12.8	16	1248.1	941	Ref	Ref
FICOS	10.1	7	695.2	503	0.80 (0.33-1.95)	0.70 (0.26-1.89)
FICIS	4.1	9	2206.3	1685	0.32 (0.14-0.72)	0.38 (0.15-0.92)

Interaction term	Adjusted HR (95%-CI)	Test of no interaction p-value
Sex		
Male		0.421
FICOS	1.10 (0.29-4.23)	
FICIS	0.64 (0.19-2.17)	
Female		
FICOS	0.42 (0.09-2.06)	
FICiS	0.21 (0.05-0.82)	
Site (district)		
Korogocho		0.567
FICOS	0.98 (0.31-3.10)	
FICIS	0.34 (0.09-1.31)	
Viwandani		
FICOS	0.28 (0.03-2.49)	
FICIS	0.37 (0.11-1.23)	
Period		
2008-2010		0.481
FICOS	0.63 (0.19-2.11)	
FICIS	0.24 (0.07-0.80)	
2011-2013		
FICOS	0.81 (0.14-4.60)	
FICIS	0.70 (0.18-2.69)	

Table 22 Survival analysis – NOT FIC split into "FIC without MCV" and otherwise

Factor	Rate	D	Pyrs	N	Crude HR (95%-CI)	Adjusted HR (95%-CI)
FIC					p=0.059	p=0.152
Not FIC	13.3	10	752.8	569	Ref	Ref
FIC without MCV	12.1	6	495.3	372	0.91 (0.33-2.50)	0.85 (0.27-2.68)
FIC	5.5	16	2901.5	2188	0.42 (0.19-0.92)	0.44 (0.18-1.08)

Interaction term	Adjusted HR (95%-CI)	Test of no interaction p-value
Sex		
Male		0.378
FIC without MCV	0.67 (0.11-4.15)	
FIC	0.65 (0.17-2.47)	
Female		
FIC without MCV	1.18 (0.27-5.20)	
FIC	0.28 (0.08-1.03)	
Site (district)		
Korogocho		0.522
FIC without MCV	0.50 (0.10-2.59)	
FIC	0.46 (0.15,1.38)	
Viwandani		
FIC without MCV	1.64 (0.26-10.2)	
FIC	0.46 (0.09-2.27)	
Period		
2008-2010		0.479
FIC without MCV	1.24 (0.32-4.84)	
FIC	0.38 (0.12-1.22)	
2011-2013		
FIC without MCV	0.38 (0.04-3.75)	
FIC	0.52 (0.13-2.10)	

Figure 13 Vaccination card used in Nairobi

IMMUNIZATIONS

PROTECT YOUR CHILD

BCG VACCINE: at birth	Date Given	Date of next visit
(Intra-dermal left fore arm)		
Dose: (0.05mls for child below 1 year)		
Dose: (0.1 mls for child above 1 year)		
BCG-Scar Checked	Date checked	Date BCG repeated
PRESENT		
ABSENT		

ORAL POLIO VACCINE (OPV)	Date Given	Date of next Visit
Dose: 2 drops orally		
Birth Dose: at birth or within 2 wks (OPV 0)		
1st dose at 6 weeks (OPV 1)		
2nd dose at 10 weeks (OPV 2)		
3rd dose at 14 weeks (OPV 3)		

DIPHTHERIA/PERTUSSIS/TETANUS/HEPATITIS B/ HAEMOPHILUS INFLUENZAE Type b	Date Given	Date of next visit
Dose:(0.5mls) Intra Muscular left outer thigh		
1st dose at 6 weeks		
2nd dose at 10 weeks		
3rd dose at 14 weeks		

PNEUMOCOCCAL VACCINE	Date Given	Date of next visit
Dose:(0.5mls) Intra Muscular right outer thigh		
1st dose at 6 weeks		
2nd dose at 10 weeks		
3rd dose at 14 weeks		

MEASLES VACCINE at 9 Months	Date Given
Dose: (0.5mls) Subcutaneously right upper arm	

YELLOW FEVER VACCINE at 9 Months**	Date Given
Dose: (0.5mls) Intra Muscular left upper deltoid	

** Only in selected districts in Rift Valley

Page 18 of 34 **NOT FOR SALE**

Appendix 2: Navrongo 2002-13

List of Tables

Table 1 Inclusion per year of visit 6
Table 2 Percent of children per year having no vaccination card 6
Table 3 Representativeness – comparison children included and excluded from the analyses 8
Table 4 FIC coverage by year of visit 9
Table 5 Coverage of FIC by year of visit and sex 10
Table 6 Coverage of FIC by year and Place of residence 10
Table 7 Coverage of FIC by year of visit and Socio-economic status (wealth index) 10
Table 8 Coverage of FIC by year of visit and maternal education 11
Table 9 Median vaccination age and lower and upper quartiles for FIC 14
Table 10 Median vaccination age and lower and upper quartiles for NOT FIC with a vaccine 14
Table 11 Among children NOT FIC, missing a specific vaccine 16
Table 12 Among children NOT FIC, missing only the particular vaccine 17
Table 13 Among children NOT FIC, number of vaccines missing 17
Table 14 Full immunization coverage in sequence (FICIS) among FIC 18
Table 15 Main reasons for out-of-sequence for FIC who are out-of-sequence (FICOS) 20
Table 16 Fully Vaccination coverage at 24 months (FIC24) for NOT FIC at 12 months of age 22
Table 17 Analyses of association between background factors and FIC 23
Table 18 Analyses of association between background factors and FICIS among FIC 24
Table 19 Survival analysis of FIC vs NOT FIC, Children followed to 3 years of age 25
Table 20 Interactions 26
Table 21 Survival analysis - splitting FIC into FICIS and FIOS 27
Table 22 Survival analysis - NOT FIC split into “FIC without MCV” and otherwise 28
Table 23 Survival and alternative FIC calculations: FIC at visit and FIC15 29

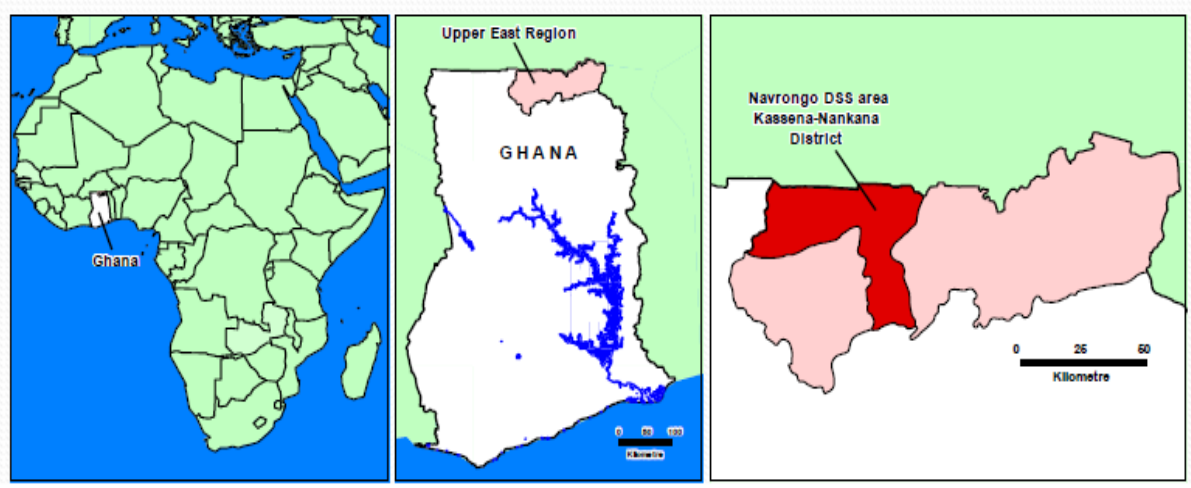
List of Figures

Figure 1 Flow chart of inclusion for Navrongo 2002-13 6
Figure 2 Histogram of visits from flow chart 7
Figure 3 FIC coverage by year of visit 9
Figure 4 FIC Coverage by key factors 12
Figure 5 Coverage curves for each vaccine among FIC, NOT FIC, and combined 13
Figure 6 Comparison of median vaccination age of FIC and NOT FIC 15
Figure 7 Among NOT FIC percent of missing a particular vaccine 16
Figure 8 Coverage of FIC-in-sequence among FIC 18
Figure 9 Coverage of FIC-in-sequence among FIC for key factors 19
Figure 10 Reason for out-of-sequence among FICOS 20
Figure 11 FIC15 Coverage curves for each vaccine among FIC, NOT FIC, and combined 21
Figure 12 Coverage of FIC24 among NOT FIC at 12 months 22
Figure 13 Vaccination card used 30

Navrongo Health Demographic Surveillance System

Description of site

The Navrongo study site is the Kassena-Nankana District[1] (KND) in the Upper East region of northern Ghana. It covers a land area of 1,675km^2 with an estimated population of 160,000 under continuous demographic surveillance. The study area has one major hospital that acts as a referral hospital to seven health centers and a private clinic. There are over 40 Community Health Compounds (CHCs) that are manned by trained nurses to provide basic health care to the communities where they are located. The district is mostly rural (80%) with the primary occupation of the people being subsistence agriculture. The district is typical of many rural areas in sub-Saharan Africa with majority of the inhabitants being subsistence farmers who live in small, scattered settlements. The study area is malaria endemic with malaria being the leading cause of death. The figure below shows a map of Africa, Ghana, Upper East Region and the study area clearly indicated.

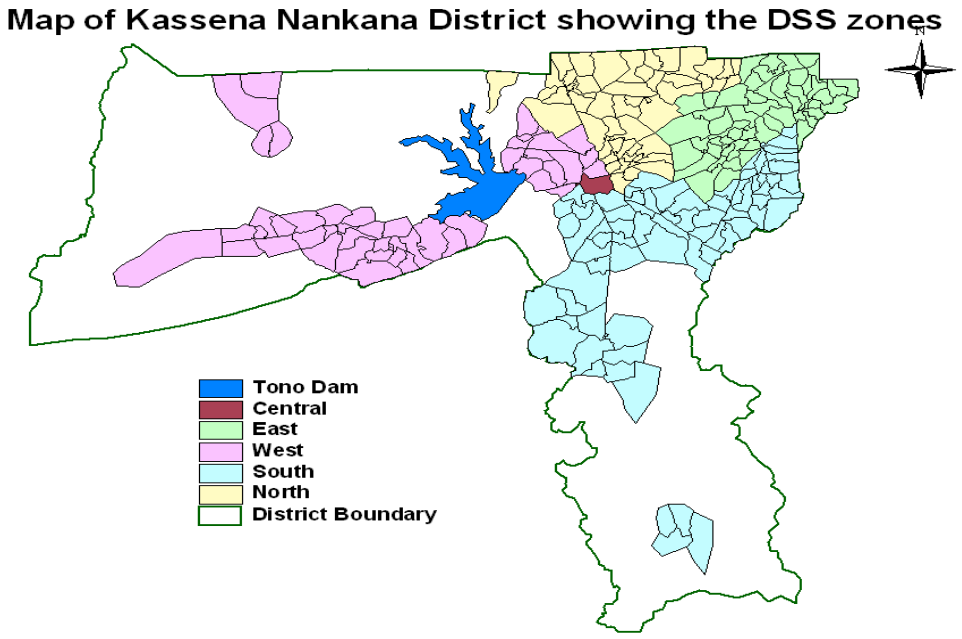


The Kassena-Nankana District was the site for a large-scale community-based intervention trial known as the Navrongo Community Health and Family Planning project which was a quasi-experimental study designed to test the hypothesis that introducing health and family planning services in a traditional African setting can induce and sustain reproductive change. Before the end of the project in 2003 changes in mortality and fertility were already evident in the Kassena-Nankana district. The results of this intervention led to the current Ghanaian policy on community-based health service delivery known as Community-based Health Planning and Services (CHPS). Fertility and mortality rates have generally declined over the period.

[1] In 2008 the Kassena-Nankana District was split into two districts – Kassena-Nankana East and Kassena-Nankana West districts. In this report we use the original name of the district to refer to the two districts.

Health and Demographic Surveillance System

The Navrongo Health and Demographic Surveillance System (HDSS) started in 1992 with an initial census. The first round of follow-up of all residents in the area took place in 1993. The aim of the HDSS is to monitor the demographic dynamics of the population in the area to provide the platform for health research that will inform policy decisions of health interventions. For operational or research purposes, the study area has been divided into five zones of North, South, East, West and Central. Please fin below a map of the study site showing the operational zones of the Navrongo Health and Demographic Surveillance System (NHDSS).



The field operations of the NHDSS involve visits to all households to collect and update health and demographic information of every individual resident in the area. Updates on health and demographic information were done every three months from 1993 to December 2005. From 2006 to 2008, updates were done three times in a year and in 2009, updates were done twice in a year. From January 2010 onwards, visits to households are done every four months.

Routine Vaccination data collection

From 2002 to 2010, all children aged two years or below and resident in the study site were visited and their vaccination information documented. The visits were done in the last quarter of the year within that period. From January 2011 onwards, all resident children aged three years or below are visited three times in a year and their vaccination records are documented. Vaccination information for new births being registered for the first time and children who have migrated into HDSS and are

aged three years or below at the start of the round data collection are also documented. All vaccination status information is being recorded from the health card of the child.

National Immunization schedules over the period: 2002-2013

Over the period covered in these analyses, pentavalent vaccine was introduced into the EPI schedule in 2002. In May 2012, rotavirus, pneumococcal and a second dose measles vaccine were also introduced into the EPI programme.

The current national EPI policy in Ghana is that each child should receive one dose of BCG at birth, four doses of OPV (at birth, 6, 10 and 14 weeks), three doses of penta (at 6, 10 and 14 weeks), two doses of rotavirus at (6 and 10 weeks), three doses of pneumococcal vaccines (at 6,10 and 14 weeks) two doses of measles (at 9 and 18 months) and one dose of yellow fever (at 9 months).

Vaccine administration in Navrongo HDSS

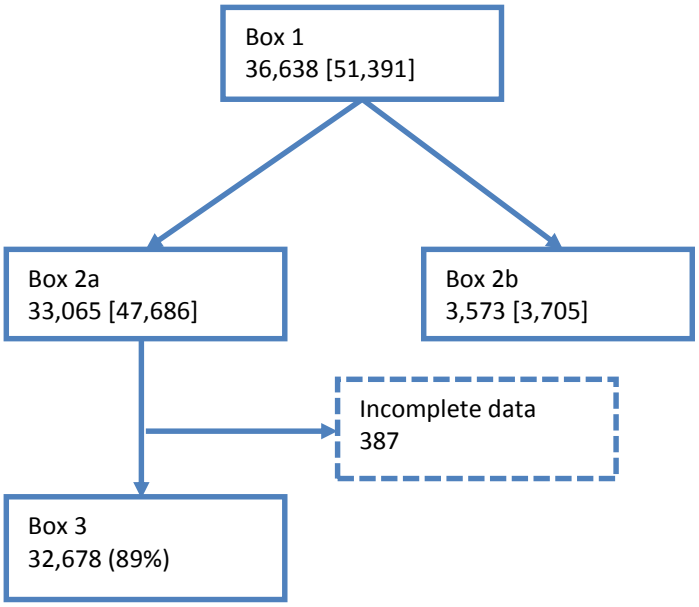
Vaccinations are given at all health facilities in the study area and supervised by the District Health Management Teams. There are also outreach services that are held for a community or a cluster of communities within a designated community and involve transporting service providers into these communities for vaccinations. In addition to these, there are Community Health Centres (CHCs) manned by trained nurses located in many of the hard to reach communities to provide basic primary health care services including the provision of routine vaccinations. The nurses in the CHCs also carry out home visits to give routine vaccinations to children who defaulted or missed some vaccines in their catchment areas using a register which contains the names and home addresses of children who visit the CHC for routine vaccinations and the vaccines they received.

The study area has one major hospital that acts as a referral hospital to seven health centers and a private clinic. There are over 40 Community Health Centres (CHCs) located in the communities to provide primary health care services. Navrongo HDSS covers two districts and each district is divided into sub-districts. Each sub district health team (SDHT) provides an integrated static and outreach EPI services to the communities in their catchment areas. The team often consists of Community Health Nurses, Field Assistants and Midwives. It is supervised by a Technical Officers (Disease Control) or more often by a Public Health Nurse. The Disease Control Officers/Field Assistants often manage the district and sub district cold chain whilst vaccination is given largely by the Community Health Nurses or Officers.

The static services for routine vaccinations are held at the health facilities levels whilst the outreach services are held in the communities. If a child is due for any vaccine, the mother simply needs to take the child to the nearest health facility to receive the vaccine. With the implementation of the Community Health and Planning Services (CHPS) in the study area, nurses have been relocated to the communities to provide primary health care including vaccinations. These nurses sometimes move from house to house to provide vaccinations services.

Other vaccinations service delivery strategies used are mass immunization campaigns e.g. Nation Immunization Days (NIDs). Immunization services are free in the area.

Figure 1 Flow chart of inclusion for Navrongo 2002-13



Box 1
Number of children alive at an HDSS home visit between 12 and 23 months of age
[Number of visits asking for vaccine card]

Box 2a
Number of children from box 1 having at least one visit with card seen
[Number of visits for these children including those where card not seen]

Box 2b
Number of children from box 1 having no seen card at any visit between 12 and 23 months of age
[Number of visits]

Box 3
Number of children included in analyses

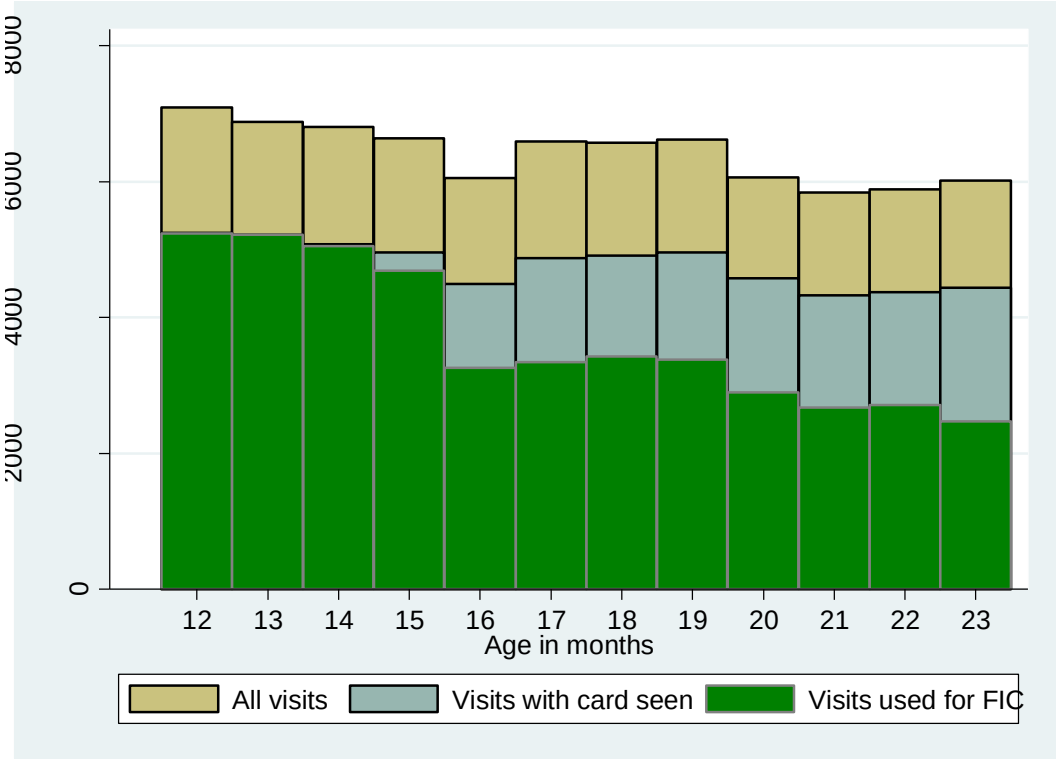
Table 1 Inclusion per year of visit

Year of Visit	Inclusion % (n/total)
2002	91 (2540/2783)
2003	84 (2703/3227)
2004	89 (2798/3142)
2005	85 (2701/3185)
2006	91 (2527/2766)
2007	82 (2474/3013)
2008	85 (2743/3211)
2009	90 (2215/2449)
2010	88 (1416/1609)
2011	91 (3941/4342)
2012	97 (3329/3444)
2013	95 (3291/3467)
Total	89 (32678/36638)

Table 2 Percent of children per year having no vaccination card

Year of Visit	No card % (n/total)
2002	3 (84/2783)
2003	1.5 (48/3227)
2004	1.8 (55/3142)
2005	0.8 (27/3185)
2006	0.6 (16/2766)
2007	0.3 (10/3013)
2008	0.3 (10/3211)
2009	0.1 (2/2449)
2010	0.7 (11/1609)
2011	0 (0/4342)
2012	0 (1/3444)
2013	0 (0/3467)
Total	0.7 (264/36638)

Figure 2 Histogram of visits from flow chart



All visits = Visits from Box 1
Visits with card seen = Visits from Box 2a
Visits used for FIC = Visits from Box 3

Table 3 Representativeness – comparison children included and excluded from the analyses

Variable	Included N (%)	Excluded N (%)	
Sex			
Male	16448 (50)	1975 (50)	0.659
Female	16230 (50)	1978 (50)	
Place of residence			
Rural	28255 (86)	3282 (83)	<0.001
Urban	4423 (14)	678 (17)	
Zone			
Central	2377 (7)	374 (9)	<0.001
North	7307 (22)	946 (24)	
South	10468 (32)	1070 (27)	
East	5884 (18)	671 (17)	
West	6642 (20)	899 (23)	
Twinning			
Yes	862 (3)	71 (2)	<0.001
No	28416 (87)	3178 (80)	
Missing	3400 (10)	711 (18)	
Ethnicity			
Kasem	15141 (46)	1870 (47)	<0.001
Nankam	14255 (44)	1507 (38)	
Buli	693 (2)	68 (2)	
Other	713 (2)	106 (3)	
Missing	1876 (6)	409 (10)	
Religion			
Traditional	13318 (41)	1547 (39)	<0.001
Christian	15458 (47)	1734 (44)	
Islam	1953 (6)	252 (6)	
Missing	1949 (6)	427 (11)	
Birth order			
1	8592 (26)	1247 (31)	<0.001
2-4	15649 (48)	1812 (46)	
5+	7839 (24)	724 (18)	
Missing	598 (2)	177 (4)	
Place of delivery			
Health facility	13777 (42)	1371 (35)	<0.001
Home/other	12726 (39)	1592 (40)	
Missing	6175 (19)	997 (25)	
Mother's education			
No education	12321 (38)	1498 (38)	<0.001
Primary/JSS	16018 (49)	1787 (45)	
Secondary/tertiary	2992 (9)	365 (9)	
Missing	1347 (4)	310 (8)	
Maternal age			
<20	3397 (10)	496 (13)	<0.001
20-34	20574 (63)	2472 (62)	
35+	7817 (24)	759 (19)	
Missing	890 (3)	233 (6)	
Wealth index *			
Poorest	7978 (24)	893 (23)	<0.001
Poorer	6491 (20)	748 (19)	
Poor	6122 (19)	751 (19)	
Less poor	6427 (20)	767 (19)	
Least poor	4569 (14)	631 (16)	
Missing	1091 (3)	170 (4)	
Season			
Rainy	17011 (52)	2108 (53)	0.162
Dry	15667 (48)	1852 (47)	

* The assets used for the wealth index is found in the next table

Assets used for the wealth index

Car	Sewing machine	Grinding mill
Motor bike	Stereo	Cattle
Bicycle	Iron	Sheep
Kerosene stove	Fan	Donkey
Electricity	Mobile phone	Goat
Solar	Gas stove	Pig
Refrigerator	Donkey car Tractor	Horse
DVD player		Ownership of land
Radio		

Table 4 FIC coverage by year of visit

Year of Visit	FIC coverage % (n/total)
2002	68 (1717/2540)
2003	70 (1880/2703)
2004	77 (2146/2798)
2005	78 (2116/2701)
2006	80 (2014/2527)
2007	82 (2035/2474)
2008	84 (2291/2743)
2009	90 (1996/2215)
2010	89 (1256/1416)
2011	91 (3596/3941)
2012	91 (3030/3329)
2013	87 (2876/3291)
Total	82 (26953/32678)

Figure 3 FIC coverage by year of visit

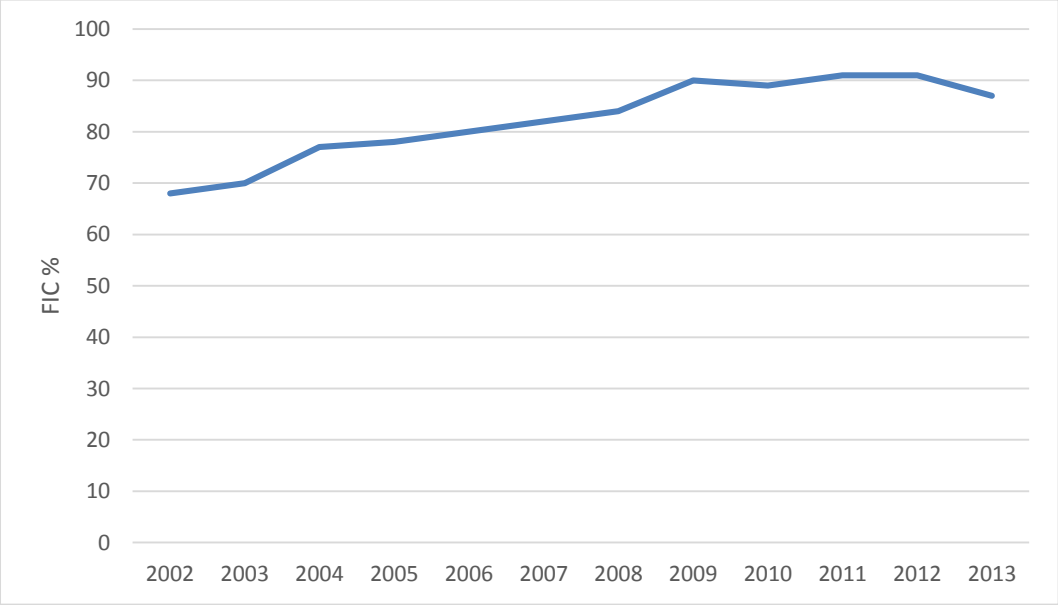


Table 5 Coverage of FIC by year of visit and sex

Year of Visit	Sex		
	Females	**Males**	Total
2002	68 (847/1251)	67 (870/1289)	68 (1717/2540)
2003	70 (901/1292)	69 (979/1411)	70 (1880/2703)
2004	77 (1047/1367)	77 (1099/1431)	77 (2146/2798)
2005	78 (1053/1349)	79 (1063/1352)	78 (2116/2701)
2006	79 (963/1212)	80 (1051/1315)	80 (2014/2527)
2007	81 (1006/1235)	83 (1029/1239)	82 (2035/2474)
2008	84 (1156/1384)	84 (1135/1359)	84 (2291/2743)
2009	90 (982/1087)	90 (1014/1128)	90 (1996/2215)
2010	91 (658/720)	86 (598/696)	89 (1256/1416)
2011	91 (1786/1966)	92 (1810/1975)	91 (3596/3941)
2012	91 (1539/1690)	91 (1491/1639)	91 (3030/3329)
2013	88 (1471/1677)	87 (1405/1614)	87 (2876/3291)
Total	83 (13409/16230)	82 (13544/16448)	82 (26953/32678)

Table 6 Coverage of FIC by year and Place of residence

Year of Visit	Place of residence		
	Rural	**Urban**	**Total**
2002	66 (1469/2241)	83 (248/299)	68 (1717/2540)
2003	67 (1605/2380)	85 (275/323)	70 (1880/2703)
2004	75 (1847/2448)	85 (299/350)	77 (2146/2798)
2005	77 (1822/2362)	87 (294/339)	78 (2116/2701)
2006	79 (1747/2203)	82 (267/324)	80 (2014/2527)
2007	81 (1729/2128)	88 (306/346)	82 (2035/2474)
2008	83 (1964/2379)	90 (327/364)	84 (2291/2743)
2009	90 (1762/1954)	90 (234/261)	90 (1996/2215)
2010	88 (1060/1203)	92 (196/213)	89 (1256/1416)
2011	91 (2992/3285)	92 (604/656)	91 (3596/3941)
2012	91 (2647/2907)	91 (383/422)	91 (3030/3329)
2013	87 (2419/2765)	87 (457/526)	87 (2876/3291)
Total	82 (23063/28255)	88 (3890/4423)	82 (26953/32678)

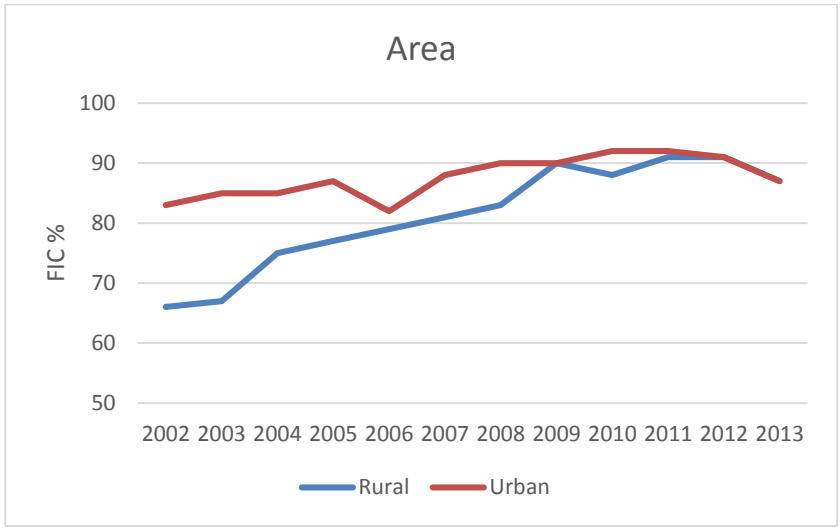
Table 7 Coverage of FIC by year of visit and Socio-economic status (wealth index)

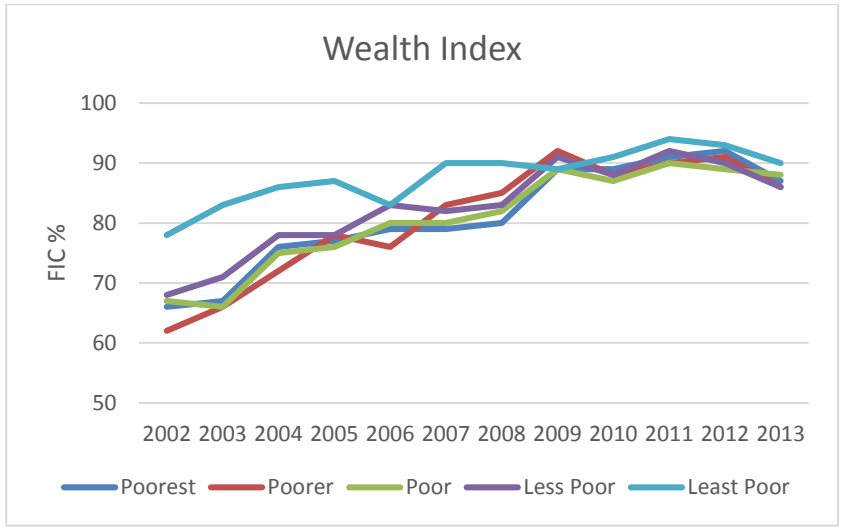
Year of Visit	Wealth index					
	Poorest	Poorer	Poor	Less Poor	Least Poor	Total
2002	66 (401/605)	62 (342/548)	67 (331/492)	68 (348/510)	78 (269/343)	68 (1691/2498)
2003	67 (453/676)	66 (353/531)	66 (350/529)	71 (395/559)	83 (286/345)	70 (1837/2640)
2004	76 (521/690)	72 (428/593)	75 (397/526)	78 (441/566)	86 (300/349)	77 (2087/2724)
2005	77 (550/710)	78 (421/542)	76 (404/535)	78 (390/498)	87 (295/340)	78 (2060/2625)
2006	79 (490/619)	76 (398/524)	80 (417/523)	83 (353/426)	83 (250/303)	80 (1908/2395)
2007	79 (490/618)	83 (397/480)	80 (363/454)	82 (408/496)	90 (300/335)	82 (1958/2383)
2008	80 (541/679)	85 (488/573)	82 (430/522)	83 (413/497)	90 (339/378)	83 (2211/2649)
2009	89 (511/571)	92 (403/440)	89 (329/370)	91 (416/457)	89 (272/305)	90 (1931/2143)
2010	89 (286/323)	88 (241/274)	87 (220/252)	88 (274/310)	91 (196/216)	89 (1217/1375)
2011	91 (851/933)	90 (643/716)	90 (615/682)	92 (757/825)	94 (612/652)	91 (3478/3808)
2012	92 (719/785)	91 (625/685)	89 (565/636)	90 (585/648)	93 (434/465)	91 (2928/3219)
2013	87 (671/769)	86 (505/585)	88 (530/601)	86 (548/635)	90 (484/538)	88 (2738/3128)
Total	81 (6484/7978)	81 (5244/6491)	81 (4951/6122)	83 (5328/6427)	88 (4037/4569)	82 (26044/31587)

Table 8 Coverage of FIC by year of visit and maternal education

Year of Visit	Maternal education			
	No education	Primary/JSS	Secondary/Tertiary	Total
2002	60 (696/1164)	72 (820/1138)	89 (158/178)	68 (1674/2480)
2003	63 (754/1205)	73 (894/1228)	88 (185/211)	69 (1833/2644)
2004	75 (954/1268)	77 (991/1279)	83 (161/193)	77 (2106/2740)
2005	76 (850/1123)	80 (1027/1290)	87 (198/227)	79 (2075/2640)
2006	78 (837/1080)	81 (963/1194)	88 (179/204)	80 (1979/2478)
2007	80 (740/930)	83 (1064/1275)	89 (194/219)	82 (1998/2424)
2008	82 (836/1021)	84 (1180/1411)	93 (229/247)	84 (2245/2679)
2009	90 (734/814)	90 (1035/1150)	93 (192/206)	90 (1961/2170)
2010	84 (370/438)	91 (695/767)	92 (136/148)	89 (1201/1353)
2011	89 (1153/1289)	92 (1873/2044)	96 (444/463)	91 (3470/3796)
2012	90 (979/1084)	91 (1544/1693)	95 (328/344)	91 (2851/3121)
2013	88 (793/905)	88 (1358/1549)	91 (320/352)	88 (2471/2806)
Total	79 (9696/12321)	84 (13444/16018)	91 (2724/2992)	83 (25864/31331)

Figure 4 FIC Coverage by key factors





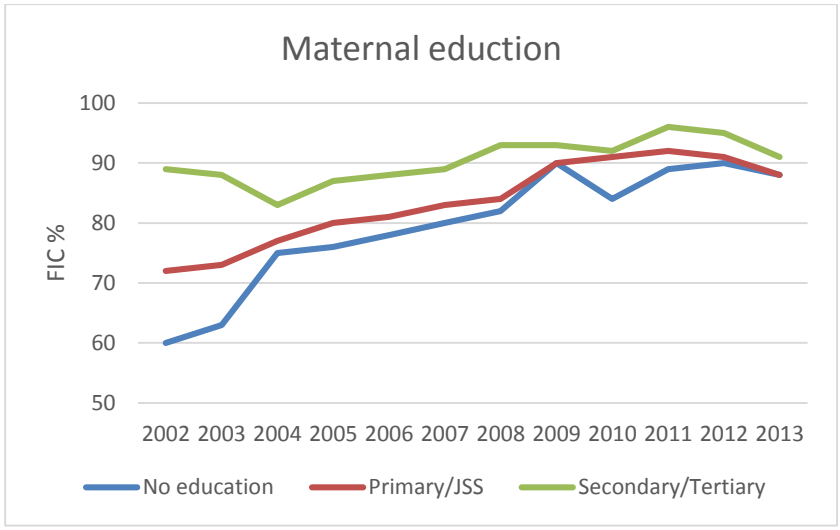
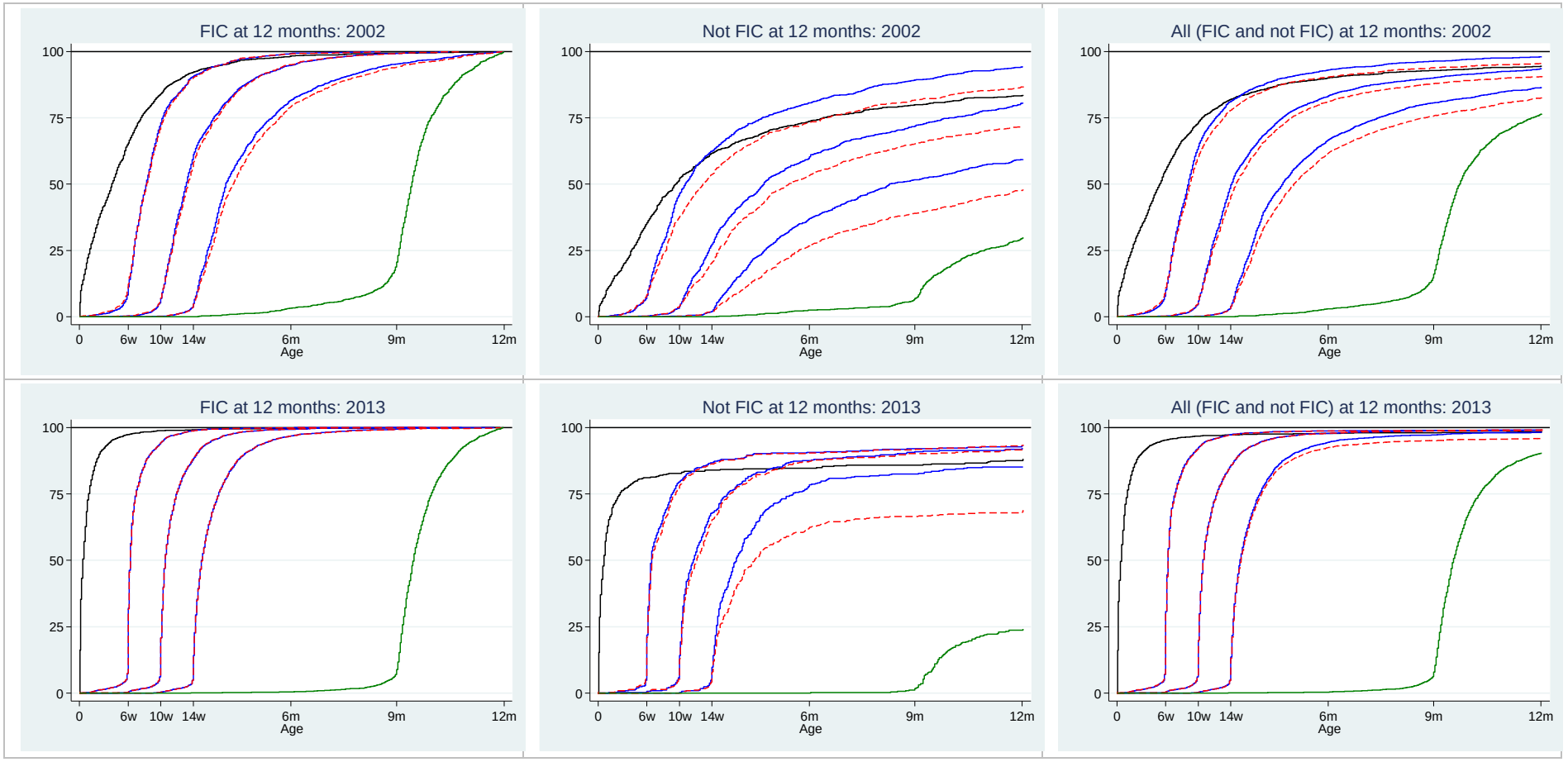


Figure 5 Coverage curves for each vaccine among FIC, NOT FIC, and combined



BCG is black; Penta is blue; OPV is dashed and red; MCV is green

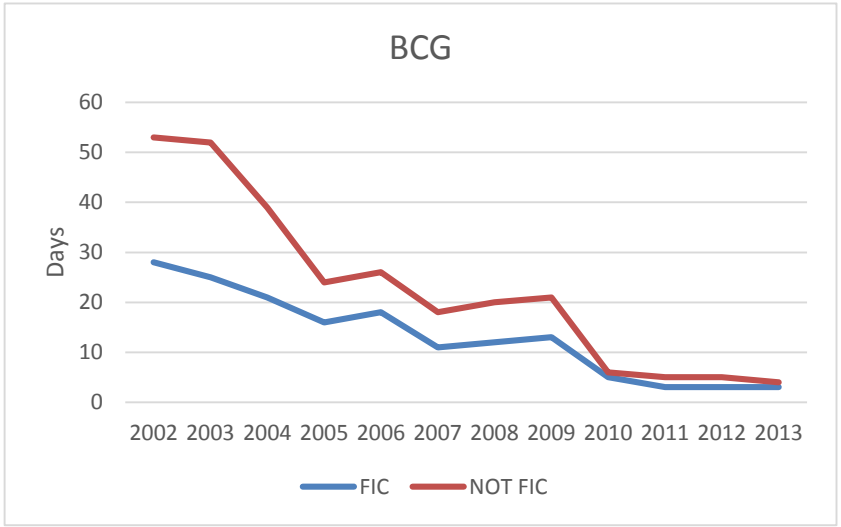
Table 9 Median vaccination age and lower and upper quartiles for FIC

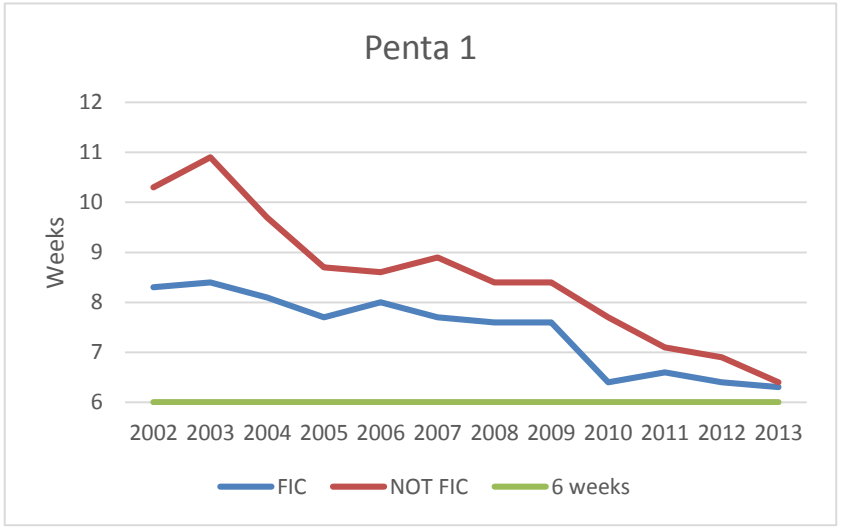
Year of visit	BCG (days)			Penta 1 (weeks)			Penta 2 (weeks)			Penta 2 (weeks)			OPV 1 (weeks)			OPV 2 (weeks)			OPV 3 (weeks)			MCV (weeks)		
	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
2002	9	28	53	6.7	8.3	10	11.3	13.1	16.6	15.7	18	23.7	6.7	8.3	10.4	11.4	13.3	17	16.1	18.9	24.6	39.3	40.9	43.3
2003	6	25	50	6.9	8.4	11	11.7	13.9	17.9	16.4	19.9	26.3	6.9	8.4	11	11.7	14	18	16.4	20	26.4	39.4	41.3	44.3
2004	4	21	49	6.7	8.1	11	11.6	13.9	17.9	16.7	20	25.6	6.7	8.3	10.7	11.7	14	17.9	16.9	20.1	25.7	39.6	41.4	44.4
2005	3	16	38	6.6	7.7	9.9	11.3	13.3	16.6	16.1	19.1	23.6	6.6	7.7	9.9	11.4	13.4	16.7	16.3	19.3	23.7	39.4	41.4	44.4
2006	5	18	47	6.7	8	9.9	11.4	13.3	16.1	16.3	19	23.3	6.7	8	10	11.4	13.3	16.3	16.3	19	23.3	39.9	41.7	44.4
2007	3	11	31	6.6	7.7	9.6	11.1	13	15.6	16	18.4	22.4	6.6	7.9	9.9	11.3	13	15.9	16.1	18.6	22.6	39.9	41.7	44.1
2008	3	12	31	6.4	7.6	9.4	11	12.6	15.1	15.7	18	21.6	6.4	7.6	9.4	11.1	12.7	15.3	15.9	18	21.7	39.9	41.7	44.1
2009	3	13	31	6.4	7.6	9.3	11	12.7	15.3	15.7	18	21.7	6.4	7.6	9.4	11	12.9	15.4	15.7	18	21.7	39.7	41.1	43.4
2010	1	5	12	6.1	6.4	7.9	10.3	11	13.3	14.6	15.9	18.9	6.1	6.4	7.9	10.3	11	13.4	14.6	15.9	19	39.7	41	43.3
2011	1	3	9	6.1	6.6	8	10.3	11.3	13.4	14.6	16.1	18.9	6.1	6.6	8.1	10.3	11.3	13.4	14.6	16.1	18.9	39.9	41.1	43.3
2012	1	3	9	6	6.4	7.7	10.1	11	12.9	14.4	15.6	17.9	6	6.4	7.7	10.1	11	12.9	14.4	15.6	18	39.7	41.1	43.3
2013	1	3	8	6	6.3	7	10.1	10.6	12	14.3	15	17.1	6	6.3	7	10.1	10.6	11.9	14.3	15.1	17.1	39.7	41.1	43.3

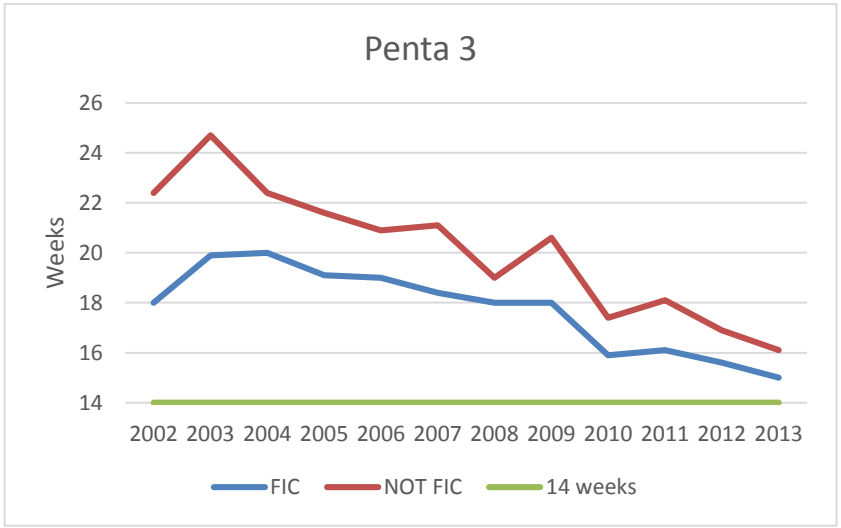
Table 10 Median vaccination age and lower and upper quartiles for NOT FIC with a vaccine

Year of visit	BCG (days)			Penta 1 (weeks)			Penta 2 (weeks)			Penta 2 (weeks)			OPV 1 (weeks)			OPV 2 (weeks)			OPV 3 (weeks)			MCV (weeks)		
	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
2002	25	53	104	7.6	10.3	18	13	17.4	26.6	17.4	22.4	32	7.3	10.3	16.7	13.6	18.3	28.7	18.5	24.3	34.5	39.4	41.5	45.3
2003	20	52	101	8	10.9	18.6	13.3	18.9	29.1	18.9	24.7	35	8	11.4	18.4	13.7	19.4	28.4	19.3	26.3	38.3	39.7	42.6	46.6
2004	12	39	70	7.4	9.7	13.7	12.9	16.1	22.3	17.9	22.4	29.3	7.3	9.7	13.9	13	16.6	22.7	18	22.6	29.4	39.3	41.3	44.7
2005	6	24	56	6.9	8.7	12.9	12.3	15.4	21	17.7	21.6	29.3	6.9	9.1	12.9	12.4	15.4	21.4	18.1	21.9	29.4	39.4	41.8	44.6
2006	6	26	62	6.9	8.6	11.3	12	14.9	19.6	17.1	20.9	26.6	6.9	8.7	11.8	12.1	15.1	19.9	17.1	21	26.7	40.4	41.9	45.1
2007	6	18	48	6.9	8.9	11.7	12.1	15.1	19.6	16.9	21.1	26.9	7	9.1	12.4	12.3	15.6	20.4	17.9	21.9	29.3	39.9	41.7	44.6
2008	5	20	45	6.9	8.4	10.9	11.9	13.9	17.4	16.4	19	23.9	6.9	8.7	11.6	12	14.3	18	16.6	19.1	24.3	40.6	43.6	46.4
2009	4	21	59	6.7	8.4	11	11.9	14.2	19	16.6	20.6	25.3	6.9	8.9	11.1	12	14.4	19	17.1	21.3	25.7	39.3	41.1	43.3
2010	2	6	19	6.3	7.7	9.9	10.6	12.4	15.5	15.6	17.4	23.3	6.3	8	10.4	10.7	12.9	17	15.9	17.9	23.6	40.3	42.2	47.4
2011	1	5	17	6.3	7.1	9.6	10.9	12.9	16.9	15.6	18.1	22.9	6.3	7.1	9.7	10.9	12.9	17	15.4	18.6	23.7	40.1	42.4	45.6
2012	1	5	13	6.1	6.9	8.9	10.4	11.9	14.6	14.9	16.9	19.7	6.3	7	9.1	10.6	12.1	14.7	15	17.1	20.7	40.6	42	44.7
2013	1	4	10	6.1	6.4	8.6	10.3	11.3	14.6	14.4	16.1	19.4	6.1	6.6	8.9	10.3	11.6	14.9	14.6	16.4	19.9	40.1	41.8	44

Figure 6 Comparison of median vaccination age of FIC and NOT FIC







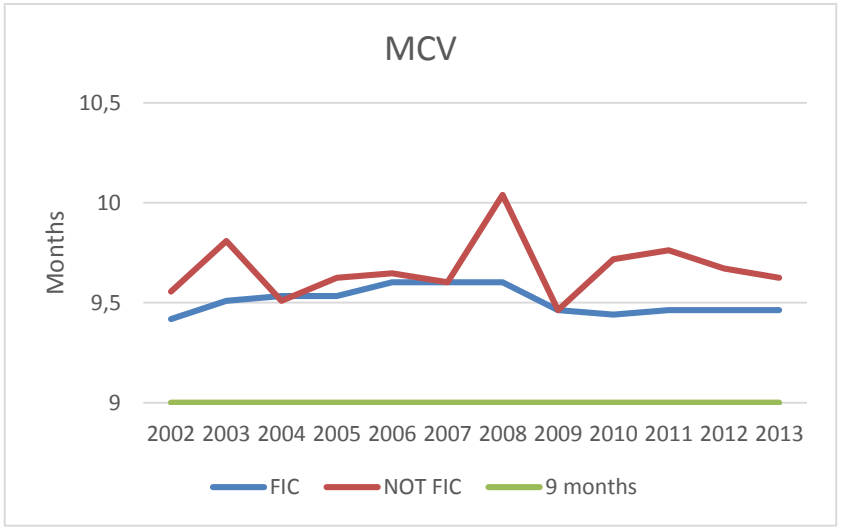


Table 11 Among children NOT FIC, missing a specific vaccine

Year of visit	BCG	Penta 1	Penta 2	Penta 3	OPV 1	OPV 2	OPV 3	MCV	Number NOT FIC
2002	17.1	6	20	42	6.1	17.4	48	72.8	823
2003	15.8	9.7	19.9	40.5	8	20.2	45.7	78.4	823
2004	17.2	6.3	10.3	24.2	5.5	10.9	31.3	76.4	652
2005	14.2	4.6	9.4	19	3.9	9.4	23.6	83.6	585
2006	22.4	5.3	9.2	17.9	4.5	8.8	27.9	74.9	513
2007	14.6	3.9	7.3	18	3.4	8.4	30.3	73.1	439
2008	17.7	5.1	7.1	15.9	4.2	7.3	22.6	81.2	452
2009	14.2	2.3	5	13.7	2.3	4.6	21.9	72.1	219
2010	14.4	11.3	15	17.5	6.3	13.8	26.9	81.3	160
2011	9.3	5.2	7.2	13.9	4.3	6.4	23.8	79.7	345
2012	9.4	3.3	5	10.4	2.7	4.3	21.7	77.6	299
2013	12.5	7	8	14.9	5.3	7.7	29.4	76.9	415
Total	15.6	6	11.7	24.3	5.1	11.3	32.3	77.2	5,725

Figure 7 Among NOT FIC percent of missing a particular vaccine

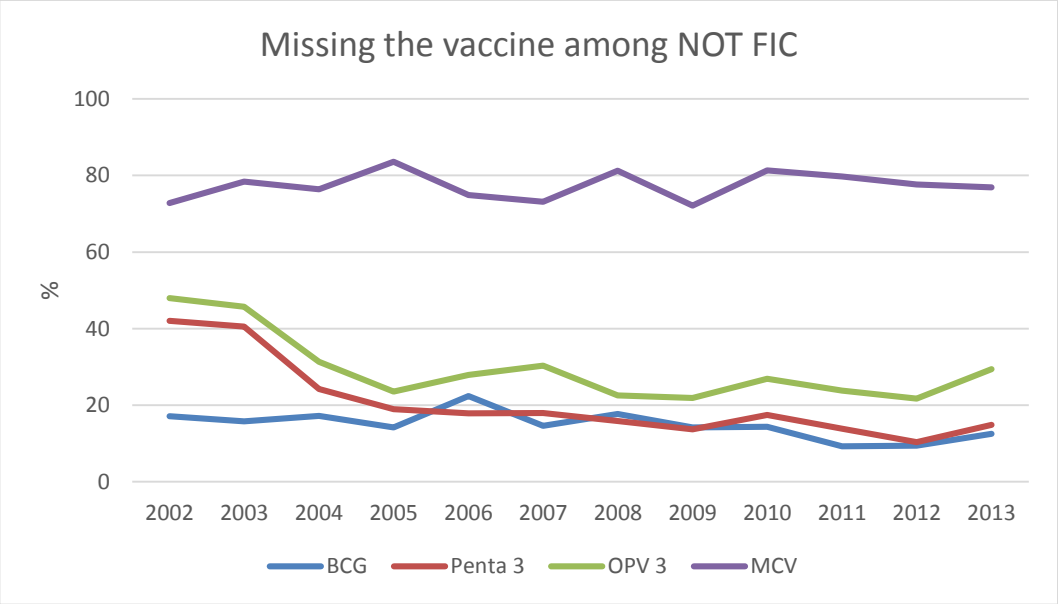


Table 12 Among children NOT FIC, missing only the particular vaccine

Year of visit	BCG	Penta 3	OPV 3	MCV
2002	7.1	2.7	9.7	34.6
2003	6.1	2.7	7.2	40.6
2004	8.6	1.1	8.7	55.2
2005	6.8	0.9	5.5	63.8
2006	12.7	0.8	10.1	53.8
2007	8.2	2.7	11.9	56.7
2008	8.2	1.3	6.4	64.4
2009	9.6	3.2	12.3	62.1
2010	5.6	1.9	10	63.1
2011	4.4	1.7	11.3	68.1
2012	6	1.3	11.4	69.9
2013	4.8	0.7	13.3	62.2
Total	7.4	1.8	9.3	54.3

Table 13 Among children NOT FIC, number of vaccines missing

	Number of vaccines missing							
Year of visit	1	2	3	4	5	6	7	8
2002	54.1	13.1	11.4	6.4	8.0	2.1	2.3	2.6
2003	56.5	10.7	11.4	3.3	8.0	2.4	3.0	4.6
2004	73.6	7.2	8.6	1.2	2.9	0.9	0.9	4.6
2005	76.9	8.9	4.1	1.4	3.9	1.0	0.7	3.1
2006	77.4	8.0	4.9	1.0	2.3	1.8	0.8	3.9
2007	79.5	7.06	5.0	1.8	2.3	0.5	2.1	1.8
2008	80.3	6.6	5.1	1.3	0.7	1.8	0.7	3.5
2009	87.2	5.9	1.8	0.9	1.4	0.5	0.0	2.3
2010	80.6	3.8	1.3	0.6	3.8	3.1	0.63	6.25
2011	85.5	4.6	2.9	0.6	1.5	0.6	1.45	2.9
2012	88.6	5.0	2.0	0.3	0.7	0.7	0.3	2.3
2013	81.0	7.2	3.9	0.7	0.5	1.5	1.7	3.6
Total	72.8	8.3	6.6	2.2	3.8	1.5	1.5	3.5

Table 14 Full immunization coverage in sequence (FICIS) among FIC

Year of visit	FICIS % (n/FIC)
2002	47 (806/1717)
2003	56 (1045/1880)
2004	57 (1231/2146)
2005	65 (1367/2116)
2006	57 (1147/2014)
2007	60 (1219/2035)
2008	69 (1589/2291)
2009	74 (1483/1996)
2010	85 (1071/1256)
2011	88 (3170/3596)
2012	87 (2638/3030)
2013	84 (2414/2876)
Total	71 (19180/26953)

FIC-in-sequence (FICIS) is defined as the strict WHO recommended sequence of vaccinations, i.e. BCG before OPV1, OPV1=Penta1, OPV2=Penta2, OPV3=Penta3 and Penta3 before MCV.

Figure 8 Coverage of FIC-in-sequence among FIC

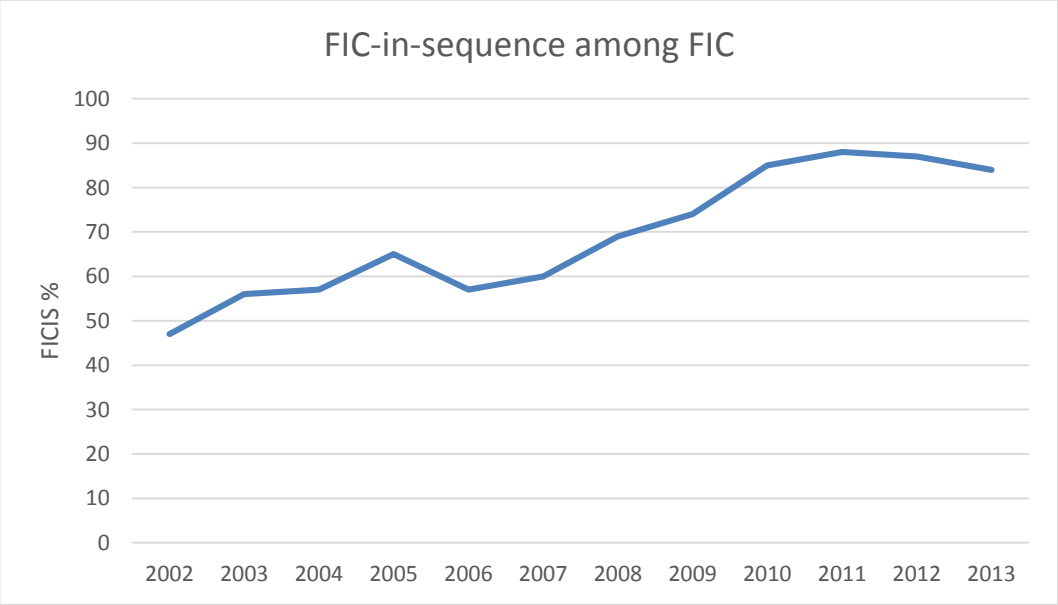


Figure 9 Coverage of FIC-in-sequence among FIC for key factors

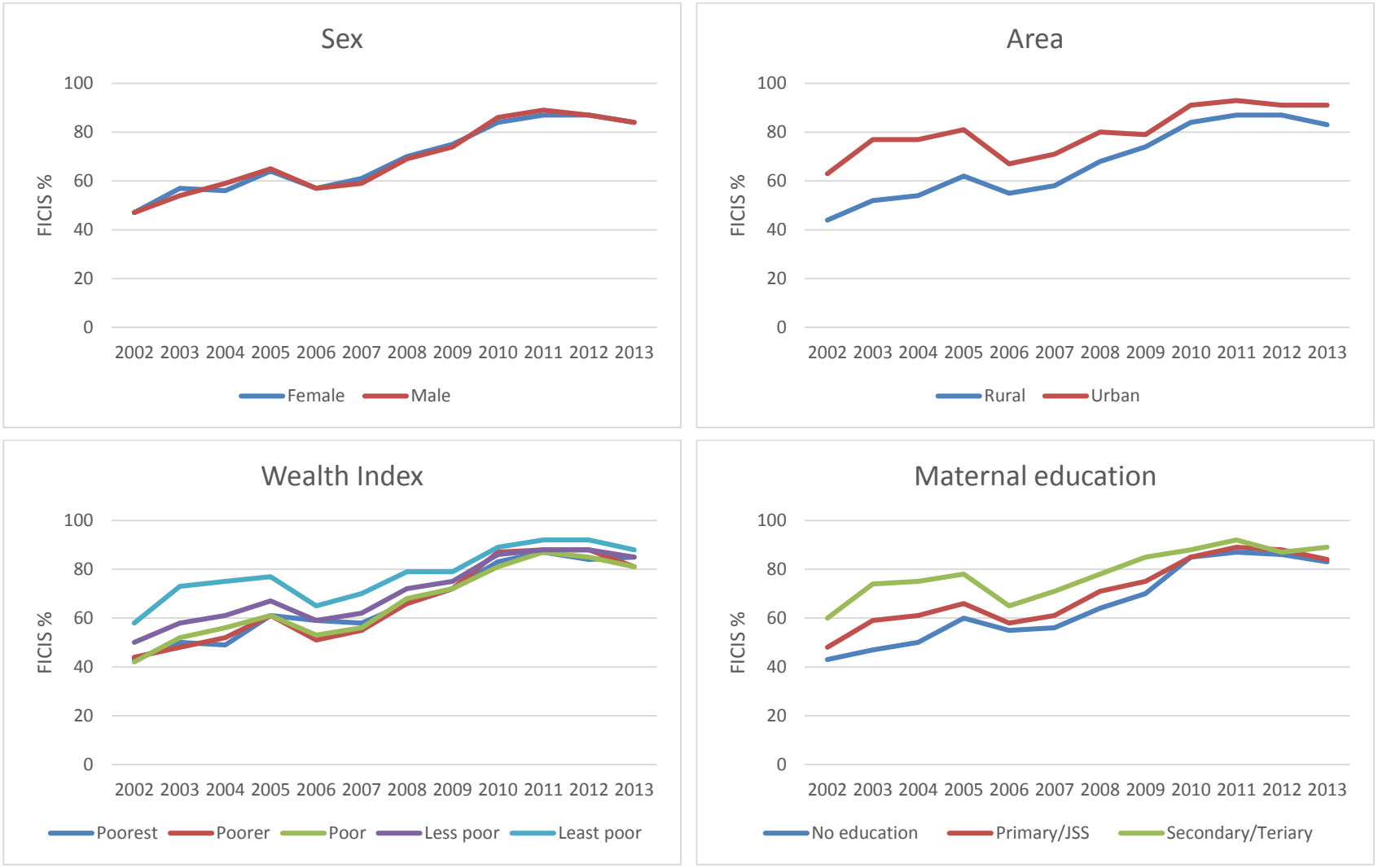


Table 15 Main reasons for out-of-sequence for FIC who are out-of-sequence (FICOS)

Year of Visit	Type of out-of-sequence % (n)			Total FICOS
	BCG ≥ Penta1 or MCV	OPV ≠ Penta	Penta ≥ MCV	
2002	64 (581)	50 (459)	11 (97)	911
2003	64 (535)	44 (367)	11 (90)	835
2004	64 (585)	46 (425)	10 (96)	915
2005	59 (444)	48 (360)	7 (54)	749
2006	57 (498)	57 (491)	5 (47)	867
2007	41 (335)	69 (565)	5 (41)	816
2008	49 (342)	59 (414)	6 (41)	702
2009	53 (273)	54 (276)	5 (25)	513
2010	29 (53)	75 (139)	6 (12)	185
2011	29 (122)	74 (317)	6 (24)	426
2012	20 (77)	83 (325)	5 (18)	392
2013	13 (62)	89 (412)	4 (17)	462
Total	50 (3907)	59 (4550)	7 (562)	7,773

Note: Percentages do not sum to 100 as children may contribute to more than one type of out-of-sequence

Figure 10 Reason for out-of-sequence among FICOS

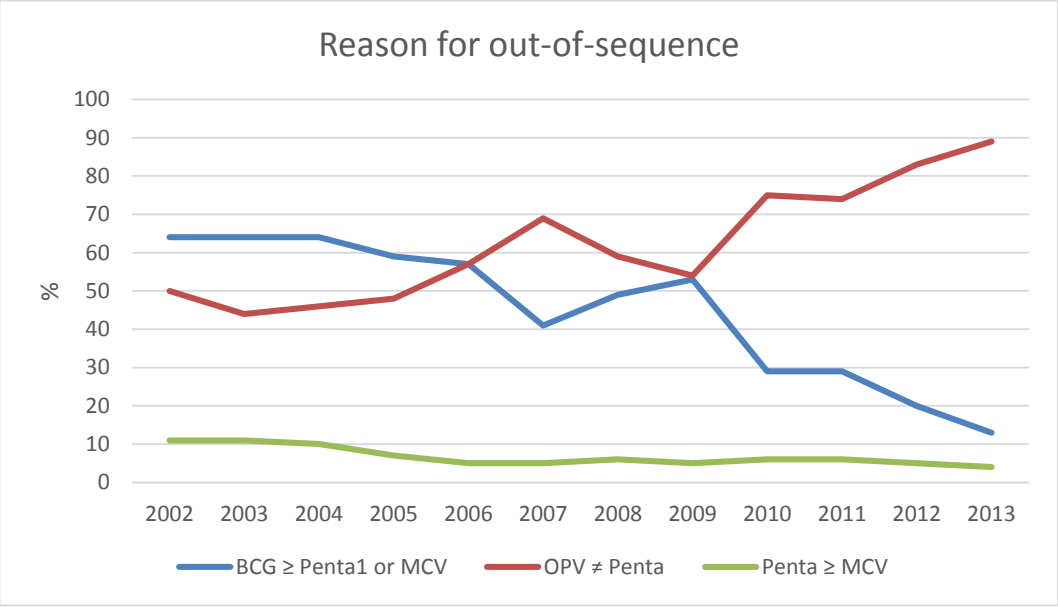
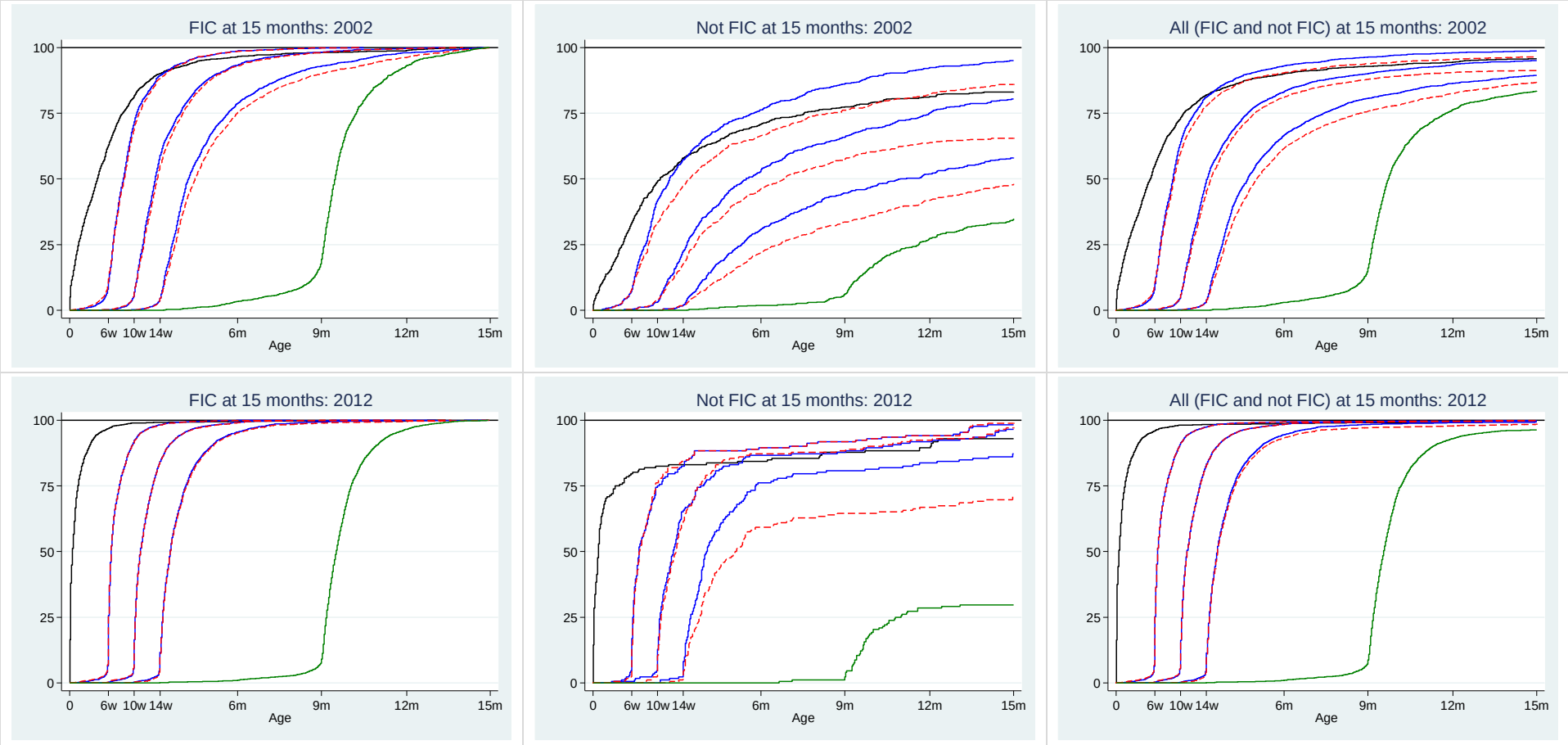


Figure 11 FIC15 Coverage curves for each vaccine among FIC, NOT FIC, and combined



BCG is black; Penta is blue; OPV is dashed and red; MCV is green
26,632 children included, i.e.81% (26632/32678) of the children in the overall FIC analyses (see Figure 1)

Table 16 Fully Vaccination coverage at 24 months (FIC24) for NOT FIC at 12 months of age

Year of Visit for FIC12	Percent (FIC24/N)
2002	50 (19/38)
2003	51 (25/49)
2004	57 (20/35)
2005	72 (43/60)
2006	74 (46/62)
2007	81 (38/47)
2008	88 (122/139)
2009	79 (60/76)
2010	79 (88/112)
2011	80 (218/271)
2012	77 (161/209)
2013	85 (28/33)
Total	77 (868/1131)

Figure 12 Coverage of FIC24 among NOT FIC at 12 months

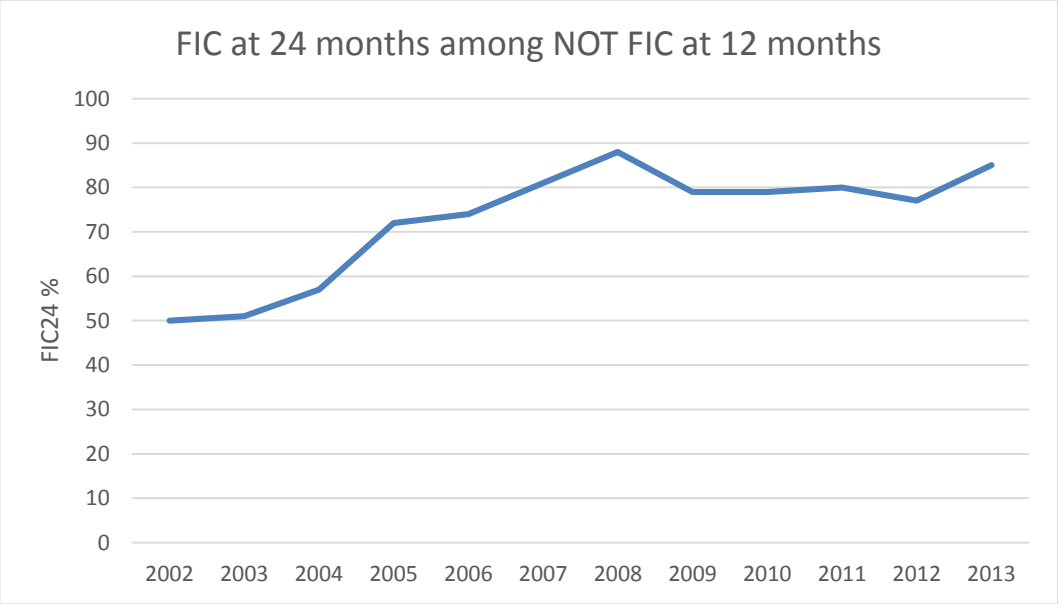


Table 17 Analyses of association between background factors and FIC

Variable	N (%)	FIC %	Unadjusted PR (95%CI)	Adjusted PR (95%CI)
Sex			[0.999]	[0.995]
Male	15159 (50)	84	1	1
Female	14979 (50)	84	1.00 (0.99-1.01)	1.00 (0.99-1.01)
Interview period			[<0.001]	[<0.001]
2003-2005	8202 (27)	75	1	1
2006-2009	9959 (33)	84	1.11 (1.09-1.13)	1.09 (1.08-1.12)
2010-2013	11977 (40)	90	1.19 (1.17-1.21)	1.16 (1.15-1.19)
Place of residence			[<0.001]	[<0.001]
Central	2225 (7)	89	1.14 (1.12-1.16)	1.02 (0.97-1.06)
North	6740 (22)	84	1.06 (1.05-1.08)	0.99 (0.95-1.02)
South	9651 (32)	84	1.07 (1.05-1.08)	1.04 (1.02-1.05)
East	5473 (18)	78	1	1
West	6049 (20)	87	1.11 (1.08-1.12)	1.02 (0.99-1.05)
Twinning			[<0.001]	[<0.001]
Yes	846 (3)	91	1.07 (1.05-1.09)	1.07 (1.04-1.09)
No	26179 (87)	84	1	1
Missing	3113 (10)	79	-	-
Ethnicity			[<0.001]	[<0.001]
Kasem	13979 (46)	86	1.05 (1.04-1.07)	1.05 (1.02-1.08)
Nankam	13241 (44)	81	1	1
Buli	643 (2)	89	1.09 (1.06-1.13)	1.06 (1.02-1.11)
Other	669 (2)	85	1.07 (1.03-1.11)	1 (0.94-1.06)
Missing	1606 (5)	81		
Religion			[<0.001]	[<0.001]
Traditional	12360 (41)	81	1	1
Christian	14273 (47)	86	1.06 (1.05-1.08)	1.03 (1.02-1.04)
Islam	1828 (6)	86	1.08 (1.06-1.11)	1.04 (1.01-1.06)
Missing	1677 (6)	81	-	-
Birth order			[<0.001]	[0.941]
1	7996 (27)	85	1.04 (1.02-1.05)	1 (0.98-1.02)
2 - 4	14386 (48)	84	1.03 (1.01-1.04)	1 (0.98-1.02)
5+	7180 (24)	82	1	1
Missing	576 (2)	78	-	-
Place of delivery			[<0.001]	[<0.001]
Health facility	13767 (46)	89	1.11 (1.09-1.12)	1.03 (1.02-1.05)
Home/other	12707 (42)	80	1	1
Missing	3664 (12)	77	-	
Mother's education			[<0.001]	[<0.001]
No education	11157 (37)	81	1	1
Primary/JSS	14880 (49)	85	1.04 (1.03-1.05)	1.01 (1-1.03)
Secondary/tertiary	2814 (9)	91	1.12 (1.11-1.14)	1.06 (1.04-1.08)
Missing	1287 (4)	81		
Maternal age			[<0.001]	[0.084]
<20	3132 (10)	83	1	1
20-34	19027 (63)	85	1.02 (1-1.04)	1.02 (1-1.04)
35+	7151 (24)	82	0.99 (0.97-1.01)	1.01 (0.98-1.04)
Missing	828 (3)	79	-	-
Wealth index			[<0.001]	[0.111]
Poorest	7373 (24)	83	1	1
Poorer	5943 (20)	82	1.00 (0.98-1.02)	1 (0.98-1.01)
Poor	5630 (19)	82	0.99 (0.97-1.01)	0.99 (0.97-1)
Less poor	5917 (20)	84	1.02 (1-1.03)	1 (0.98-1.02)
Least poor	4226 (14)	89	1.08 (1.06-1.09)	1.02 (1-1.05)
Missing	1049 (3)	84		
Season of birth			[0.002]	[0.001]
Rainy	15771 (52)	85	1.02 (1.01-1.03)	1.02 (1.01-1.03)
Dry	14367 (48)	82	1	1

Table 18 Analyses of association between background factors and FICIS among FIC

Variable	N (%)	FICIS %	Unadjusted PR (95%CI)	Adjusted PR (95%CI)
Sex			[0.823]	[0.898]
Male	13544 (50)	71	ref	Ref
Female	13409 (50)	71	1.00 (0.99-1.02)	1.00 (0.98-1.02)
Interview period			[<0.001]	[<0.001]
2003-2005	7859 (29)	57	ref	Ref
2006-2009	8336 (31)	65	1.10 (1.07-1.13)	1.09 (1.06-1.13)
2010-2013	10758 (40)	86	1.46 (1.43-1.50)	1.42 (1.39-1.46)
Place of residence			[<0.001]	[<0.001]
Central	2106 (8)	80	1.28 (1.23-1.32)	0.96 (0.88-1.04)
North	6068 (23)	75	1.21 (1.17-1.24)	1.06 (1.00-1.12)
South	8652 (32)	70	1.13 (1.09-1.16)	1.08 (1.06-1.12)
East	4408 (16)	62	Ref	ref
West	5719 (21)	73	1.17 (1.13-1.20)	1.02 (0.97-1.08)
Twinning			[0.121]	[0.140]
Yes	780 (3)	76	1.04 (0.99-1.08)	1.04 (0.99-1.08)
No	23534 (87)	71	Ref	ref
Missing	2639 (10)	69		
Ethnicity			[<0.001]	[0.001]
Kasem	12965 (48)	75	1.12 (1.10-1.14)	1.08 (1.04-1.14)
Nankam	11286 (42)	66	Ref	ref
Buli	613 (2)	71	1.09 (1.03-1.14)	1.03 (0.97-1.09)
Other	601 (2)	80	1.17 (1.11-1.22)	1.02 (0.93-1.12)
Missing	1488 (6)	72		
Religion			[<0.001]	[<0.001]
Traditional	10532 (39)	67	Ref	ref
Christian	13199 (49)	74	1.11 (1.09-1.13)	1.04 (1.02-1.06)
Islam	1671 (6)	80	1.19 (1.16-1.23)	1.07 (1.03-1.12)
Missing	1551 (6)	72		
Birth order			[<0.001]	[0.515]
1	7241 (27)	74	1.09 (1.06-1.11)	0.98 (0.95-1.02)
2 - 4	12956 (48)	71	1.06 (1.04-1.09)	0.99 (0.97-1.02)
5+	6292 (23)	67	Ref	ref
Missing	464 (2)	75		
Place of delivery			[<0.001]	[<0.001]
Health facility	12226 (45)	81	1.28 (1.26-1.30)	1.08 (1.06-1.11)
Home/other	10196 (38)	64	Ref	ref
Missing	4531 (17)	61		
Mother's education			[<0.001]	[<0.001]
No education	9696 (36)	66	ref	ref
Primary/JSS	13444 (50)	73	1.10 (1.08-1.12)	1.04 (1.02-1.06)
Secondary/tertiary	2724 (10)	81	1.22 (1.19-1.25)	1.07 (1.04-1.12)
Missing	1089 (4)	76		
Maternal age			[<0.001]	[<0.001]
<20	2788 (10)	70	ref	ref
20-34	17179 (64)	72	1.03 (1.01-1.06)	1.03 (0.99-1.06)
35+	6291 (23)	68	0.96 (0.93-0.99)	0.99 (0.94-1.03)
Missing	695 (3)	73		
Wealth index			[<0.001]	[0.105]
Poorest	6484 (24)	68	ref	ref
Poorer	5244 (19)	68	1.00 (0.97-1.03)	0.99 (0.97-1.02)
Poor	4951 (18)	68	1.00 (0.97-1.03)	0.98 (0.95-1.01)
Less poor	5328 (20)	73	1.06 (1.03-1.09)	1.01 (0.98-1.03)
Least poor	4037 (15)	80	1.17 (1.14-1.19)	1.03 (0.99-1.07)
Missing	909 (3)	77		
Season			[<0.001]	[<0.001]
Rainy	14261 (53)	73	1.05 (1.04-1.07)	1.06 (1.04-1.08)
Dry	12692 (47)	69	ref	ref

Table 19 Survival analysis of FIC vs NOT FIC, Children followed to 3 years of age

Variable	Mortality rate/1000 pyrs	Deaths/Pyrs	Number of children	Unadjusted P-value HR (95%CI)	Adjusted P-value HR (95%CI)
FIC				0.001	0.020
No	15	89/5790	4418	ref	Ref
Yes	11	304/28478	22153	0.67 (0.53-0.85)	0.71 (0.53-0.95)
Sex				0.818	0.512
Male	12	201/17353	13410	Ref	Ref
Female	11	192/16915	13161	0.98 (0.80-1.19)	0.92 (0.73-1.17)
Interview period				<0.001	0.261
2003-2005	14	155/11439	8139	Ref	Ref
2006-2009	11	152/14101	9874	0.79 (0.63-0.99)	1.25 (0.95-1.64)
2010-2012	10	86/8729	8558	0.64 (0.49-0.83)	1.07 (0.75-1.52)
Place of residence				0.111	0.557
Central	6	16/2496	1916	Ref	Ref
North	12	96/7745	5919	1.95 (1.15-3.30)	1.26 (0.51-3.10)
South	11	123/11096	8616	1.74 (1.03-2.92)	1.04 (0.37-2.92)
East	13	80/6136	4826	2.04 (1.19-3.50)	1.25 (0.43-3.70)
West	11	78/6795	5294	1.80 (1.05-3.08)	0.98 (0.39-2.49)
Twinning				0.799	0.786
Yes	10	10/1002	756	Ref	Ref
No	11	343/30045	23093	1.15 (0.61-2.15)	1.10 (0.54-2.24)
Missing	12	40/3221	2722		
Ethnicity				0.411	0.156
Kasem	9	146/16102	12307	Ref	Ref
Nankam	11	161/15070	11750	1.18 (0.94-1.47)	0.90 (0.47-1.73)
Buli	7	5/742	572	0.74 (0.30-1.80)	0.81 (0.28-2.33)
Other	11	8/724	564	1.22 (0.60-2.48)	2.99 (1.14-7.86)
Missing	45	73/1631	1378		
Religion				0.018	0.471
Traditional	12	164/14214	11009	Ref	Ref
Christian	9	140/16289	12547	0.74 (0.59-0.93)	0.92 (0.71-1.20)
Islam	7	15/2051	1573	0.63 (0.37-1.07)	0.65 (0.32-1.33)
Missing	43	74/1715	1442		
Birth order				0.082	0.251
1	12	98/8336	6837	Ref	Ref
2 - 4	10	171/16716	12799	0.88 (0.69-1.13)	0.75 (0.53-1.06)
5+	13	117/8800	6506	1.16 (0.88-1.51)	0.84 (0.54-1.31)
Missing	17	7/413	429		
Place of delivery				<0.001	0.151
Health facility	8	111/13427	11051	ref	Ref
Home/other	14	230/17023	12248	1.72 (1.37-2.16)	1.23 (0.93-1.64)
Missing	14	52/3818	3272		
Mother's education				<0.001	0.058
No education	13	178/13230	10160	ref	Ref
Primary/JSS	11	192/17150	13218	0.82 (0.67-1.01)	0.97 (0.75-1.24)
Secondary/tertiary	3	11/3153	2435	0.26 (0.14-0.47)	0.40 (0.19-0.85)
Missing	16	12/734	758		
Maternal age				0.024	0.647
<20	14	48/3366	2743	Ref	Ref
20-34	10	219/21511	16745	0.72 (0.52-0.98)	0.84 (0.55-1.29)
35+	13	114/8671	6421	0.93 (0.67-1.31)	0.92 (0.53-1.58)
Missing	17	12/720	662		
Wealth index				<0.001	0.008
Poorest	11	96/8485	6537	1.86 (1.23-2.82)	1.78 (0.92-3.47)
Poorer	14	97/6742	5304	2.36 (1.56-3.57)	2.40 (1.24-4.64)
Poor	16	101/6420	4990	2.58 (1.71-3.90)	2.17 (1.12-4.18)
Less poor	8	57/6765	5229	1.38 (0.88-2.15)	1.35 (0.70-2.60)
Least poor	6	29/4724	3635	Ref	Ref
Missing	11	13/1132	876		
Season of birth				0.378	0.461
Rainy	11	219/19135	13951	Ref	Ref
Dry	11	174/15133	12620	1.10 (0.89-1.34)	1.10 (0.86-1.40)

Table 20 Interactions

	Adjusted HR (95%CI)	P-value
Males	0.56 (0.39-0.81)	0.069
Females	0.96 (0.61-1.49)	
Rural	0.75 (0.55-1.01)	0.170
Urban	0.38 (0.15-0.96)	
2003-2005	0.99 (0.60-1.63)	0.116
2006-2009	0.67 (0.44-1.00)	
2010-2013	0.43 (0.23-0.80)	

Table 21 Survival analysis - splitting FIC into FICIS and FIOS

	Rate	Deaths	Pyrs	N	Crude HR (95%CI)	Adjusted HR (95%CI)
FIC status					p=0.010	p=0.063
Not FIC	15	89	5790	4,420	1	1
FICOS	13	107	8500	6,340	0.79 (0.59-1.05)	0.69 (0.49-0.97)
FICIS	10	197	19978	15,796	0.60 (0.46-0.77)	0.72 (0.53-0.98)

	Adjusted HR (95%CI)	Test of no interaction p-value
Male		0.159
FICOS	0.51 (0.32-0.82)	
FICIS	0.59 (0.40-0.87)	
Female		
FICOS	0.98 (0.59-1.65)	
FICIS	0.95 (0.59-1.51)	
Rural		0.096
FICOS	0.69 (0.48-0.99)	
FICIS	0.78 (0.57-1.08)	
Urban		
FICOS	0.69 (0.22-2.15)	
FICIS	0.30 (0.11-0.82)	
Year of visit		
2003-5		0.172
FICOS	1.02 (0.58-1.80)	
FICIS	0.97 (0.56-1.68)	
2006-9		
FICOS	0.66 (0.40-1.07)	
FICIS	0.67 (0.43-1.04)	
2010-13		
FICOS	0.19 (0.05-0.67)	
FICIS	0.46 (0.25-0.87)	

Table 22 Survival analysis - NOT FIC split into "FIC without MCV" and otherwise

	Rate	Deaths	Pyrs	N	Crude HR (95%CI)	Adjusted HR (95%CI)
FIC status					p=0.010	p=0.063
Not FIC	17	42	2504	1,895	1	1
FIC without MCV	14	47	3286	2,525	0.85 (0.56-1.29)	1.06 (0.64-1.77)
FIC	11	304	28478	22,136	0.62 (0.45-0.85)	0.74 (0.48-1.12)

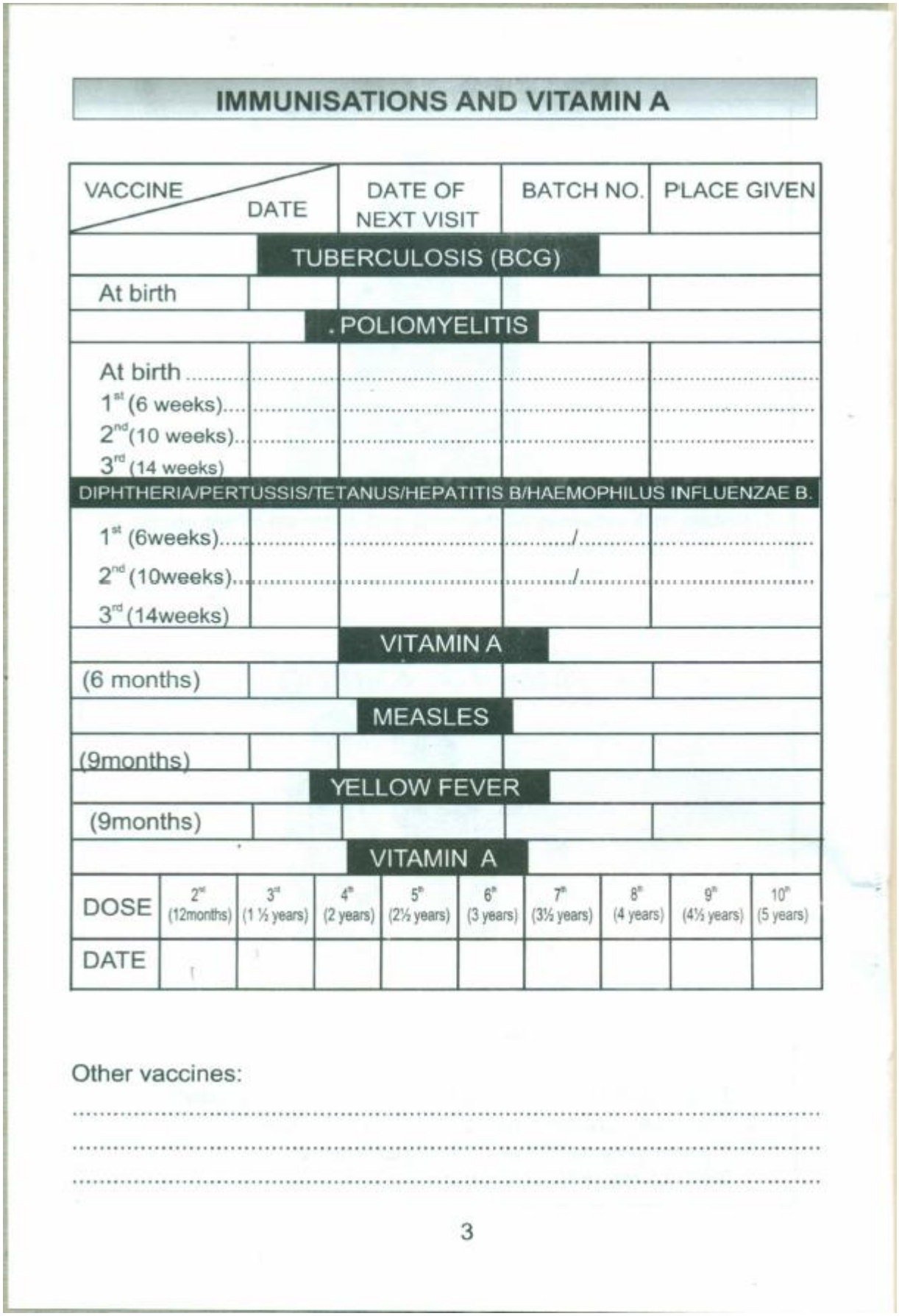
	Adjusted HR (95%CI)	Test of no interaction p-value
Male		0.137
FIC without MCV	1.28 (0.66-2.46)	
FIC	0.65 (0.37-1.14)	
Female		
FIC without MCV	0.81 (0.36-1.81)	
FIC	0.85 (0.45-1.58)	
Rural		0.283
FIC without MCV	1.12 (0.66-1.92)	
FIC	0.80 (0.51-1.26)	
Urban		
FIC without MCV	0.62 (0.12-3.14)	
FIC	0.29 (0.08-1.00)	
Year of visit		
2003-5		0.240
FIC without MCV	1.43 (0.59-3.45)	
FIC	1.22 (0.58-2.56)	
2006-9		
FIC without MCV	0.75 (0.36-1.53)	
FIC	0.56 (0.32-0.99)	
2010-13		
FIC without MCV	1.18 (0.32-4.38)	
FIC	0.49 (0.15-1.56)	

Table 23 Survival and alternative FIC calculations: FIC at visit and FIC15

	FIC at visit * Number of deaths =393		FIC15 # Number of deaths = 254	
Factor	**Crude Hazard ratio (95%-CI)**	**Adjusted Hazard ratio (95%-CI)**	**Crude Hazard ratio (95%-CI)**	**Adjusted Hazard ratio (95%-CI)**
FIC	P=0.008	p=0.031	P=0.262	p=0.412
No	Ref	Ref	Ref	Ref
Yes	0.61 (0.43-0.88)	0.67 (0.46-0.96)	0.77 (0.49-1.21)	0.82 (0.52-1.31)

* FIC at visits means that vaccines given between 12 months of age and first visit (after 12 months of age) are included in the calculation of FIC status
# FIC15 is FIC at 15 months of age, i.e. only visits after 15 months of age is used and all vaccines until 15 months of age are used in the calculation of FIC15 status

Figure 13 Vaccination card used



IMMUNISATIONS AND VITAMIN A

VACCINE / DATE	DATE OF NEXT VISIT	BATCH NO.	PLACE GIVEN
TUBERCULOSIS (BCG)			
At birth			
. POLIOMYELITIS			
At birth			
1st (6 weeks)			
2nd (10 weeks)			
3rd (14 weeks)			
DIPHTHERIA/PERTUSSIS/TETANUS/HEPATITIS B/HAEMOPHILUS INFLUENZAE B.			
1st (6weeks)		/	
2nd (10weeks)		/	
3rd (14weeks)			
VITAMIN A			
(6 months)			
MEASLES			
(9months)			
YELLOW FEVER			
(9months)			
VITAMIN A			

DOSE	2nd (12months)	3rd (1 ½ years)	4th (2 years)	5th (2½ years)	6th (3 years)	7th (3½ years)	8th (4 years)	9th (4½ years)	10th (5 years)
DATE									

Other vaccines:

.....

.....

.....

3

Appendix 3: Kintampo 2011-13

List of Tables

Table 1 Inclusion per year of visit 6
Table 2 Percent of children per year having no vaccination card 6
Table 3 Representativeness – comparison children included and excluded from the analyses 8
Table 4 FIC coverage by year of visit 9
Table 5 Coverage of FIC by year of visit and sex 10
Table 6 Coverage of FIC by year and Place of residence 10
Table 7 Coverage of FIC by year of visit and Socio-economic status (wealth index) 10
Table 8 Coverage of FIC by year of visit and maternal education 10
Table 9 Median vaccination age and lower and upper quartiles for FIC 13
Table 10 Median vaccination age and lower and upper quartiles for NOT FIC with a vaccine 13
Table 11 Among children NOT FIC, missing a specific vaccine 15
Table 12 Among children NOT FIC, missing only the particular vaccine 16
Table 13 Among children NOT FIC, number of vaccines missing 16
Table 14 Full immunization coverage (FIC) in sequence (FICIS) and out of sequence (FICOS) 17
Table 15 Main reasons for out-of-sequence for FIC who are out-of-sequence (FICOS) 19
Table 16 Fully Vaccination coverage at 24 months (FIC24) for NOT FIC at 12 months of age 21
Table 17 Analyses of association between background factors and FIC 22
Table 18 Analyses of association between background factors and FICIS among FIC 23

List of Figures

Figure 1 The flow chart of inclusion for Kintampo 2011-13 6
Figure 2 Histogram of visits from flow chart 7
Figure 3 FIC coverage by year of visit 9
Figure 4 Coverage by key factors 11
Figure 5 Coverage curves for each vaccine among FIC, NOT FIC, and combined 12
Figure 6 Comparison of median vaccination age of FIC and NOT FIC 14
Figure 7 Among NOT FIC percent of missing a particular vaccine 15
Figure 8 Coverage of FIC-in-sequence among FIC 17
Figure 9 Coverage of FIC-in-sequence among children who are FIC among key factors 18
Figure 10 Reason for out-of-sequence among FICOS 19
Figure 11 FIC15 Coverage curves for each vaccine among FIC, NOT FIC, and combined 20
Figure 12 Coverage of FIC24 among NOT FIC at 12 months 21
Figure 13 Vaccination card used 24

Kintampo Health Research Centre (KHRC)

Description of site

The Kintampo Health Research Centre (KHRC) is located in the Kintampo North Municipal and Kintampo South District of the Brong Ahafo Region in Ghana. It is situated in the Forest Savana transitional ecological zone. The two districts have a surface area of 7,162 square kilometres which represent 18.1% of the total land area of the Brong Ahafo Region with a population of 148,124[2] under a continuous demographic and health surveillance.

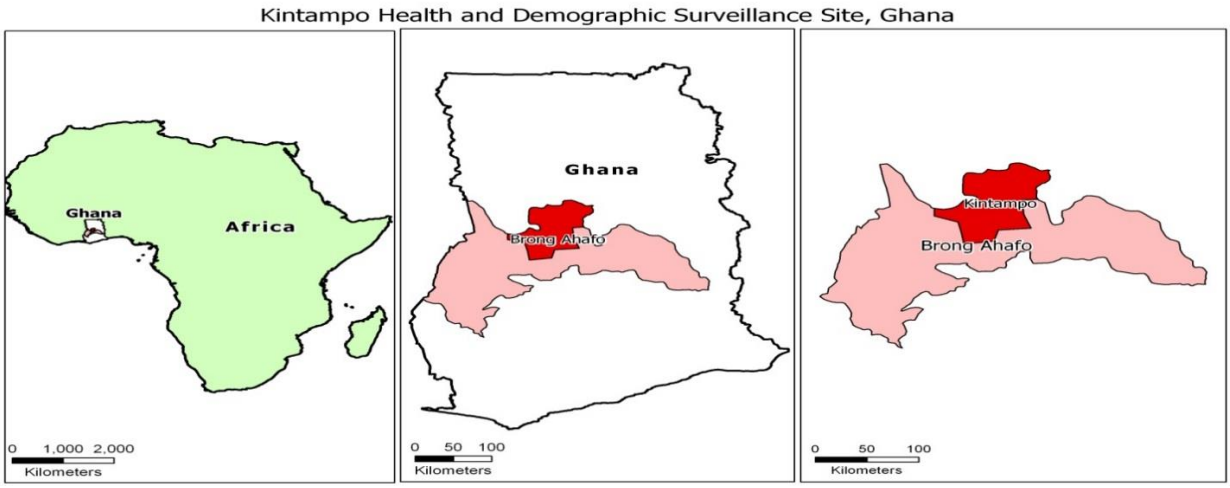
The vegetation is mainly of the forest-savannah transition type. There are two rainy seasons. The major rainy season starts from March to June and the minor season from July-November. Majority of the population are engaged in subsistence agriculture, with yam, maize and Cowpea cultivation as the main food crops and mango and cashew as the main cash crops farmed.

There are two major indigenous ethnic groups, with large immigrant population from the northern parts of the country. The settlements are mostly concentrated in the Southern part and along the main trunk road linking the two District capitals (Kintampo and Jema) to Northern Region. Over 60% of the population lives in rural communities

There are 24 public health facilities made up of 2 hospitals, 7 health centre and 15 Community-based Health Planning and Services (CHPS) compounds providing health services to the people. The 2 hospitals are located at the district capitals and serves as a referral facility for the health facilities in the districts. In the private sector, there are 3 private clinics and 3 private maternity homes. All villages and compounds have been geo referenced using Geographic Information System (GIS)

Antenatal attendance is very high with 97% of women attending antenatal clinics during pregnancy and health facility delivery is around 60%. Malaria is the leading cause of death among children less than one year accounting for 38.5% of all under one deaths[3]. The total fertility rate is 4.4.

The figure below shows a map of Africa, Ghana, Brong Ahafo Region and the study area of the Kintampo Health Research centre.

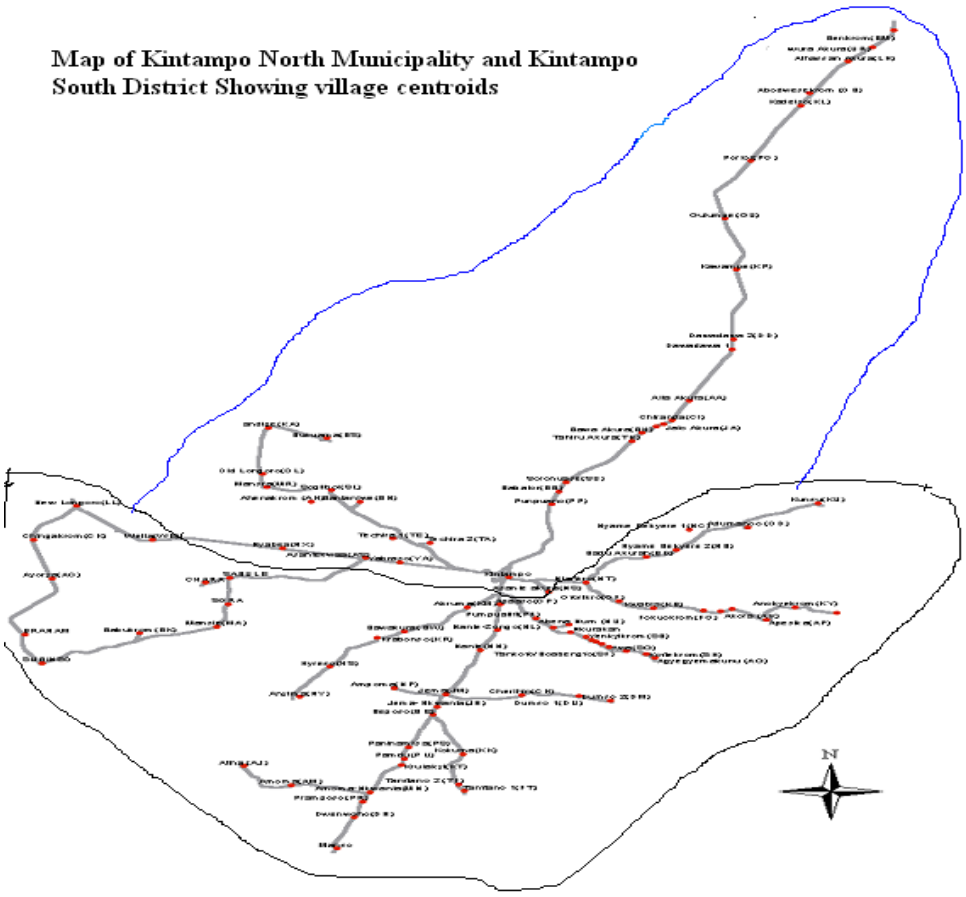


Health and Demographic Surveillance System

The Kintampo Health and Demographic Surveillance System (KHDSS) of the Kintampo Health Research Centre was started in 2003 with an initial census and it covers over 95% of the population of both the municipality and the district.

As part of its operations, the KHDSS collects and routinely updates the health and demographic information on the population at the individual level within each household. The KHDSS has an objective of documenting demographic dynamics in the area, provide a framework for population-based health research that addresses local health priorities, and to serve as a platform for research that informs population and health policy in Ghana and beyond

From 2003 to 2009, each household was visited every six months corresponding to an update round. This was changed to every four months from 2010 to 2013. The visits were reduced from three to two update rounds per year from January 2014. In each round, updates on pregnancies, births, deaths, and migration are made. In addition verbal autopsies are conducted for each death that is registered. Annual updates on Education are conducted and bi-annual information on household assets and socio-economic indicators such as employment are updated for individuals and households respectively. Below is a map of centroids of all villages within the study area.



Routine Vaccination data collection

Vaccination information of all children who were residing in the area and below the age of 5 were collected or updated annually from 2006 to 2010 in the last 6 months of each year. This was reviewed in 2011 and all children residing in the area and are under 3 years of age were visited every four months until 2013 for updates of their vaccination status. Since 2014 the visits have been reduced from 3 to 2 per year. Vaccination records of all new born and migrants into the study area who are 3 years or below are collected at their initial contact. All vaccination records are transcribed from the health cards of the children

National Immunization schedules over the period: 2011-2013

The period covered in this analysis saw changes to the vaccination schedule in the country with the introduction of the rotavirus, pneumococcal and a second dose of measles vaccine in May 2012
The current national policy of the EPI follows the schedule of providing one dose of BCG at birth, four doses of OPV (at birth, 6, 10 and 14 weeks), three doses of pentavalent (at 6, 10 and 14 weeks), two doses of rotavirus at (6 and 10 weeks), three doses of pneumococcal vaccines (at 6,10 and 14 weeks) two doses of measles (at 9 and 18 months) and one dose of yellow fever (at 9 months).

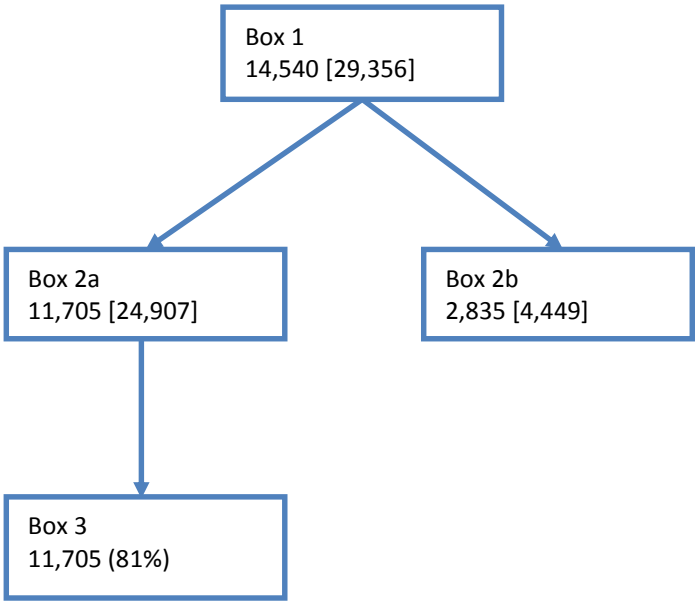
Administration of vaccines in the Kintampo HDSS

Four strategies namely static, outreach, mini-mass and campaigns are used for delivery of Expanded Programme of Immunization (EPI) services in the area. The static and outreach services are documented in the health cards of all children, but the mini mass and the campaigns are not documented in the cards. The EPI services are organized at the sub district level with each sub district having oversight responsible for Community-based Health and Planning Services (CHPS) compounds in the sub district. Each health facility is responsible for organizing the EPI in a number of communities within their catchment area. The overall supervision and support is provided by the Health Management Teams at the municipal and district levels.

Static vaccination services are provided at all the public health facilities. The private health facilities do not provide vaccination services. Some sub districts have weekly clinics whilst others have monthly clinics. Outreach services are organized for communities without public health facility within the catchment area of each facility. The outreach services are provided monthly.

Mothers are informed of their next visit for vaccination when they attend a vaccination session, but are responsible for ensuring that their children are sent when they are due for the next vaccination. All vaccination services are provided free of charge.

Figure 1 The flow chart of inclusion for Kintampo 2011-13



Box 1
Number of children alive at an HDSS home visit between 12 and 23 months of age
[Number of visits asking for vaccine card]

Box 2a
Number of children from box 1 having at least one visit with card seen
[Number of visits for these children including those where card not seen]

Box 2b
Number of children from box 1 having no seen card at any visit between 12 and 23 months of age
[Number of visits]

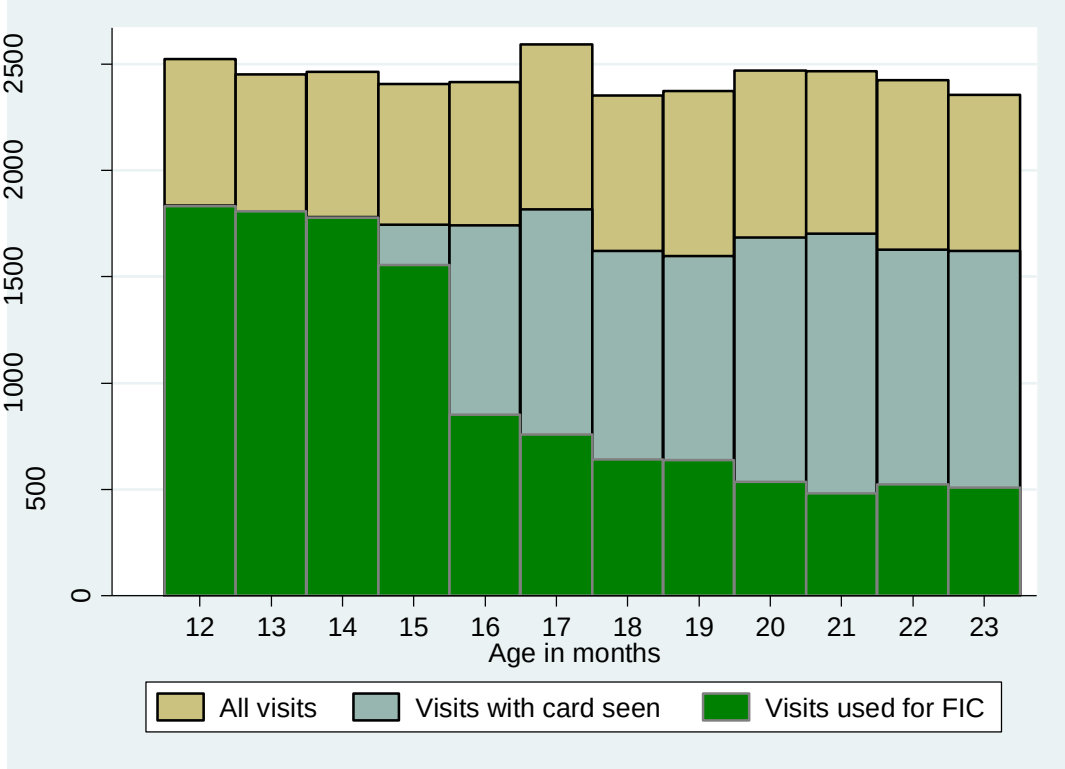
Box 3
Number of children included in analyses

Table 1 Inclusion per year of visit

Year of Visit	Inclusion % (n/total)
2011	75 (3637/4877)
2012	85 (4030/4763)
2013	82 (4038/4900)
Total	81 (11705/14540)

Table 2 Percent of children per year having no vaccination card

Figure 2 Histogram of visits from flow chart



All = Visits from Box 1
Card seen = Visits from Box 2a
Used for FIC = Visits fromBox 3

Table 3 Representativeness – comparison children included and excluded from the analyses

Variable	Included n (%)	Excluded n (%)	P-Value
Sex			
Male	5955 (51)	1463 (52)	0,486
Female	5750 (49)	1372 (48)	
Place of residence			
Rural	8010 (68,4)	1840 (64,9)	<0.001
Urban	3695 (31,6)	995 (35,1)	
District			
North	6551 (56)	1780 (62,8)	<0.001
South	5154 (44)	1055 (37,2)	
Ethnicity			
Akan/Ewe/Ga	2267 (19,4)	450 (15,9)	<0.001
Dargati/Grushie/Sisala	2681 (22,9)	420 (14,8)	
Mo/Pantra	1351 (11,5)	206 (7,3)	
Gonja/Dagomba/Gruma	3308 (28,3)	668 (23,6)	
Fulani/Zambraba/Wangara	876 (7,5)	162 (5,7)	
Missing	1222 (10,4)	929 (32,8)	
Religion			
Christian	6045 (51,6)	1020 (36)	<0.001
Muslim	3399 (29)	689 (24,3)	
Traditionalist	231 (2)	51 (1,8)	
No Religion	789 (6,7)	133 (4,7)	
Missing	1241 (10,6)	942 (33,2)	
Parity			
1	2265 (19,4)	688 (24,3)	<0.001
2 - 3	3865 (33)	868 (30,6)	
4 - 5	2572 (22)	432 (15,2)	
6+	1811 (15,5)	263 (9,3)	
Missing	1192 (10,2)	584 (20,6)	
Place of delivery			
Health Facility	5503 (47)	1246 (44)	<0.001
TBA/Home	5010 (42,8)	1005 (35,4)	
Missing	1192 (10,2)	584 (20,6)	
Maternal Education			
None	4817 (41,2)	875 (30,9)	<0.001
Basic	4271 (36,5)	818 (28,9)	
Higher	505 (4,3)	117 (4,1)	
Missing	2112 (18)	1025 (36,2)	
Wealth Index			
Poorest	2722 (23,3)	530 (18,7)	<0.001
Poorer	2465 (21,1)	576 (20,3)	
Poor	2174 (18,6)	476 (16,8)	
Less poor	1830 (15,6)	448 (15,8)	
Least poor	1552 (13,3)	384 (13,5)	
Missing	962 (8,2)	421 (14,9)	
Season of Birth			
Major Rains	4278 (36,5)	1005 (35,4)	0,059
Minor Rains	4967 (42,4)	1271 (44,8)	
Dry	2460 (21)	559 (19,7)	

Table 4 FIC coverage by year of visit

Year of Visit	FIC % (n/N)
2011	67 (2419/3637)
2012	71 (2846/4030)
2013	76 (3086/4038)
Total	71 (8351/11705)

Figure 3 FIC coverage by year of visit

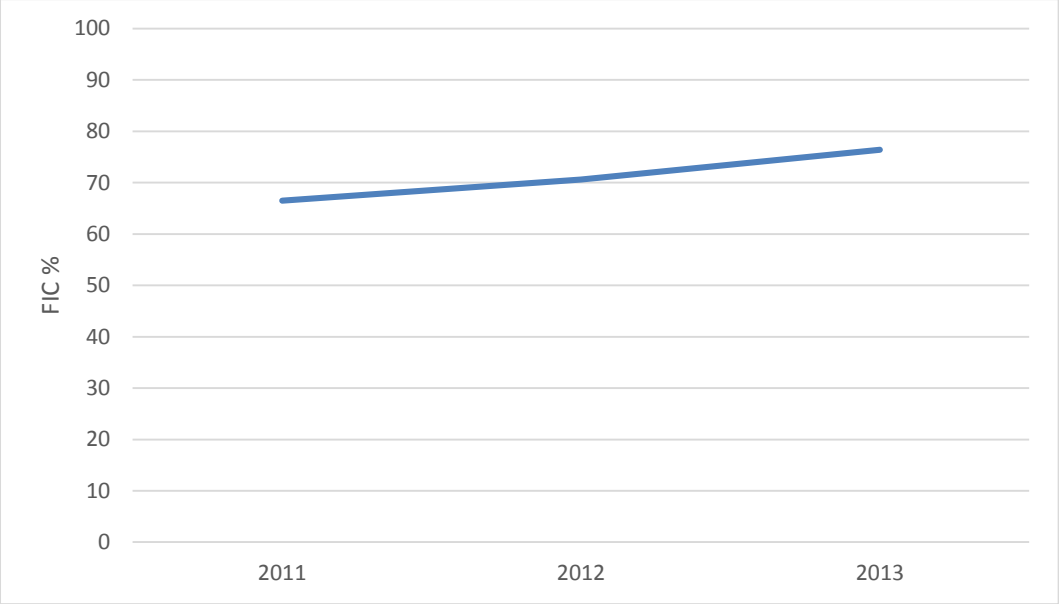


Table 5 Coverage of FIC by year of visit and sex

Year of Visit	Sex		
	Females	Males	Total
2011	68 (1190/1746)	65 (1229/1891)	67 (2419/3637)
2012	71 (1431/2005)	70 (1415/2025)	71 (2846/4030)
2013	75 (1500/1999)	78 (1586/2039)	76 (3086/4038)
Total	72 (4121/5750)	71 (4230/5955)	71 (8351/11705)

Table 6 Coverage of FIC by year and Place of residence

Year of Visit	Place of residence		
	Rural	Urban	Total
2011	63 (1622/2583)	76 (797/1054)	67 (2419/3637)
2012	68 (1866/2756)	77 (980/1274)	71 (2846/4030)
2013	74 (1970/2671)	82 (1116/1367)	76 (3086/4038)
Total	68 (5458/8010)	78 (2893/3695)	71 (8351/11705)

Table 7 Coverage of FIC by year of visit and Socio-economic status (wealth index)

Year of Visit	Wealth index				
	Poorest	Poorer	Poor	Less poor	Least poor
2011	62 (591/952)	64 (498/782)	65 (443/687)	71 (365/514)	80 (348/433)
2012	63 (566/895)	72 (637/889)	68 (487/719)	73 (482/659)	83 (442/536)
2013	72 (627/873)	75 (599/794)	74 (574/771)	78 (511/655)	87 (506/582)
Total	66 (1784/2720)	70 (1734/2465)	69 (1504/2177)	74 (1358/1828)	84 (1296/1551)

Table 8 Coverage of FIC by year of visit and maternal education

Year of Visit	Maternal education		
	None	Basic	Higher
2011	63 (995/1589)	71 (915/1297)	75 (105/140)
2012	66 (1084/1648)	75 (1117/1495)	86 (155/180)
2013	74 (1160/1576)	81 (1198/1478)	85 (158/187)
Total	67 (3239/4813)	76 (3230/4270)	82 (418/507)

Figure 4 Coverage by key factors

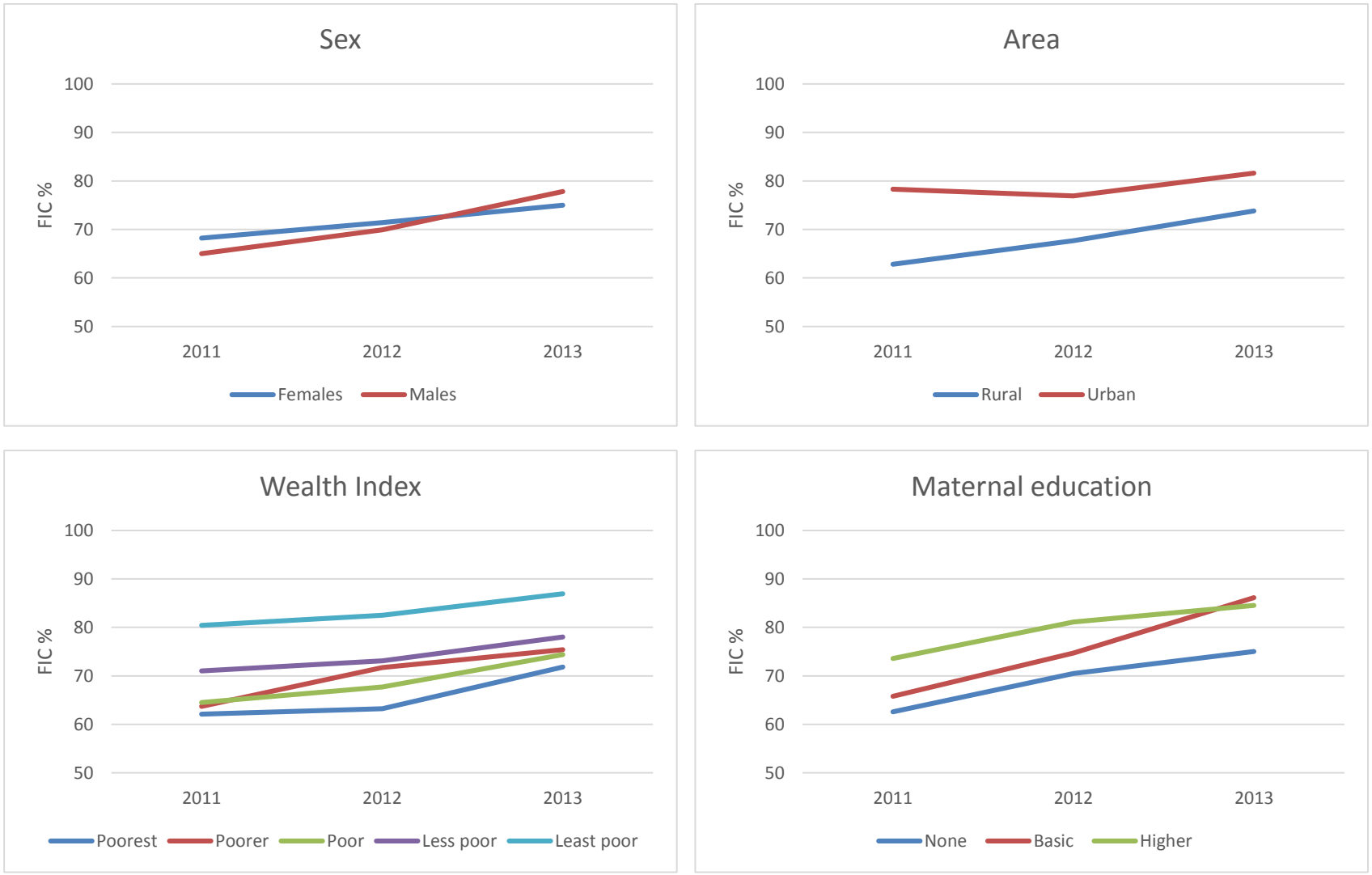
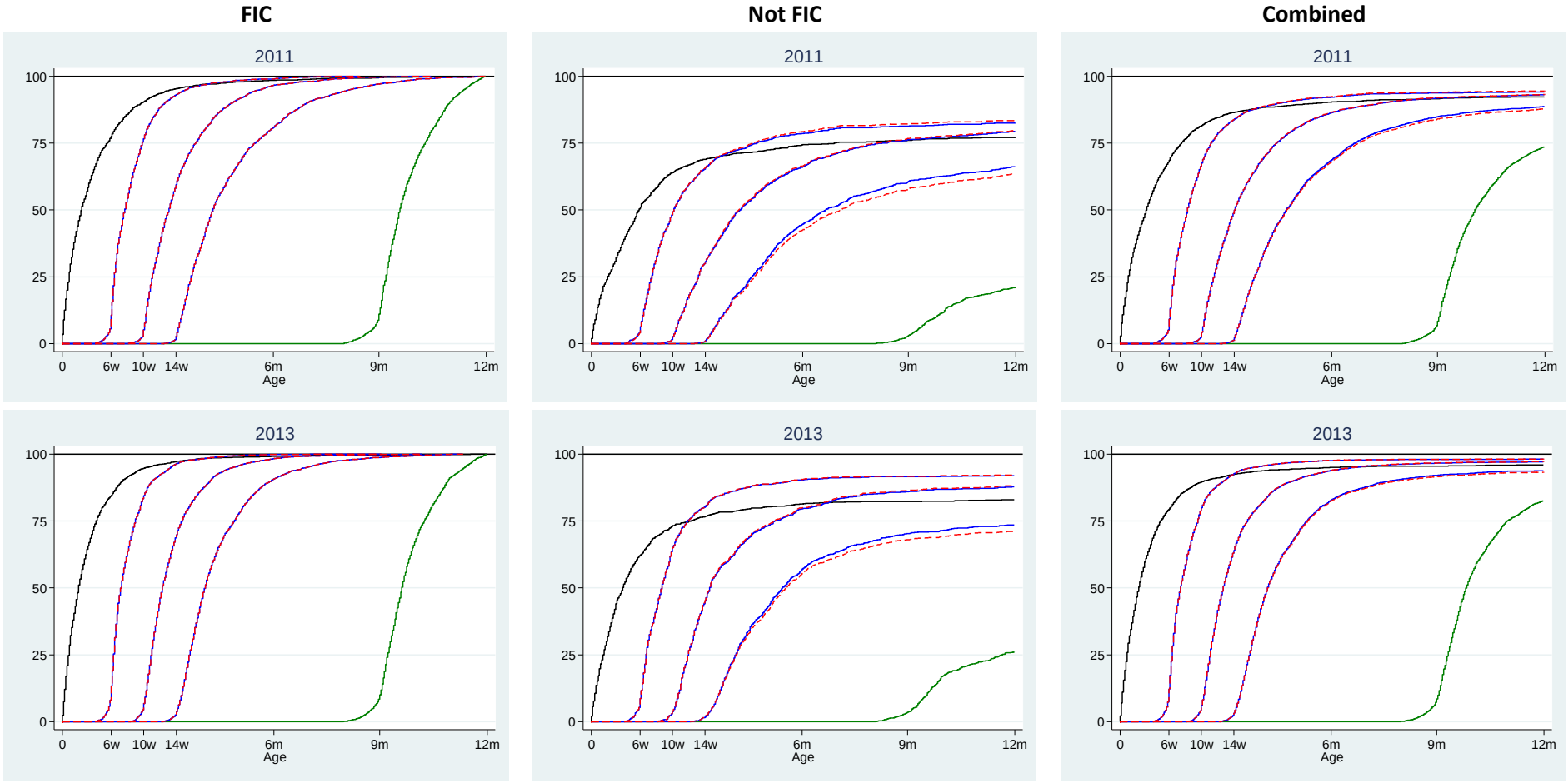


Figure 5 Coverage curves for each vaccine among FIC, NOT FIC, and combined



BCG is black; Penta is blue; OPV is dashed and red; MCV is green

Table 9 Median vaccination age and lower and upper quartiles for FIC

Year of visit	BCG (days)			Penta 1 (weeks)			Penta 2 (weeks)			Penta 3 (weeks)			OPV 1 (weeks)			OPV 2 (weeks)			OPV 3 (weeks)			MCV (weeks)		
	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
2011	6	17	39	6	8	10	11	13	16	16	19	24	6	8	10	11	13	16	16	19	24	40	42	45
2012	5	15	34	6	8	10	11	13	16	16	18	22	6	8	10	11	13	16	16	18	22	40	42	45
2013	6	14	29	6	7	9	11	12	15	16	18	21	6	7	9	11	12	15	16	18	21	40	42	44
Total	5	15	33	6	7	9	11	13	15	16	18	22	6	7	9	11	13	15	16	18	22	40	42	45

Table 10 Median vaccination age and lower and upper quartiles for NOT FIC with a vaccine

Year of visit	BCG (days)			Penta 1 (weeks)			Penta 2 (weeks)			Penta 3 (weeks)			OPV 1 (weeks)			OPV 2 (weeks)			OPV 3 (weeks)			MCV (weeks)		
	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
2011	10	28	56	7	9	13	12	16	22	18	23	34	7	9	13	7	9	22	18	23	34	40.1	42.6	45.4
2012	7	22	47	7	9	12	12	14	19	17	21	28	7	9	12	7	9	19	17	21	28	39.6	42	45
2013	8	20	43	7	8	11	12	14	19	17	20	28	7	8	11	7	8	18	17	21	28	40.3	42	45.2
Total	8	23	49	7	9	12	12	15	20	17	22	30	7	9	12	12	15	20	17	22	30	40.1	42.3	45.1

Figure 6 Comparison of median vaccination age of FIC and NOT FIC

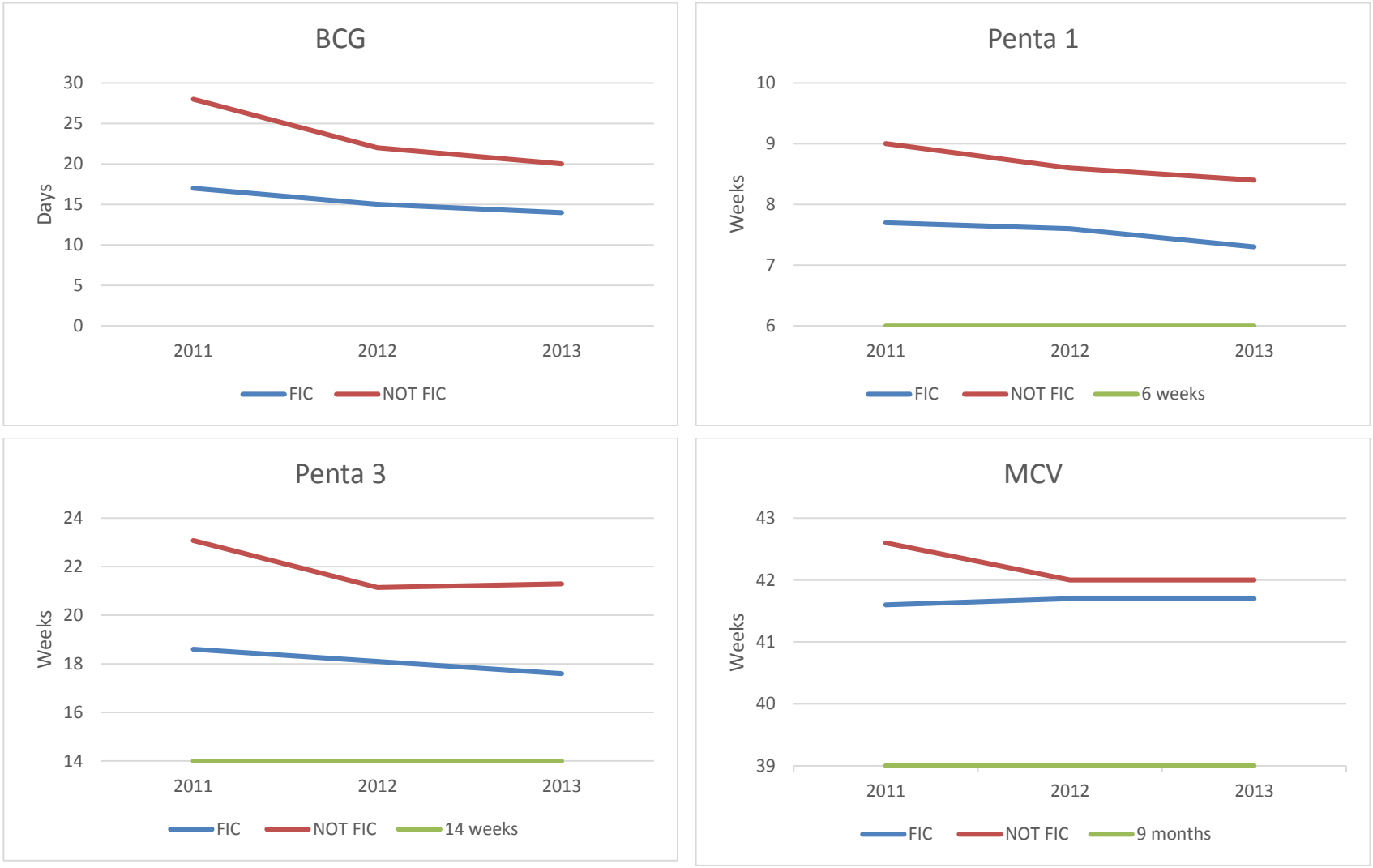


Table 11 Among children NOT FIC, missing a specific vaccine

Year of visit	BCG	Penta 1	Penta 2	Penta 3	OPV 1	OPV 2	OPV 3	MCV	Number NOT FIC
2011	22.6	17.3	20.5	33.8	16.3	20.2	36.3	78.7	1218
2012	21.6	15.4	17.8	28.0	14.4	17.6	28.7	79.5	1184
2013	16.9	8.2	12.4	26.8	8.0	12.0	29.2	74.2	952
Total	20.6	14.0	17.3	29.8	13.2	16.9	31.6	77.7	3354

Figure 7 Among NOT FIC percent of missing a particular vaccine

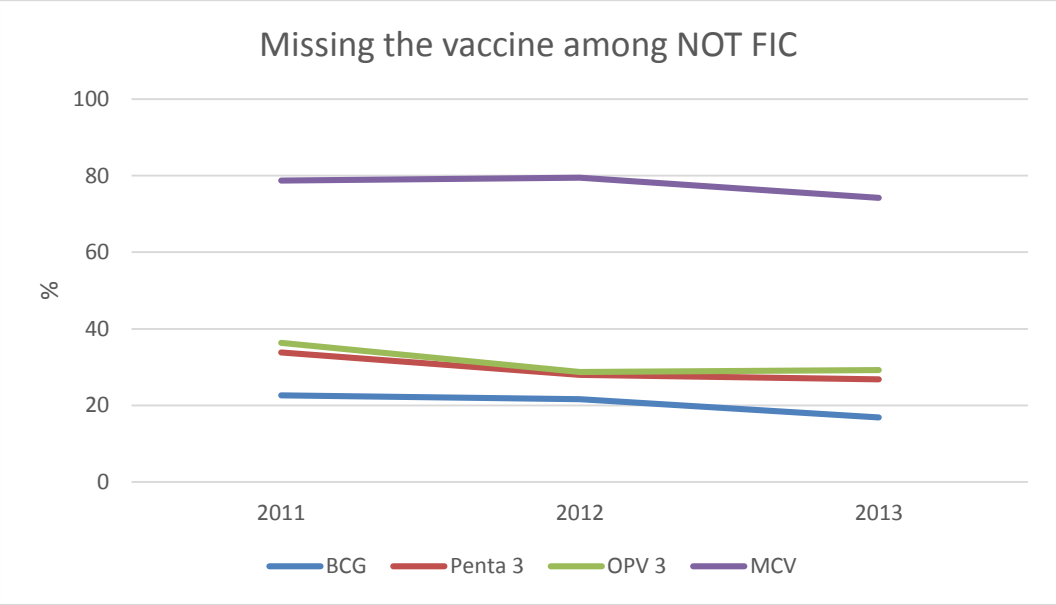


Table 12 Among children NOT FIC, missing only the particular vaccine

Year of visit	BCG	Penta 3	OPV 3	MCV
2011	5.8 (70)	0.5 (6)	3.2 (39)	50.8 (619)
2012	5.5 (65)	1.0 (12)	1.5 (18)	57.5 (681)
2013	8.6 (81)	0.6 (6)	2.5 (24)	54.4 (518)
Total	6.5 (217)	0.7 (24)	2.4 (81)	54.2 (1818)

Table 13 Among children NOT FIC, number of vaccines missing

	Number of vaccines missing % (n)							
Year of visit	1	2	3	4	5	6	7	8
2011	61.2 (746)	8.6 (105)	9.7 (118)	1.8 (22)	3.5 (43)	0.8 (10)	5.9 (72)	8.4 (102)
2012	66.4 (786)	9.0 (107)	6.8 (80)	1.7 (20)	3.0 (36)	1.2 (14)	6.2 (73)	5.7 (68)
2013	67.3 (641)	13.3 (127)	7.6 (72)	2.1 (20)	2.8 (27)	0.2 (13)	3.5 (33)	2.0 (19)
Total	64.8 (2173)	10.1 (339)	8.1 (270)	1.8 (62)	3.2 (106)	1.1 (37)	5.2 (178)	5.6 (189)

Table 14 Full immunization coverage (FIC) in sequence (FICIS) and out of sequence (FICOS)

Year of visit	FICIS % (n/FIC)
2011	80 (1933/2419)
2012	84 (2386/2846)
2013	86 (2662/3086)
Total	84 (6981/8351)

FICIS is defined as the WHO recommended sequence of vaccinations, i.e. BCG before OPV1, OPV1=Penta1, OPV2=Penta2, OPV3=Penta3 and Penta3 before MCV.

Figure 8 Coverage of FIC-in-sequence among FIC

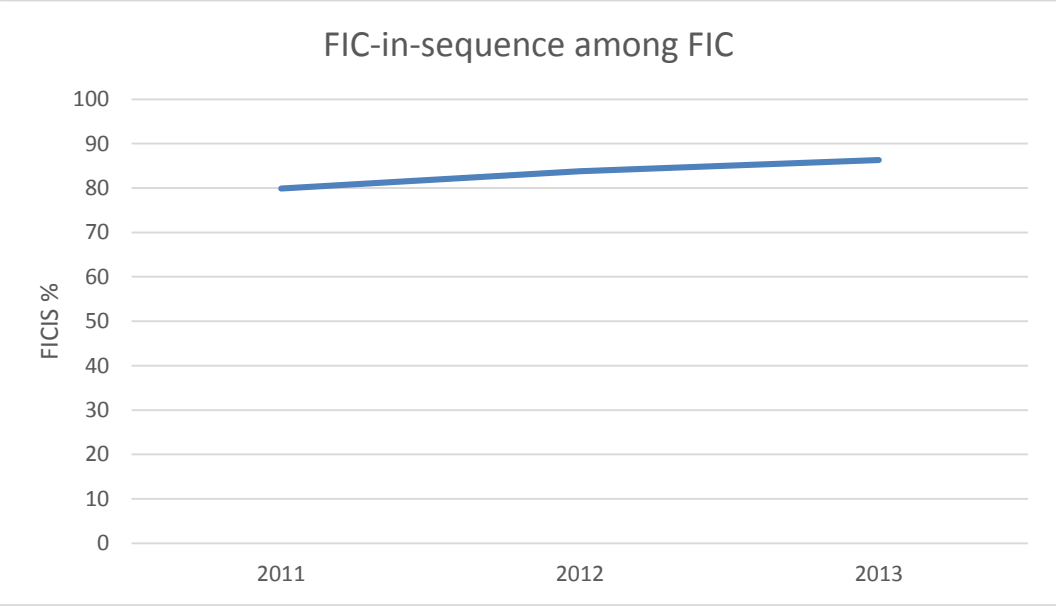
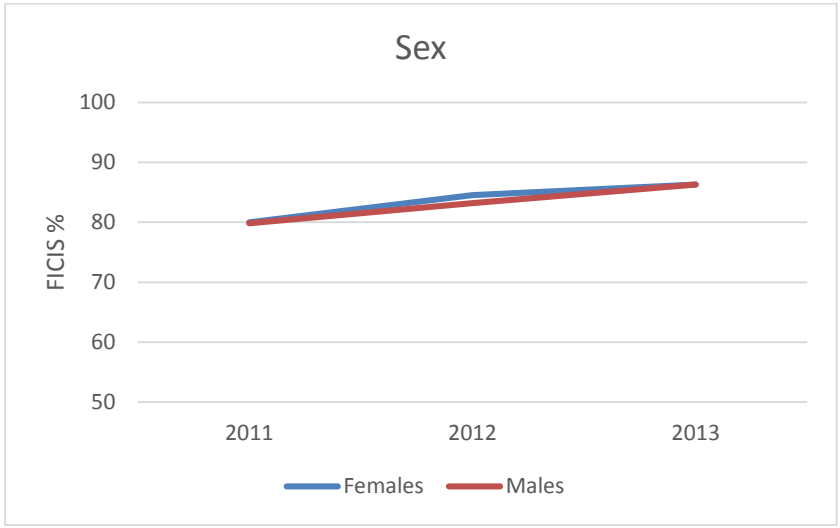


Figure 9 Coverage of FIC-in-sequence among children who are FIC among key factors



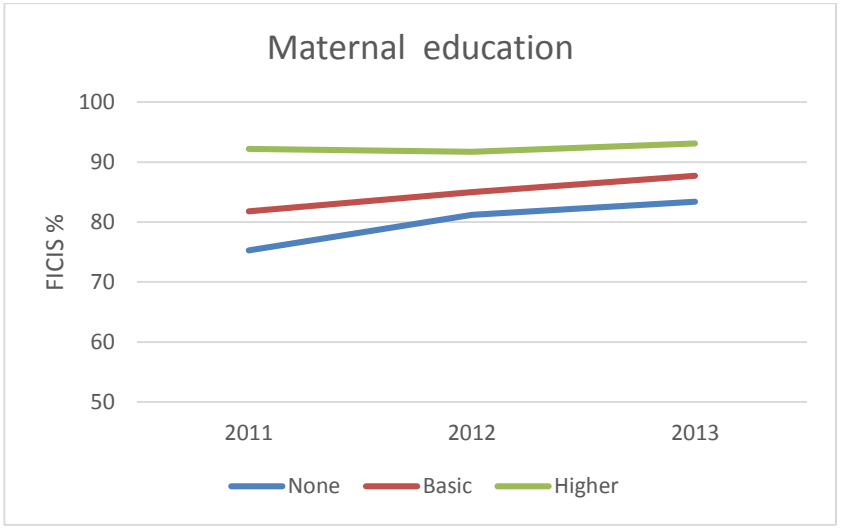


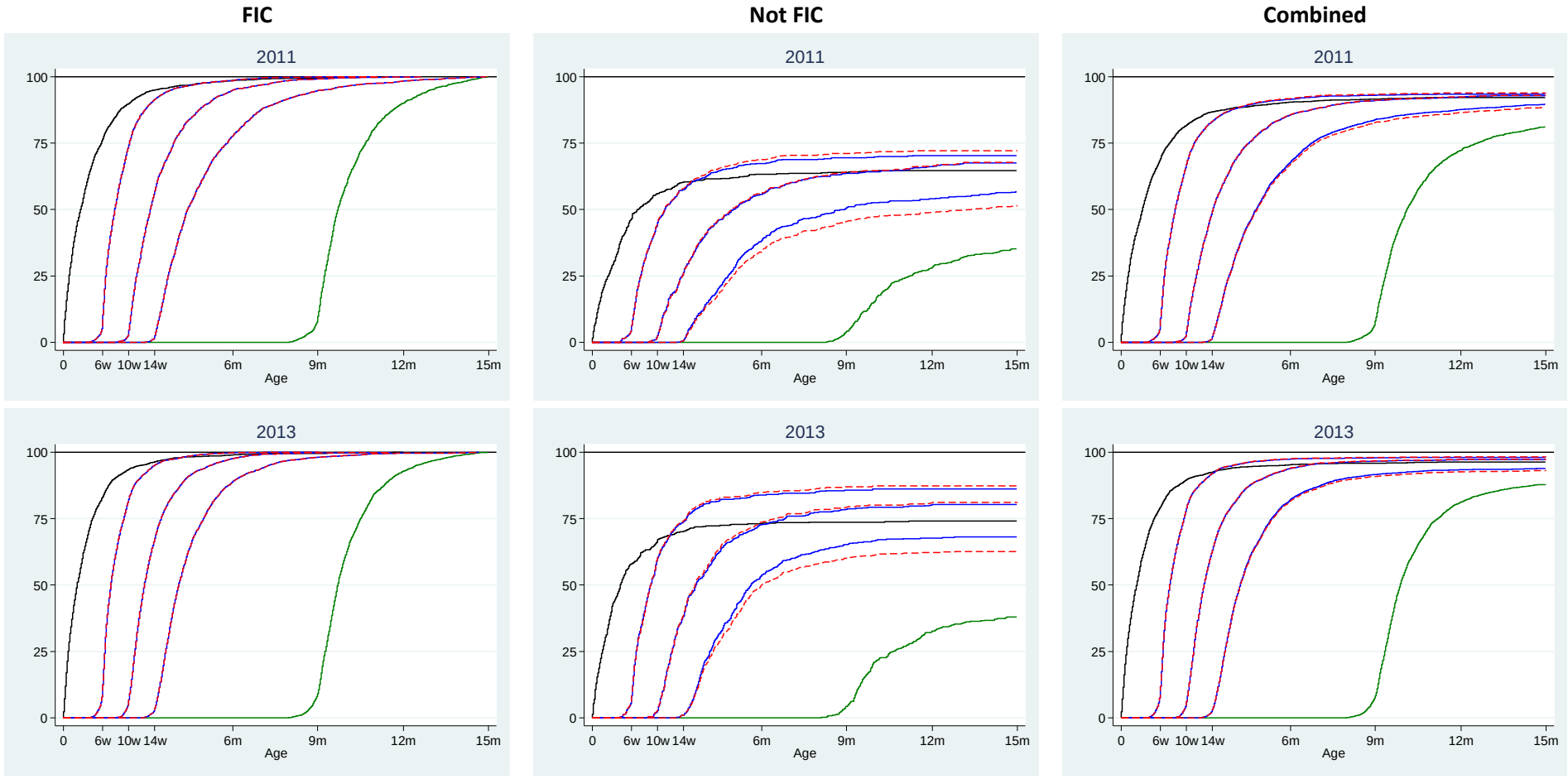
Table 15 Main reasons for out-of-sequence for FIC who are out-of-sequence (FICOS)

NA

Figure 10 Reason for out-of-sequence among FICOS

NA

Figure 11 FIC15 Coverage curves for each vaccine among FIC, NOT FIC, and combined



BCG is black; Penta is blue; OPV is dashed and red; MCV is green

Table 16 Fully Vaccination coverage at 24 months (FIC24) for NOT FIC at 12 months of age

Year of visit for FIC12 status	Percent (FIC24/N)
2011	43 (88/204)
2012	37 (294/794)
2013	47 (420/903)
Total	42 (802/1901)

Figure 12 Coverage of FIC24 among NOT FIC at 12 months

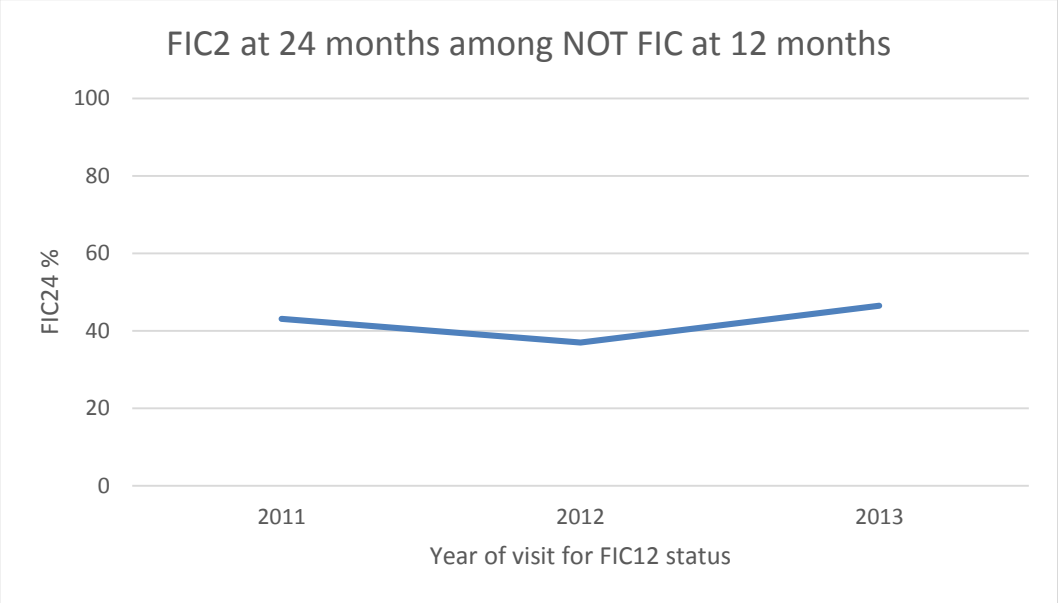


Table 17 Analyses of association between background factors and FIC

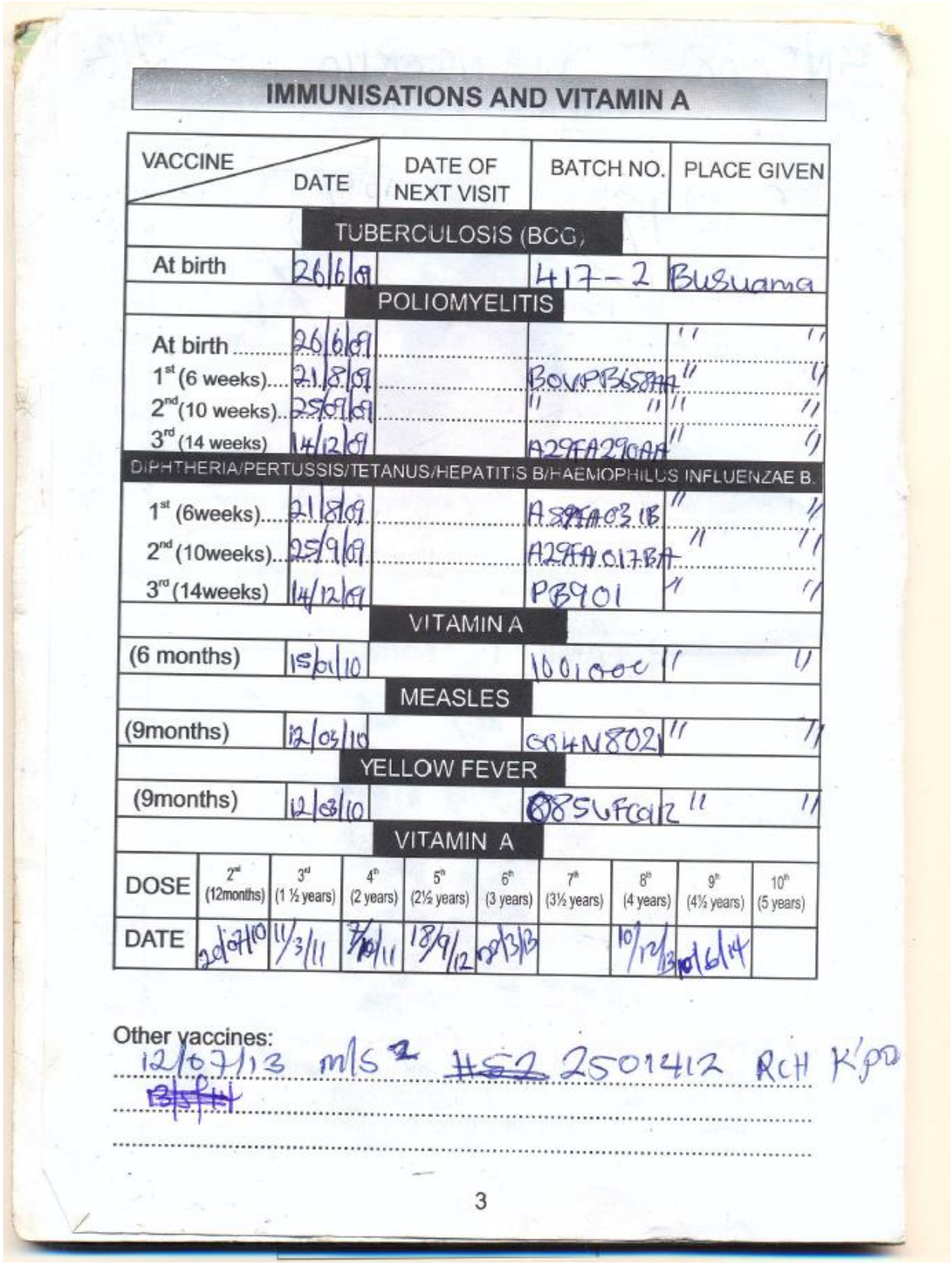
Background Factors	FIC %	Unadjusted [P-value*] PR (95% CI)	Adjusted [P-value*] aPR (95% CI)
Sex		[P=0,446]	[P=0.388]
Male	71	Ref	Ref
Female	71.7	1.00 (0.99-1.03)	1.01 (0.98-1.04)
Place of residence		[P<0.001]	[P=0.003]
Rural	68.1	Ref	Ref
Urban	78.3	1.14 (1.12-1.18)	1.07 (1.03-1.12)
District		[P=0.017]	[P=0.891]
South	70.2	Ref	Ref
North	72.2	1.02 (1.01-1.05)	0.99 (0.97-1.03)
Ethnicity		[P<0.001]	[P=0.020]
Fulani/Zambraba/Wangara	69.7	Ref	Ref
Akan/Ewe/Ga	78.6	1.07 (1.02-1.13)	1.05 (1.14-2.88)
Dargati/Grushie/Sisala	69.8	0.95 (0.90-1.01)	1.00 (1.08-2.74)
Mo/Pantra	77.4	1.05 (1.00-1.12)	1.07 (1.16-2.93)
Gonja/Dagomba/Gruma	66.2	0.89 (0.85-0.95)	0.99 (1.07-2.71)
Missing	69.9	-	-
Religion		[P<0.001]	[P<0.001]
No Religion	71.4	Ref	Ref
Christian	75.1	1.05 (1.00-1.1.0)	0.99 (1.04-2.69)
Muslim	65.6	0.91 (0.87-0.97)	0.90 (0.95-2.46)
Traditionalist	64.9	0.91 (0.82-1.01)	0.93 (1.04-2.56)
Missing	70.1	-	-
Parity		[P<0.001]	[P=0.063]
>5	65.9	Ref	Ref
1	75.6	1.14 (1.10-1.19)	1.04 (1.09-2.84)
2-3	73.9	1.12 (1.08-1.16)	1.05 (1.10-2.87)
4-5	69.6	1.05 (1.01-1.10)	1.02 (1.07-2.79)
Missing	67.2	-	-
Place of delivery		[P<0.001]	[P<0.001]
TBA/Home	76.7	Ref	Ref
Health Facility	66.4	1.15 (1.13-1.18)	1.07 (1.04-1.11)
Missing	67.2	-	-
Maternal Education		[P<0.001]	[P=0.152]
None	67.3	Ref	Ref
Basic	75.7	1.12 (1.10-1.15)	1.02 (1.06-2.80)
Higher	82.4	1.22 (1.17-1.28)	1.05 (1.14-2.88)
Missing	69.2		
Wealth Index		[P<0.001]	[P<0.001]
Poorest	65.6	Ref	Ref
Poorer	70.2	1.07 (1.03-1.11)	1.05 (1.10-2.87)
Poor	69.2	1.05 (1.01-1.10)	0.98 (1.04-2.69)
Less poor	74.4	1.13 (1.09-1.18)	1.01 (1.07-2.77)
Least poor	83.5	1.27 (1.23-1.32)	1.11 (1.18-3.05)
Missing	70	-	-
Season of Birth		[P=0.11]	[P=0.132]
Dry	69.9	Ref	Ref
Major Rains	72.3	1.03 (1.00-1.07)	1.03 (1.07-2.81)
Minor Rains	71.3	1.01 (0.99-1.05)	1.00 (1.05-2.74)

Table 18 Analyses of association between background factors and FICIS among FIC

Background Factors	N (%)	FIC IS %	Unadjusted [P-value*] PR (95% CI)	Adjusted [P-value*] aPR (95% CI)
Sex			[P<0.001]	[P=0,552]
Male	4230 (50.7)	83	Ref	Ref
Female	4121 (49.3)	84	0.97 (0.88-1.07)	1.03 (0.92-1.16)
Place of residence			[P<0.001]	[P<0.001]
Rural	5458 (65.4)	79	Ref	Ref
Urban	2893 (78.3)	93	0.35 (0.31-0.4)	0.55 (0.44-0.71)
District			[P<0.001]	[P<0.001]
South	3619 (43.3)	79	Ref	Ref
North	5154 (44)	87	0.63 (0.58-0.7)	0.78 (0.68-0.91)
Ethnicity			[P<0.001]	[P<0.001]
Fulani/Zambraba/Wangara	611 (7.3)	84	Ref	Ref
Akan/Ewe/Ga	1781 (21.3)	89	0.85 (0.65-1.13)	0.74 (0.53-1.03)
Dargati/Grushie/Sisala	1870 (22.4)	80	1.54 (1.19-2.01)	0.95 (0.71-1.29)
Mo/Pantra	1046 (12.5)	81	1.42 (1.08-1.88)	1.22 (0.89-1.68)
Gonja/Dagomba/Gruma	2189 (26.2)	84	1.29 (1-1.68)	0.77 (0.57-1.04)
Missing	854 (10.2)	84	-	-
Religion			[P<0.001]	[P<0.001]
No Religion	563 (6.7)	79	Ref	Ref
Christian	4539 (54.4)	84	0.75 (0.64-0.9)	1.00 (0.8-1.26)
Muslim	2229 (26.7)	84	0.74 (0.62-0.9)	1.10 (0.87-1.4)
Traditionalist	150 (1.8)	74	1.24 (0.91-1.7)	1.44 (0.98-2.13)
Missing	870 (10.4)	84	-	-
Parity			[P<0.001]	[P=<0.001]
>5	1193 (14.3)	80	Ref	Ref
1	1712 (20.5)	86	0.68 (0.58-0.81)	1.02 (0.83-1.25)
2-3	2855 (34.2)	84	0.76 (0.67-0.88)	1.01 (0.86-1.21)
4-5	1790 (21.4)	83	0.82 (0.71-0.97)	0.98 (0.82-1.18)
Missing	801 (9.6)	82	-	-
Place of delivery			[P<0.001]	[P<0.001]
TBA/Home	3329 (50.5)	78	Ref	Ref
Health Facility	4221 (39.9)	89	0.50 (0.45-0.56)	0.73 (0.64-0.84)
Missing	801 (9.6)	82	-	-
Maternal Education			[P<0.001]	[P=<0.001]
None	3241 (38.8)	80	Ref	Ref
Basic	3231 (38.7)	85	0.75 (0.68-0.84)	0.89 (0.77-1.03)
Higher	416 (5)	92	0.37 (0.26-0.53)	0.85 (0.59-1.23)
Missing	1463 (17.5)	85	-	
Wealth Index			[P<0.001]	[P<0.001]
Poorest	1783 (21.4)	75	Ref	Ref
Poorer	1733 (20.8)	79	0.86 (0.76-0.97)	0.87 (0.75-1.03)
Poor	1505 (18)	85	0.62 (0.55-0.73)	0.81 (0.68-0.98)
Less poor	1357 (16.2)	89	0.44 (0.37-0.53)	0.74 (0.59-0.94)
Least poor	1299 (15.6)	94	0.24 (0.19-0.3)	0.55 (0.39-0.78)
Missing	674 (8.1)	84	-	-
Season of Birth			[P=0.063]	[P0.063]
Dry	1719 (20.6)	85	Ref	Ref
Major Rains	3092 (37)	84	1.01 (0.88-1.16)	0.99 (0.84-1.18)
Minor Rains	3540 (42.4)	83	1.13 (0.99-1.29)	1.12 (0.95-1.32)

Figure 13 Vaccination card used

In use until mid 2012



IMMUNISATIONS AND VITAMIN A

VACCINE / DATE	DATE OF NEXT VISIT	BATCH NO.	PLACE GIVEN
TUBERCULOSIS (BCG)			
At birth 26/6/09		417-2	Busuama
POLIOMYELITIS			
At birth 26/6/09			" "
1st (6 weeks) 21/8/09		BOVPB358AA	" "
2nd (10 weeks) 25/9/09		" "	" "
3rd (14 weeks) 14/12/09		A29FA29OAA	" "
DIPHTHERIA/PERTUSSIS/TETANUS/HEPATITIS B/HAEMOPHILUS INFLUENZAE B.			
1st (6weeks) 21/8/09		A29FA03 1B	" "
2nd (10weeks) 25/9/09		A29FA017BA	" "
3rd (14weeks) 14/12/09		PB901	" "
VITAMIN A			
(6 months) 15/01/10		1001000	" "
MEASLES			
(9months) 12/03/10		G04N802	" "
YELLOW FEVER			
(9months) 12/03/10		085VFCA12	" "
VITAMIN A			

DOSE	2nd (12months)	3rd (1 ½ years)	4th (2 years)	5th (2½ years)	6th (3 years)	7th (3½ years)	8th (4 years)	9th (4½ years)	10th (5 years)
DATE	29/07/10	11/3/11	7/10/11	18/9/12	08/3/13		10/12/13	10/6/14	

Other vaccines:
12/07/13 m/s 2 #52 2501412 RCH K'pong
13/5/14

3

Currently in use

Immunizations and Vitamin A					
Age Period	Vaccine	Date Given	Batch No.	Place Given	Date of Next Visit
At Birth	BCG				
	Polio				
	Hepatitis B				
6 Weeks	Polio				
	DPT/Hep B/ Hib 1 (5 in 1)		V: D:		
	Pneumococcal				
	Rotavirus				
10 Weeks	Polio				
	DPT/Hep B/ Hib 2 (5 in 1)		V: D:		
	Pneumococcal				
	Rotavirus				
14 Weeks	Polio				
	DPT/Hep B/ Hib 3 (5 in 1)		V: D:		
	Pneumococcal				
6 Months	Vitamin A				
9 Months	Measles 1		V: D:		
	Yellow Fever				
12 Months	Vitamin A				
18 Months	Vitamin A				
	Measles 2		V: D:		
	Treated Net (LLIN)				

V - Vaccine Batch Number
D - Diluent Batch Number

Appendix 4: Nouna 2012-14

List of Tables

Table 1 Inclusion per year of visit 5
Table 2 Percent of children per year having no vaccination card 5
Table 3 Representativeness – comparison children included and excluded from the analyses 7
Table 4 FIC coverage by year of visit 8
Table 5 Coverage of FIC by year of visit and sex 9
Table 6 Coverage of FIC by year and place of residence 9
Table 7 Coverage of FIC by year of visit and place of birth 9
Table 8 Coverage of FIC by year of visit and maternal education 9
Table 9 Median vaccination age (days) and lower and upper quartiles for FIC 12
Table 10 Median vaccination age (days) and lower and upper quartiles for NOT FIC with a vaccine 12
Table 11 Among children NOT FIC, missing a specific vaccine 14
Table 12 Among children NOT FIC, missing only the particular vaccine 14
Table 13 Among children NOT FIC, number of vaccines missing 14
Table 14 Full immunization coverage in sequence (FICIS) among FIC 15
Table 15 Main reasons for out-of-sequence for FIC who are out-of-sequence (FICOS) 17
Table 16 Fully Vaccination coverage at 24 months (FIC24) for NOT FIC at 12 months of age 17
Table 17 Analyses of association between background factors and FIC 19
Table 18 Analyses of association between background factors and FICIS among FIC 20
Table 19 Survival analysis of FIC vs NOT FIC, Children followed to 3 years of age 21
Table 20 Interactions 22
Table 21 Survival analysis - splitting FIC into FICIS and FICOS 22
Table 22 Survival analysis - NOT FIC split into “FIC without MCV” and otherwise 23

List of Figures

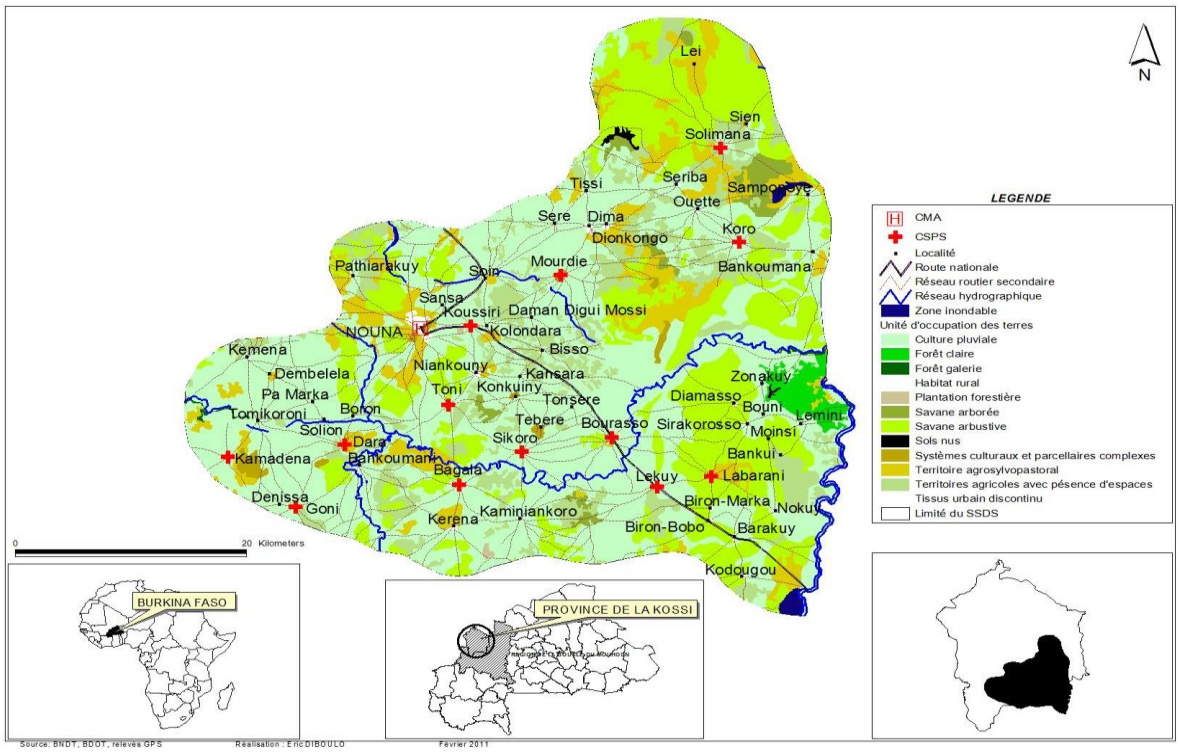
Figure 1 Flow chart of inclusion Nouna 2012-14 5
Figure 2 Histogram of visits from flow chart 6
Figure 3 FIC coverage by year of visit 8
Figure 4 FIC Coverage by key factors 10
Figure 5 Coverage curves for each vaccine among FIC, NOT FIC, and combined 11
Figure 6 Comparison of median vaccination age of FIC and NOT FIC 13
Figure 7 Among NOT FIC percent of missing a particular vaccine 14
Figure 8 Coverage of FIC-in-sequence among FIC 15
Figure 9 Coverage of FIC-in-sequence among FIC for key factors 16
Figure 10 Reason for out-of-sequence among FICOS 17
Figure 11 FIC15 Coverage curves for each vaccine among FIC, NOT FIC, and combined 18
Figure 12 Vaccination card used 24

Nouna Health Demographic Surveillance System

Description of the site

The Centre de Recherche en Santé de Nouna (CRSN) began in the early 1990s as a collaborative project between University of Heidelberg/Germany and the Ministry of Health in Burkina Faso. The CRSN began as a research project funded by the European Commission and the German Ministry of Research and Technology. It was institutionalised by the Government of Burkina-Faso in 1999 as a national centre for biomedical and health systems research with the allocation of substantial financial and structural resources.

The research area of the CRSN is located in a district in northwest Burkina Faso, 300 km from the capital, Ouagadougou. It has about 95,000 inhabitants and 13300 households, settled over 1,775 km². The Nouna research area is a dry orchard savannah, populated almost exclusively with subsistence farmers of various ethnic groups. The area has a sub-Saharan climate, with a mean annual rainfall of 796 mm (range 483-1083 mm) over the past five decades. The population of the Nouna district is about 312,080 inhabitants and the population of Burkina Faso is 17,880,386. Burkina Faso is located in the middle of West Africa and covers an area of 274,200 km². It is bordered to the north and west by Mali, northeast by Niger, the southeast by Benin and south by Togo, Ghana and Ivory Coast.



Current data collection and processing

The baseline census was conducted in 1992, and gathered relevant demographic information from all individuals in the rural study area. The baseline census for the suburban part (Nouna town) took place in January 2000.

Regular update rounds

Two further censuses were carried out in 1994 and 1998, to check and update information from previous censuses. Census update rounds are planned for every 2 years to supplement the vital-events registration and produce a clear picture of the study population at certain fixed points in time. Previously programmed as a monthly activity, the vital-event registration has collected data every 3 months from all households of the DSS area since January 2000. Previously, an interviewer visited the key informant of each village to obtain information about any vital events. Now, the fourteen interviewers visit each household to inquire about all members previously registered or actually living in the household and identify all new vital events since the previous visits. Data are collected on births, deaths, pregnancies, and migration in or out of the household, including all dates related to these events.

Vaccination data

On a trial basis we have started collecting vaccination data since January 2009. The data are collected three times per year during the update round for vital events in the 59 villages in the DSS area. The vaccination data are collected from the vaccination cards of the children during the home visit. All children less than 3 years of age are followed.

Vaccination services in Burkina Faso

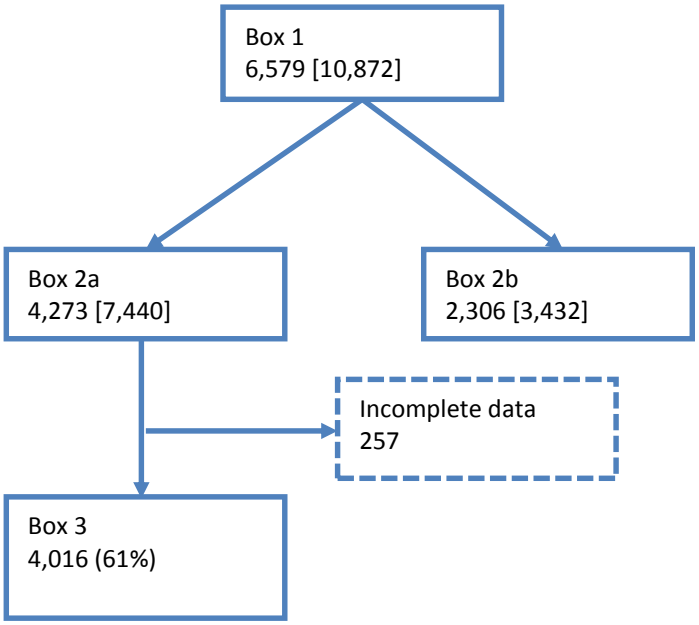
The Ministry of Health formulates the program to fight diseases prevented by vaccination. These program are implemented by the 13 health regional directions (DRS) each responsible for a number of hospitals and peripheral health centers (CSPS). Each center conducts monthly vaccination sessions, except for the urban CSPS which performs vaccinations every day in the health facility.

The routine vaccination program in Burkina Faso recommends seven different vaccines for the prevention of infections by 11 pathogens: Bacillus Calmette-Guérin (BCG), Oral Polio Vaccine (OPV), and Pentavalent Vaccine (diphtheria, tetanus, pertussis, hepatitis B, and Haemophilus influenzae type b (Penta)), measles vaccine and yellow fever vaccine. Since 2013 rotavirus and pneumococcal vaccines have been added. The recommended vaccination schedule in Burkina Faso is BCG and first

dose of OPV (OPV0) at birth, first dose of Penta (Penta1), rotavirus vaccine, pneumococcal vaccine and OPV1 at 8 weeks, Penta2 , rotavirus, pneumococcal, and OPV2 at 12 weeks, Penta3,rotavirus, pneumococcal, and OPV3 at 16 weeks, and measles and yellow fever vaccination at 9 months of age. Children living in the villages in the catchment area of respective CSPS are visited once per month by a CSPS vaccination team.

Each health facility (CSPS) has community health workers and village midwives who give the information about vaccination schedule. On the day before a vaccination session, health workers give a vaccination slip to all the mothers whose children are due to be vaccinated in a session to allow them to bring their children. The community health workers also facilitate the occasional vaccination campaigns (e.g. oral polio, vitamin A and mebendazole) which are often conducted door to door.

Figure 1 Flow chart of inclusion Nouna 2012-14



Box 1
Number of children alive at an HDSS home visit between 12 and 23 months of age
[Number of visits asking for vaccine card]

Box 2a
Number of children from box 1 having at least one visit with card seen
[Number of visits for these children including those where card not seen]

Box 2b
Number of children from box 1 having no seen card at any visit between 12 and 23 months of age
[Number of visits]

Box 3
Number of children included in analyses

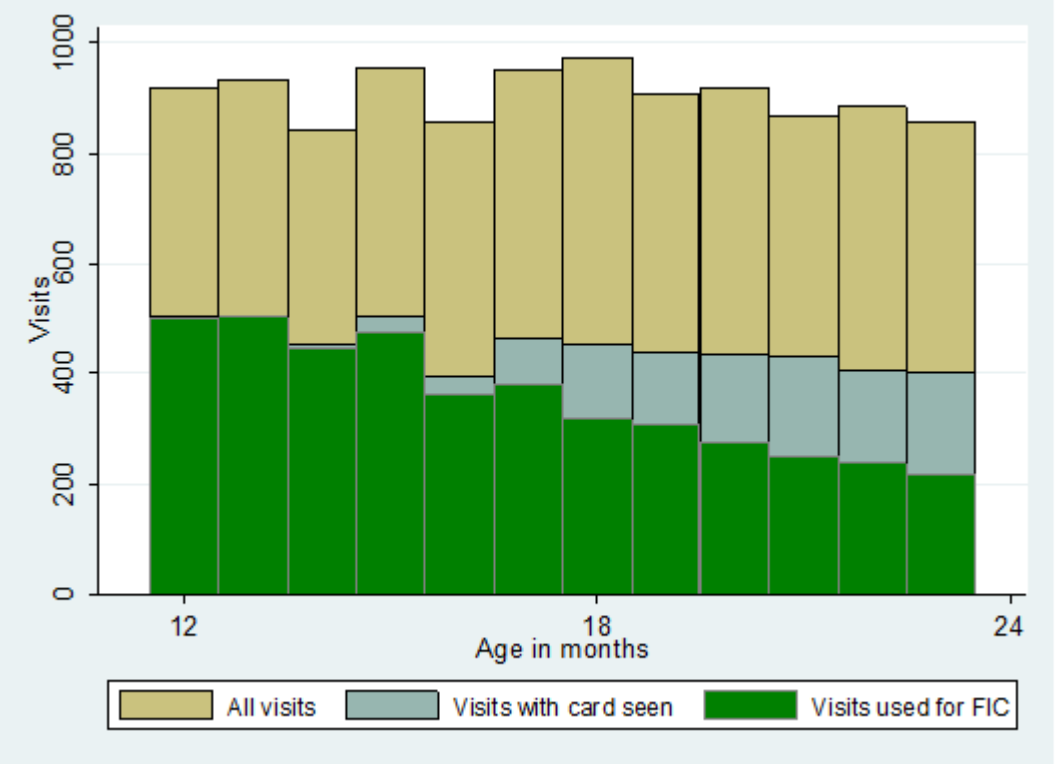
Table 1 Inclusion per year of visit

Year of Visit	Inclusion % (n/total)
2012	57 (648/1129)
2013	62 (2082/3373)
2014	62 (1286/2077)
Total	61 (4016/6579)

Table 2 Percent of children per year having no vaccination card

Year of Visit	No card % (n/total)
2012	3 (30/1129)
2013	2 (80/3373)
2014	4 (73/2077)
Total	3 (183/6579)

Figure 2 Histogram of visits from flow chart



All visits = Visits from Box 1
Visits with card seen = Visits from Box 2a
Visits used for FIC = Visits from Box 3

Table 3 Representativeness – comparison children included and excluded from the analyses

Variable	Included n (%)	Excluded n (%)	P-value
Sex			0.930
Male	1996 (50)	1271 (50)	
Female	2020 (50)	1292 (50)	
Year of visit			0.022
2012	648 (16)	481 (19)	
2013	2082 (52)	1292 (50)	
2014	1286 (32)	790 (31)	
Place of residence			0.004
Rural	3210 (80)	2121 (83)	
Urban	806 (20)	442 (17)	
Twin			<0.001
No	3729 (93)	2314 (90)	
Yes	118 (3)	81 (3)	
Missing	169 (4)	168 (7)	
Ethnic			<0.001
Bwamu	1098 (27)	587 (23)	
Dafing	1424 (35)	1020 (40)	
Mossi	656 (16)	348 (14)	
Peulh	371 (9)	292 (11)	
Samo	223 (6)	110 (4)	
Autres	75 (2)	38 (1)	
Missing	169 (4)	168 (7)	
Religion			<0.001
Muslim	2354 (59)	1598 (62)	
Catholic	1328 (33)	721 (28)	
Others	164 (4)	76 (3)	
Missing	170 (4)	168 (7)	
Place of delivery			<0.001
Health facility	3506 (87)	2109 (82)	
Home/elsewhere	337 (8)	285 (11)	
Missing	173 (4)	169 (7)	
Maternal education			0.514
No	3646 (91)	2339 (91)	
Yes	370 (9)	224 (9)	
Mother age			<0.001
10-19	622 (15)	409 (16)	
20 -34	2631 (66)	1668 (65)	
34 -49	588 (15)	317 (12)	
Missing	175 (4)	169 (7)	
Marital status			<0.001
Not married	128 (3)	93 (3)	
Married	3719 (93)	2301 (90)	
Missing	169 (4)	169 (7)	
Season of birth			0.556
Rainy season	1637 (41)	1026 (40)	
Dry season	2379 (59)	1537 (60)	
Occupation			<0.001
No salary	3644 (91)	2281 (89)	
Salary	200 (5)	108 (4)	
Missing	172 (4)	174 (7)	

Table 4 FIC coverage by year of visit

Year of Visit	FIC coverage % (n/total)
2012	72 (468/648)
2013	79 (1640/2082)
2014	81 (1040/1286)
Total	78 (3148/4016)

Figure 3 FIC coverage by year of visit

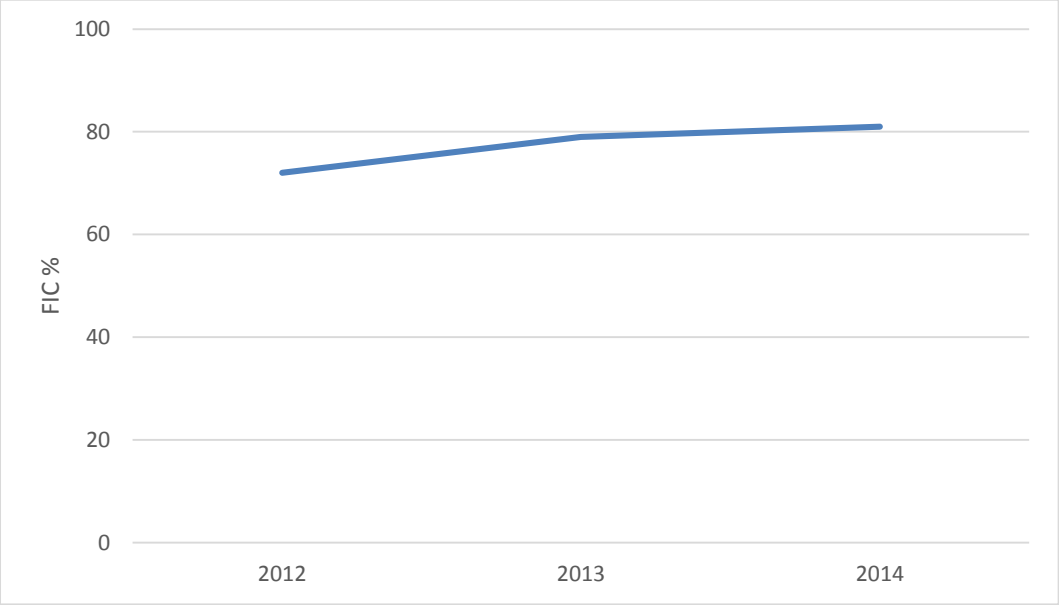


Table 5 Coverage of FIC by year of visit and sex

Year of Visit	Sex		
	Females	**Males**	**Total**
2012	71 (237/332)	73 (231/316)	72 (468/648)
2013	79 (818/1036)	79 (822/1046)	79 (1640/2082)
2014	80 (524/653)	82 (516/633)	81 (1040/1286)
Total	78 (1579/2021)	79 (1569/1995)	78 (3148/4016)

Table 6 Coverage of FIC by year and place of residence

Year of Visit	Place of residence		
	Urban	**Rural**	**Total**
2012	41 (39/95)	78 (429/553)	72 (468/648)
2013	68 (306/447)	82 (1334/1635)	79 (1640/2082)
2014	78 (205/264)	82 (835/1022)	81 (1040/1286)
Total	68 (550/806)	81 (2598/3210)	78 (3148/4016)

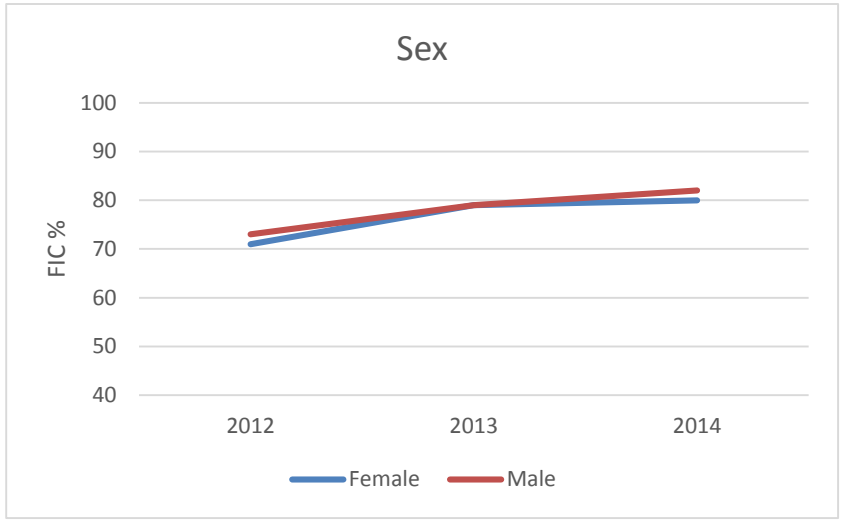
Table 7 Coverage of FIC by year of visit and place of birth

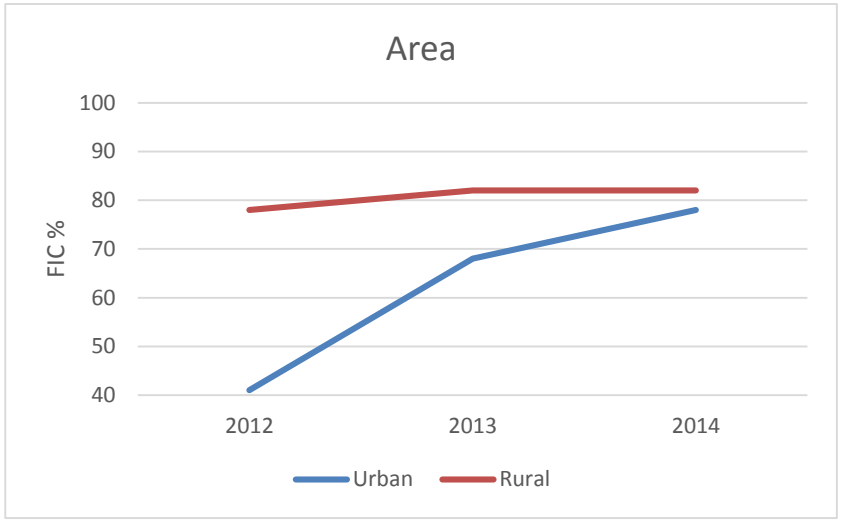
Year of Visit	Place of birth		
	Health facility	**Home**	**Total**
2012	73 (386/530)	81 (44/54)	72 (468/648)
2013	80 (1464/1829)	79 (116/147)	79 (1640/2,082)
2014	81 (932/1147)	78 (106/136)	81 (1040/1286)
Total	79 (2782/3506)	79 (266/337)	79 (3048/3843)

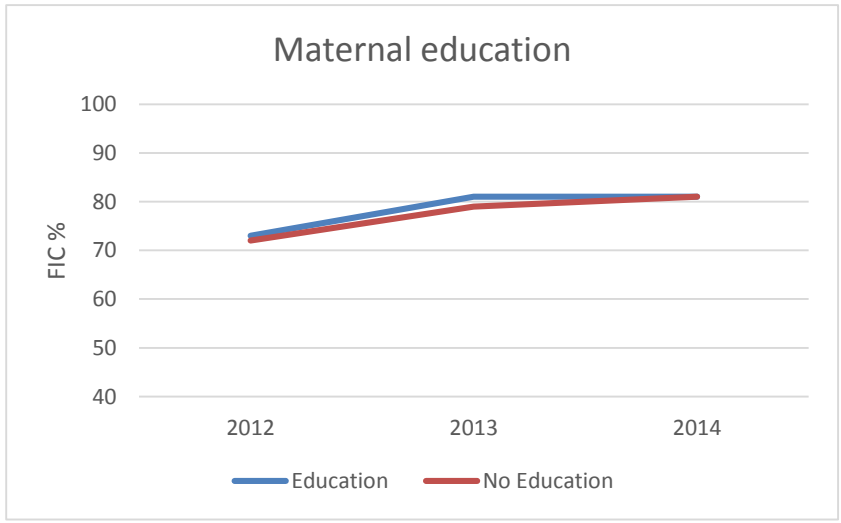
Table 8 Coverage of FIC by year of visit and maternal education

Year of Visit	Maternal education		
	No	**Yes**	**Total**
2012	72 (428/593)	73 (40/55)	72 (468/648)
2013	79 (1480/1884)	81 (160/198)	79 (1640/2082)
2014	81 (945/1169)	81 (95/117)	81 (1040/1286)
Total	78 (2853/3646)	80 (295/370)	78 (3148/4016)

Figure 4 FIC Coverage by key factors







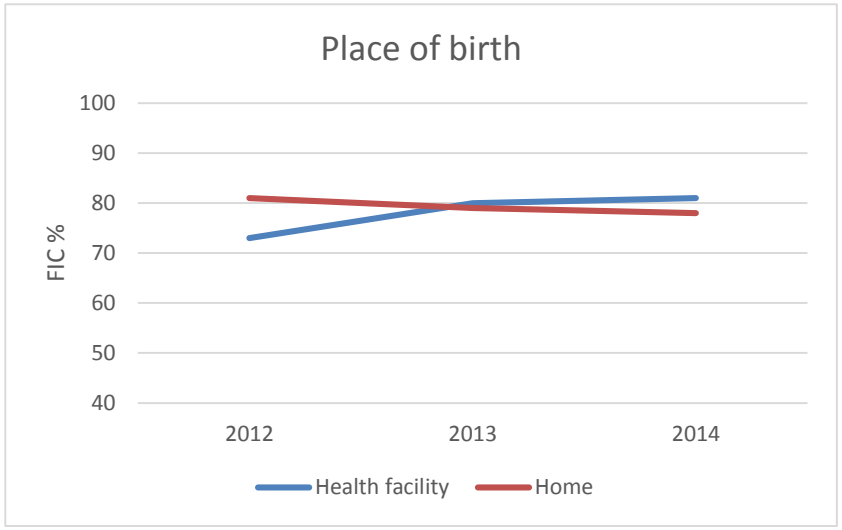
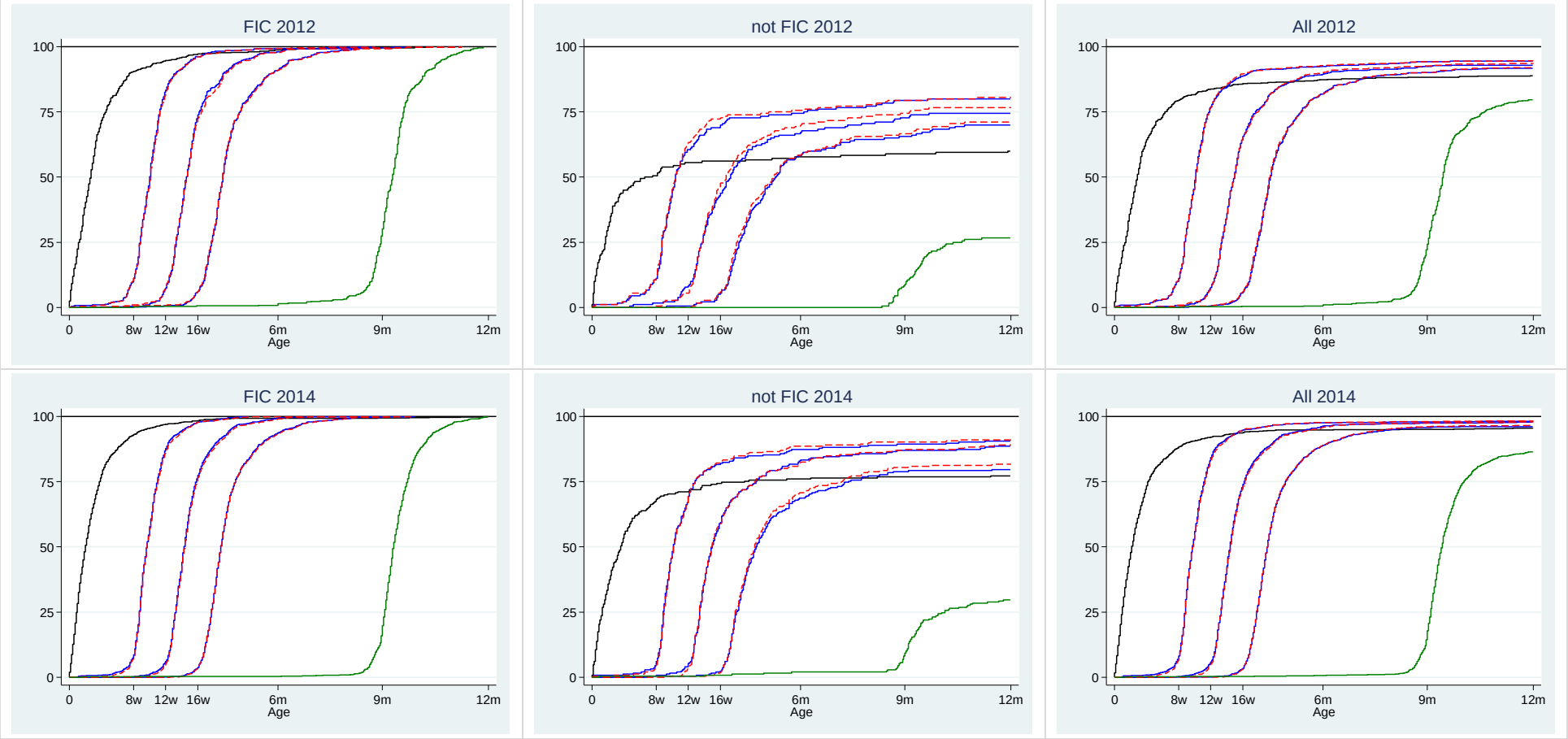


Figure 5 Coverage curves for each vaccine among FIC, NOT FIC, and combined



BCG is black; Penta is blue; OPV is dashed and red; MCV is green

Table 9 Median vaccination age (days) and lower and upper quartiles for FIC

Year of visit	BCG			Penta 1			Penta 2			Penta 2			OPV 1			OPV 2			OPV 3			MCV		
	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
2012	9	19	33	62	71	79	93	103	115	124	134	150	62	71	79	93	103	117	124	134	150	272	282	292
2013	6	15	26	61	67	77	92	100	110	123	132	145	60	67	76	91	100	110	123	132	145	270	280	290
2014	7	14	26	61	68	77	93	100	111	124	132	145	61	68	77	93	101	111	124	132	145	275	283	295
Total	6	15	27	61	68	77	92	100	111	124	133	146	61	68	77	92	101	111	123	132	145	272	281	292

Table 10 Median vaccination age (days) and lower and upper quartiles for NOT FIC with a vaccine

Year of visit	BCG			Penta 1			Penta 2			Penta 3			OPV 1			OPV 2			OPV 3			MCV		
	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
2012	4	14	27	61	69	89	92	106	130	124	138	164	60	68	83	92	105	127	122	137	164	267	282	293
2013	6	14	27	61	67	79	92	101	118	123	134	154	61	67	79	92	102	118	123	135	155	269	281	292
2014	6	16	33	62	69	84	94	102	122	124	136	156	62	70	84	94	102	125	124	135	156	272	279	294
Total	6	14	29	61	68	82	93	102	122	123	135	158	61	68	82	93	102	122	123	135	158	270	281	292

Figure 6 Comparison of median vaccination age of FIC and NOT FIC

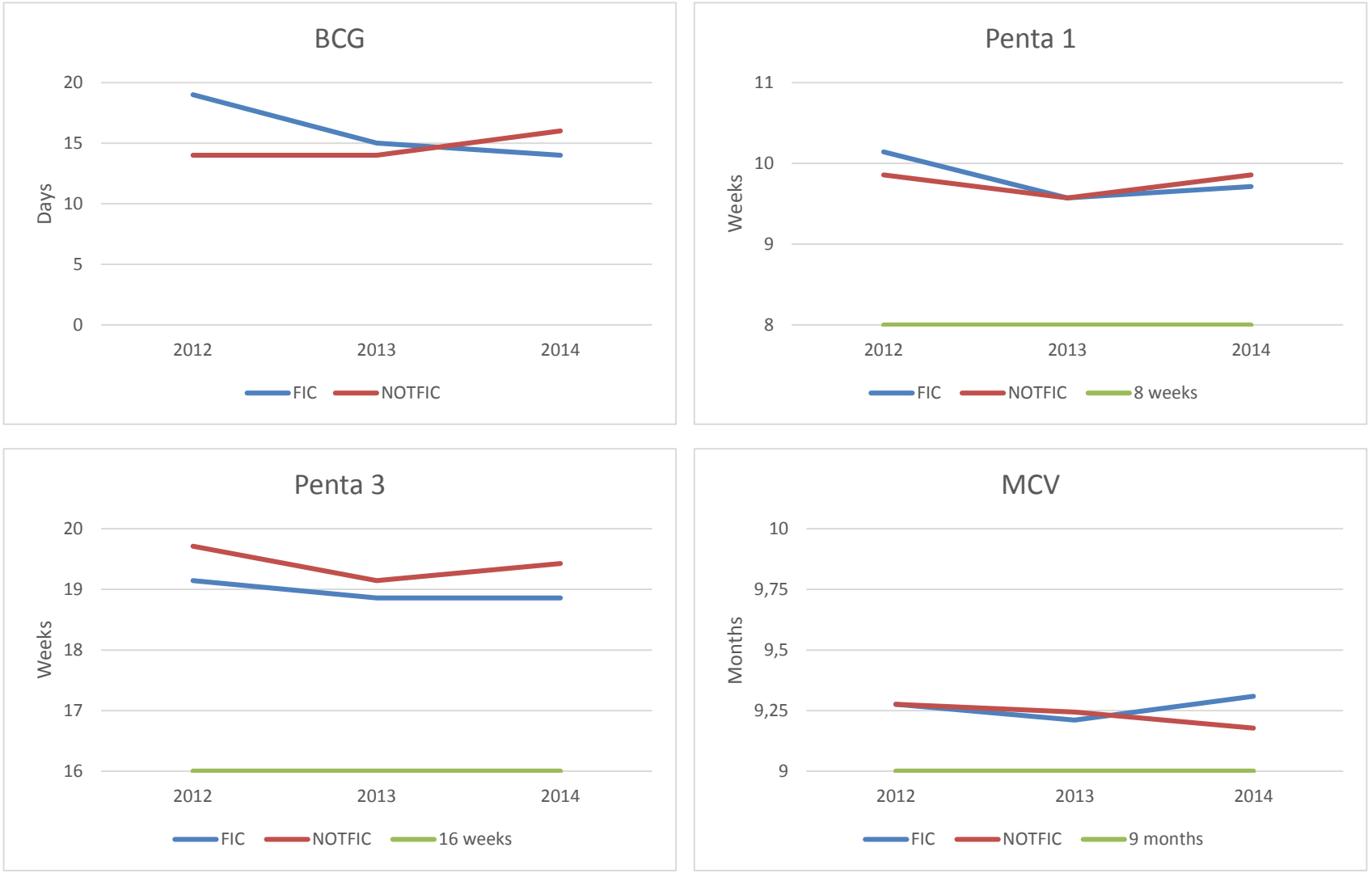


Table 11 Among children NOT FIC, missing a specific vaccine

Year of visit	BCG	Penta 1	Penta 2	Penta 3	OPV 1	OPV 2	OPV 3	MCV	Number NOT FIC
2012	40% (72)	20% (36)	26% (46)	30% (54)	19% (35)	23% (42)	29% (52)	73% (132)	180
2013	27% (119)	20% (87)	25% (109)	34% (150)	20% (88)	25% (112)	31% (139)	73% (321)	442
2014	23% (56)	9% (23)	11% (28)	20% (50)	9% (22)	11% (27)	18% (45)	70% (173)	246
Total	28% (247)	17% (146)	21% (183)	29% (254)	17% (145)	21% (181)	27% (236)	72% (626)	868

Figure 7 Among NOT FIC percent of missing a particular vaccine

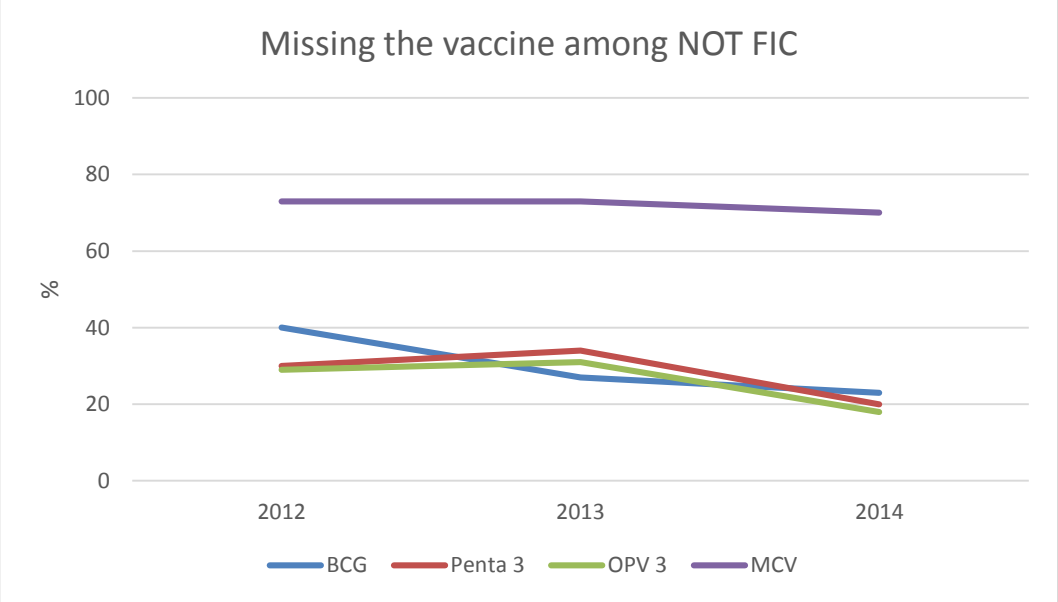


Table 12 Among children NOT FIC, missing only the particular vaccine

Year of visit	BCG	Penta 3	OPV 3	MCV
2012	43% (33)	2% (2)	1% (1)	68% (76)
2013	24% (47)	5% (13)	2% (4)	76% (198)
2014	29% (40)	3% (5)	1% (2)	74% (136)
Total	29% (120)	4% (20)	1% (7)	74% (410)

Table 13 Among children NOT FIC, number of vaccines missing

	Number of vaccines missing							
Year of visit	1	2	3	4	5	6	7	8
2012	63% (113)	8% (14)	5% (9)	2% (4)	4% (7)	2% (3)	4% (8)	12% (22)
2013	63% (280)	7% (32)	7% (31)	2% (7)	3% (15)	1% (5)	5% (21)	12% (51)
2014	78% (193)	7% (18)	5% (12)	0% (1)	2% (4)	0% (1)	3% (7)	4% (10)
Total	68% (586)	7% (64)	6% (52)	1% (12)	3% (26)	1% (9)	4% (36)	10% (83)

Table 14 Full immunization coverage in sequence (FICIS) among FIC

Year of visit	FICIS % (n/FIC)
2012	76 (354/468)
2013	78 (1282/1640)
2014	85 (884/1040)
Total	80 (2522/3148)

FICIS is defined as the WHO recommended sequence of vaccinations, i.e. BCG before OPV1, OPV1=Penta1, OPV2=Penta2, OPV3=Penta3 and Penta3 before MCV.

Figure 8 Coverage of FIC-in-sequence among FIC

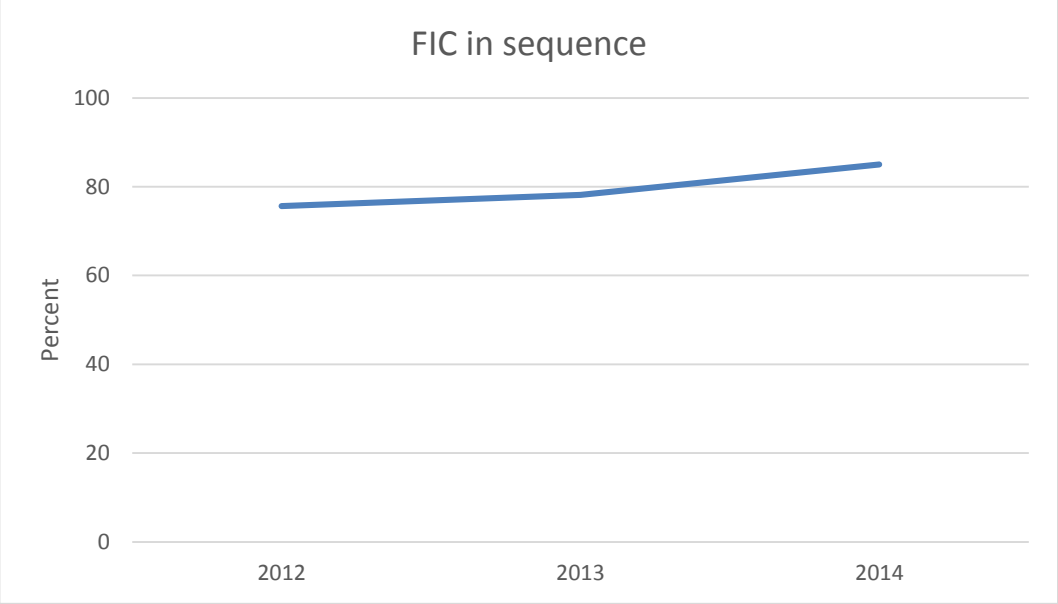


Figure 9 Coverage of FIC-in-sequence among FIC for key factors

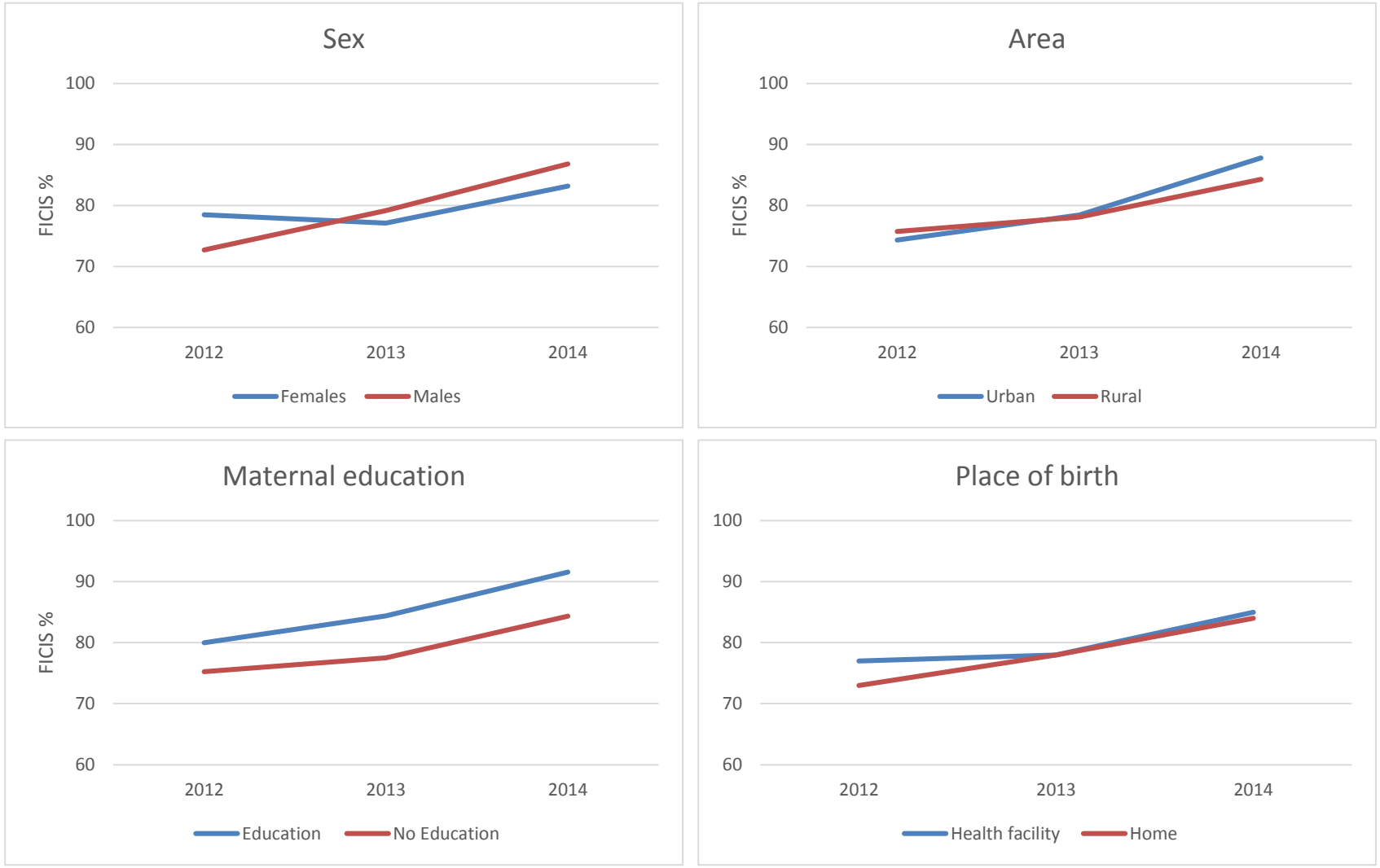


Table 15 Main reasons for out-of-sequence for FIC who are out-of-sequence (FICOS)

Year of Visit	Type of out-of-sequence % (n)			
	BCG ≥ Penta1 or MCV	OPV ≠ Penta	Penta ≥ MCV	Total FICOS
2012	39 (45)	68 (78)	4 (5)	114
2013	28 (100)	72 (258)	10 (37)	358
2014	41 (64)	65 (101)	3 (5)	156
Total	33 (209)	70 (437)	7 (47)	628

Note: Percentages do not need to sum up to 100 as children may contribute to more than one type of out-of-sequence.

Figure 10 Reason for out-of-sequence among FICOS

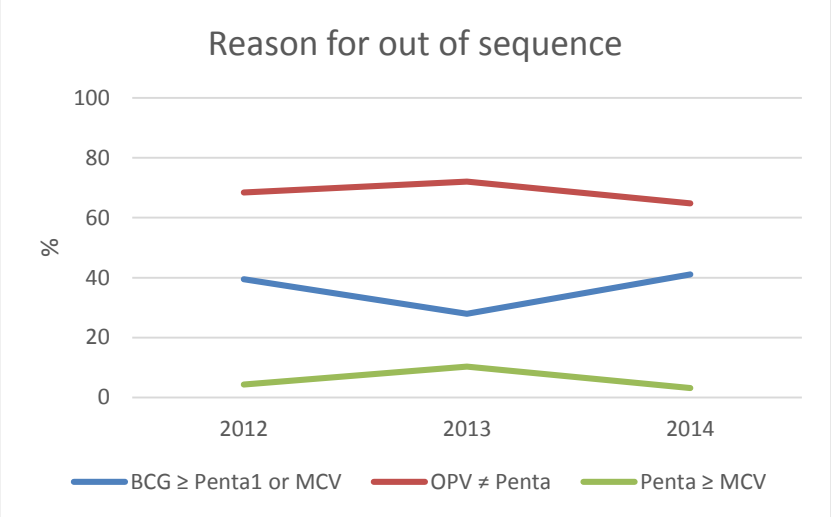
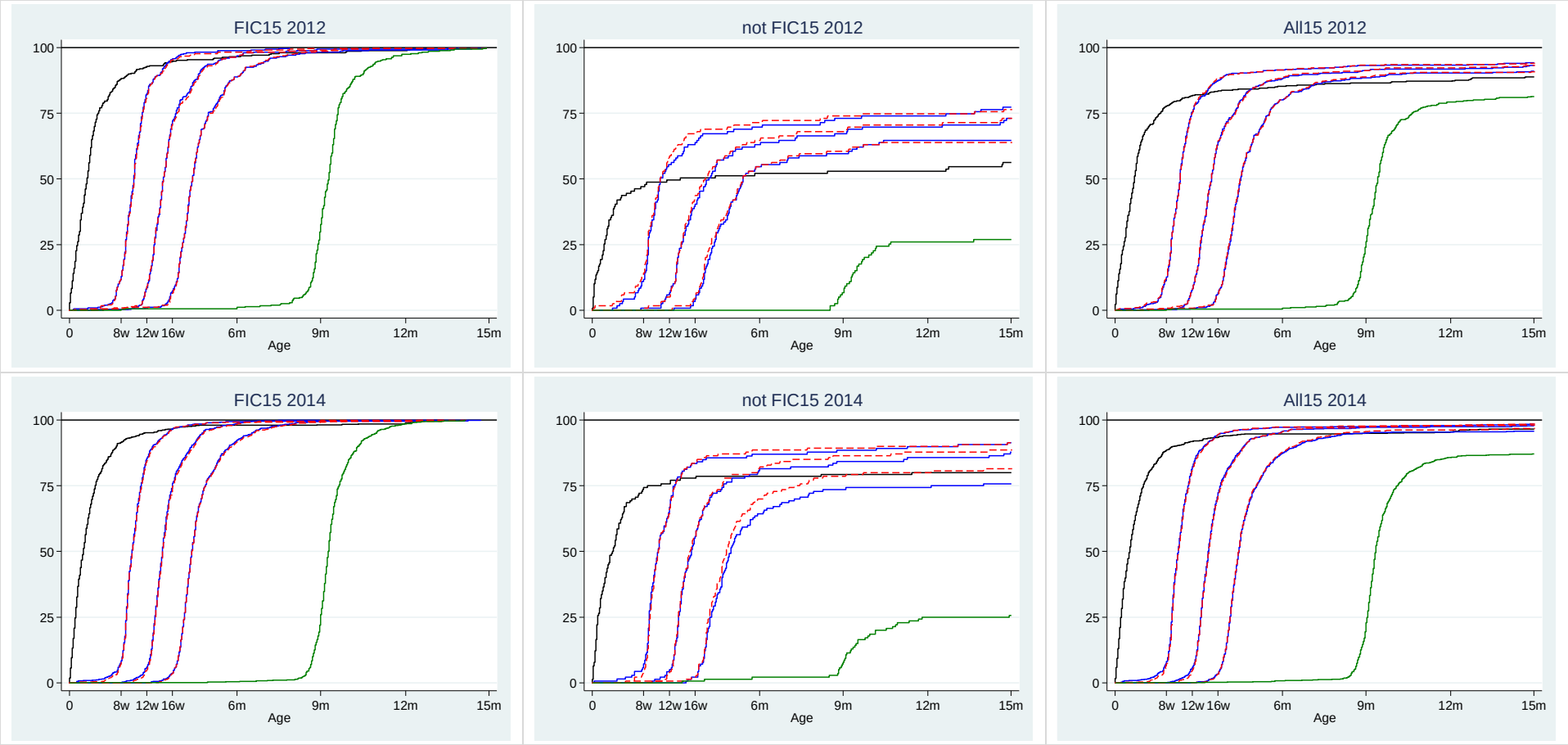


Table 16 Fully Vaccination coverage at 24 months (FIC24) for NOT FIC at 12 months of age

Year of visit for FIC12	Percent (FIC24/N)
2012	31 (30/96)
2013	42 (67/161)
2014	*NA*
Total	38 (97/257)

Figure 11 FIC15 Coverage curves for each vaccine among FIC, NOT FIC, and combined



N=2651 children included, i.e. 66% (2651/4016) of the children in the overall FIC analyses (see Figure 1)

Table 17 Analyses of association between background factors and FIC

Background Factors	N (%)	FIC %	Unadjusted [P-value*] PR (95%CI)	Adjusted [P-value] aPR (95%CI)
Sex			[P=0.69]	[P=0.80]
Male	1995 (50)	79	Ref	Ref
Female	2021 (50)	78	0.99 (0.96-1.03)	0.99 (0.96-1.02)
Year of visit			[P=0.00]	[P=0.01]
2012	648 (16)	72	Ref	Ref
2013	2082 (52)	79	1.09 (1.03-1.15)	1.07 (1.02-1.13)
2014	1286 (32)	81	1.12 (1.06-1.18)	1.07 (1.02-1.13)
Area			[P=0.00]	[P=0.00]
Rural	3210 (80)	81	Ref	Ref
Urban	806 (20)	68	0.84 (0.80-0.89)	0.84 (0.79-0.88)
Twin			[P=0.39]	Not included
No	3729 (93)	79	Ref	
Yes	118 (3)	82	1.04 (0.95-1.13)	
Missing	169 (4)			
Religion			[P=0.26]	[P=0.06]
Muslim	2354 (59)	79	Ref	Ref
Catholic	1328 (34)	79	0.99 (0.95-1.02)	0.96(0.92-0.99)
Others	164 (3)	84	1.05 (0.98-1.12)	1.00 (0.93-1.08)
Missing	170 (4)			
Place of birth			[P=0.85]	[P=0.29]
Health facility	3506 (87)	79	Ref	Ref
Home	337 (8)	79	0.99 (0.94-1.05)	0.96 (0.91-1.02)
Missing	173 (4)			
Education			[P=0.49]	[P=0.02]
No educated	3646 (91)	78	Ref	Ref
Educated	370 (9)	80	1.02 (0.97-1.08)	1.07 (1.01-1.13)
Mother age			[P=0.45]	[P=0.29]
10-19	622 (15)	77	Ref	Ref
20-34	2631 (66)	80	1.03 (0.98-1.08)	1.03 (0.98-1.07)
34-49	588 (15)	80	1.04 (0.98-1.10)	1.04 (0.98-1.10)
Missing	170 (4)			
Marital status			[P=0.21]	Omitted
No married	125 (3)	74	Ref	
Married	3722 (93)	79	1.07 (0.96-1.19)	
Missing	169 (4)			
Season of birth			[P=0.68]	Omitted
Dry season	2379 (59)	79	Ref	
Rainy season	1637 (41)	78	0.99 (0.96-1.03)	
Occupation			[P=0.15]	Omitted
No salary	3656 (91)	80	Ref	
Salary	186 (5)	75	0.94 (0.86-1.02)	
Missing	174 (4)		-	

Table 18 Analyses of association between background factors and FICIS among FIC

Background Factors	N (%)	FICIS %	Unadjusted [P-value*] PR (95%CI)	Adjusted [P-value] aPR(95%CI)
Sex			[P=0.32]	[P=0.57]
Male	1569 (50)	81	Ref	Ref
Female	1579 (50)	79	1.02 (0.98-1.05)	0.98 (0.95-1.02)
Year of visit			[P<0.001]	[P<0.001]
2012	468 (15)	76	Ref	Ref
2013	1640 (52)	78	1.03 (0.97-1.09)	1.02 (0.96-1.08)
2014	1040 (33)	85	1.12 (1.06-1.19)	1.11 (1.04-1.18)
Area			[P=0.30]	[P=0.97]
Rural	2598 (83)	80	Ref	Ref
Urban	550 (17)	82	1.02 (0.97-1.07)	1.00 (0.95-1.05)
Twin			[P=0.85]	[P=0.77]
No	2954 (93)	80	Ref	Ref
Yes	97 (3)	79	0.99 (0.89-1.09)	0.98 (0.88-1.09)
Missing	75 (4)	77		
Religion			[P=0.35]	[P=0.38]
Muslim	1869 (59)	80	Ref	Ref
Catholic	902 (29)	82	1.02 (0.99-1.07)	1.02 (0.98-1.06)
Others	279 (9)	79	0.98 (0.89-1.07)	1.00 (0.94-1.06)
Missing	98 (3)	78		
Place of birth			[P=0.85]	[P=0.96]
Health facility	2782 (88)	80	Ref	Ref
Home	266 (8)	80	0.99 (0.93-1.06)	1.00 (0.94-1.06)
Missing	100 (3)	78		
Education			[P=0.00]	[P=0.01]
No educated	2853 (91)	79	Ref	Ref
Educated	254 (9)	86	1.08 (1.03-1.14)	1.07 (1.01-1.13)
Mother age			[P=0.29]	[P=0.07]
10-19	482 (15)	78	Ref	Ref
20-34	2092 (66)	81	1.04 (0.98-1.09)	1.05 (0.99-1.11)
34-49	472 (15)	80	1.02 (0.96-1.09)	1.03 (0.96-1.10)
Missing	77 (3)	75		
Marital status			[P=0.23]	[P=0.10]
No married	93 (3)	85	Ref	
Married	2958 (94)	80	0.94 (0.86-1.02)	0.92 (0.84-1.01)
Missing	97 (3)	77		
Season of birth			[P=0.05]	[P=0.11]
Dry season	1870 (59)	81	Ref	Ref
Rainy season	1278 (41)	78	0.96 (0.93-1.00)	0.97 (0.93-1.01)
Occupation			[P=0.72]	[P=0.82]
No salary	2908 (91)	80	Ref	Ref
Salary	139 (5)	81	1.01 (0.93-1.10)	0.98 (0.90-1.08)
Missing	101 (4)	77		

Table 19 Survival analysis of FIC vs NOT FIC, Children followed to 3 years of age

Factor	Mortality Rate/1000 pyrs	Deaths/pyrs &	Number of children ¤	Crude Hazard ratio (95%-CI)	Adjusted Hazard ratio [P-value] (95%-CI)
FIC				[p=0.39]	[p=0.50]
No	20	10 / 496	586	Ref	Ref
Yes	15	24 / 1643	2046	0.72 (0.34-1.51)	0.75 (0.33-1.71)
Sex				[p=0.02]	[p=0.01]
Male	23	24 / 1059	1313	Ref	Ref
Female	9	10 / 1079	1319	0.41 (0.19-0.85)	0.38 (0.18-0.83)
Year				[p=0.01]	[p=0.07]
2012	10	7 / 717	631	Ref	Ref
2013	19	27 / 1422	2000	1.94 (0.83-4.54)	2.38 (0.95-6.00)
2014	*NA*				
Area				[p=0.75]	[p=0.58]
Rural	15	27 / 1743	2125	Ref	Ref
Urban	18	7 / 395	507	1.15 (0.50-2.64)	0.76 (0.28-2.03)
Twin				[p=0.32]	
No	15	30 / 1942	2413	Ref	Omitted
Yes	32	2 / 62	78	2.08 (0.50-8.70)	
Religion				[p=0.01]	[p=0.009]
Muslim	19	23 / 1199	1519	Ref	Ref
Catholic	7	5 / 725	868	0.36 (0.14-0.94)	0.39 (0.15-1.04)
Others	50	4 / 81	104	2.62 (0.90-7.57)	3.18 (1.07-9.47)
Birth Place				[p=0.72]	[p=0.67]
Health Facility	16	30 / 1844	2296	Ref	Ref
Home	13	2 / 159	194	0.77 (0.18-3.22)	0.73 (0.17-3.08)
Maternal Education				[p=0.23]	
None	17	33 / 1940	2393	Ref	Omitted
1-4 grade	5	1 / 199	239	0.30 (0.04-2.16)	
Maternal Age				[p=0.51]	[p=0.50]
<20	24	7 / 294	383	Ref	Ref
20-34	15	21 / 1402	1730	0.63 (0.27-1.49)	0.62 (0.26-1.46)
>35	13	4 / 306	374	0.55 (0.16-1.88)	0.55 (0.16-1.89)
Season of Birth				[p<0.001]	[p=0.80]
Dry season	17	20 / 1208	1443	Ref	Ref
Rainy season	15	14 / 931	1189	0.88 (0.44-1.77)	0.91 (0.44-1.90)
Maternal Occupation				[p=0.]	
No salary	16	30 / 1909	2379	Ref	Omitted
Salary	21	2 / 94	109	1.36 (0.33-5.71)	

& pyrs = person years of observation; ¤ Number of children contributing to rate calculation

Table 20 Interactions

	Adjusted HR (95%CI)	P-value
Males	1.19 (0.40-3.57)	0.13
Females	0.32 (0.09-1.21)	
Rural	0.72 (0.29-1.79)	0.82
Urban	0.91 (0.15-5.50)	

Table 21 Survival analysis - splitting FIC into FICIS and FICOS

Factor	Mortality Rate/1000 pyrs	Deaths/pyrs	Number of children	Crude Hazard ratio (95%-CI)	Adjusted Hazard ratio (95%-CI)
FIC status				[p=0.61]	[p=0.71]
NOTFIC	20	10 / 496	586	Ref	Ref
FICOS	11	3 / 271	330	0.55 (0.15-1.99)	0.58 (0.15-2.21)
FICIS	15	21 / 1.371	1716	0.76 (0.36-1.61)	0.79 (0.34-1.82)

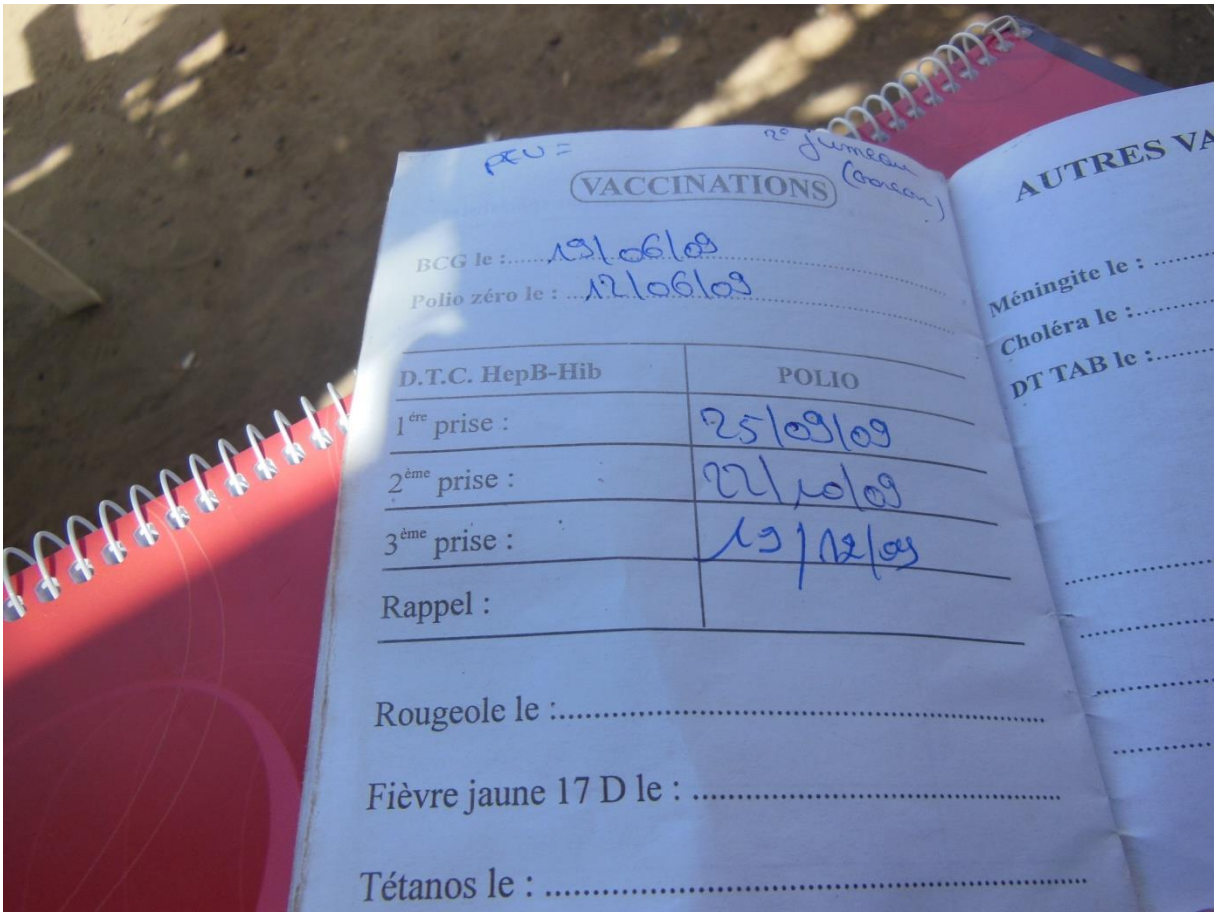
	Adjusted HR (95%CI)	Test of no interaction p-value
Male		0.09
FICOS	0.40 (0.04-3.61)	
FICIS	1.35 (0.45-4.05)	
Female		
FICOS	0.72 (0.13-3.95)	
FICIS	0.23 (0.05-1.06)	
Rural		0.92
FICOS	0.65 (0.54-0.16)	
FICIS	0.74 (0.52-0.29)	
Urban		
FICOS	*NA*	
FICIS	1.12 (0.90-0.18)	

Table 22 Survival analysis - NOT FIC split into "FIC without MCV" and otherwise

Factor	Mortality Rate/1000 pyrs	Deaths/pyrs	Number of children	Crude Hazard ratio (95%-CI)	Adjusted Hazard ratio (95%-CI)
FIC status			0	[p=0.63]	[p=0.79]
NOT FIC	18	5 / 279	330	Ref	Ref
FIC without MCV	23	5 / 217	2.046	1.27 (0.37-4.39)	1.09 (0.27-4.42)
FIC	15	24 / 1.643	2046	0.81 (0.31-2.12)	0.79 (0.26-2.35)

	Adjusted HR (95%CI)	Test of no interaction p-value
Male		0.32
FIC without MCV	1.07 (0.15-7.75)	
FIC	1.24 (0.28-5.46)	
Female		
FIC without MCV	1.12 (0.16-8.02)	
FIC	0.34 (0.06-1.78)	
Rural		0.92
FIC without MCV	1.79 (0.32-9.90)	
FIC	1.02 (0.24-4.40)	
Urban		
FIC without MCV	*NA*	
FIC	0.59 (0.10-3.58)	

Figure 12 Vaccination card used



Appendix 5: Chakaria 2012-14

List of Tables

Table 1 Inclusion per year of visit 5
Table 2 Percent of children per year having no vaccination card 5
Table 3 Representativeness – comparison children included and excluded from the analyses 7
Table 4 FIC coverage by year of visit 8
Table 5 Coverage of FIC by year of visit and sex 9
Table 6 Coverage of FIC by year and Place of residence 9
Table 7 Coverage of FIC by year of visit and Socio-economic status (wealth index) 9
Table 8 Coverage of FIC by year of visit and maternal education 9
Table 9 Median vaccination age (days) and lower and upper quartiles for FIC 12
Table 10 Median vaccination age (days) and lower and upper quartiles for NOT FIC with a vaccine 12
Table 11 Among children NOT FIC, missing a specific vaccine 14
Table 12 Among children NOT FIC, missing only the particular vaccine 14
Table 13 Among children NOT FIC, number of vaccines missing 14
Table 14 Full immunization coverage in sequence (FICIS) among FIC 15
Table 15 Main reasons for out-of-sequence for FIC who are out-of-sequence (FICOS) 17
Table 16 Fully Vaccination coverage at 24 months (FIC24) for NOT FIC at 12 months of age 17
Table 17 Analyses of association between background factors and FIC 19
Table 18 Analyses of association between background factors and FICIS among FIC 20
Table 19 Survival analysis of FIC vs NOT FIC, Children followed to 3 years of age 21
Table 20 Hospitalization analysis of FIC vs NOT FIC, Children followed to 3 years of age 22
Table 21 Hospitalization analyses: Interactions between FIC and sex and between FIC and area 23
Table 22 Hospitalization analyses – splitting FIC into FICIS and FICOS 23
Table 23 Hospitalization analyses – NOT FIC split into “FIC without MCV” and otherwise 24

List of Figures

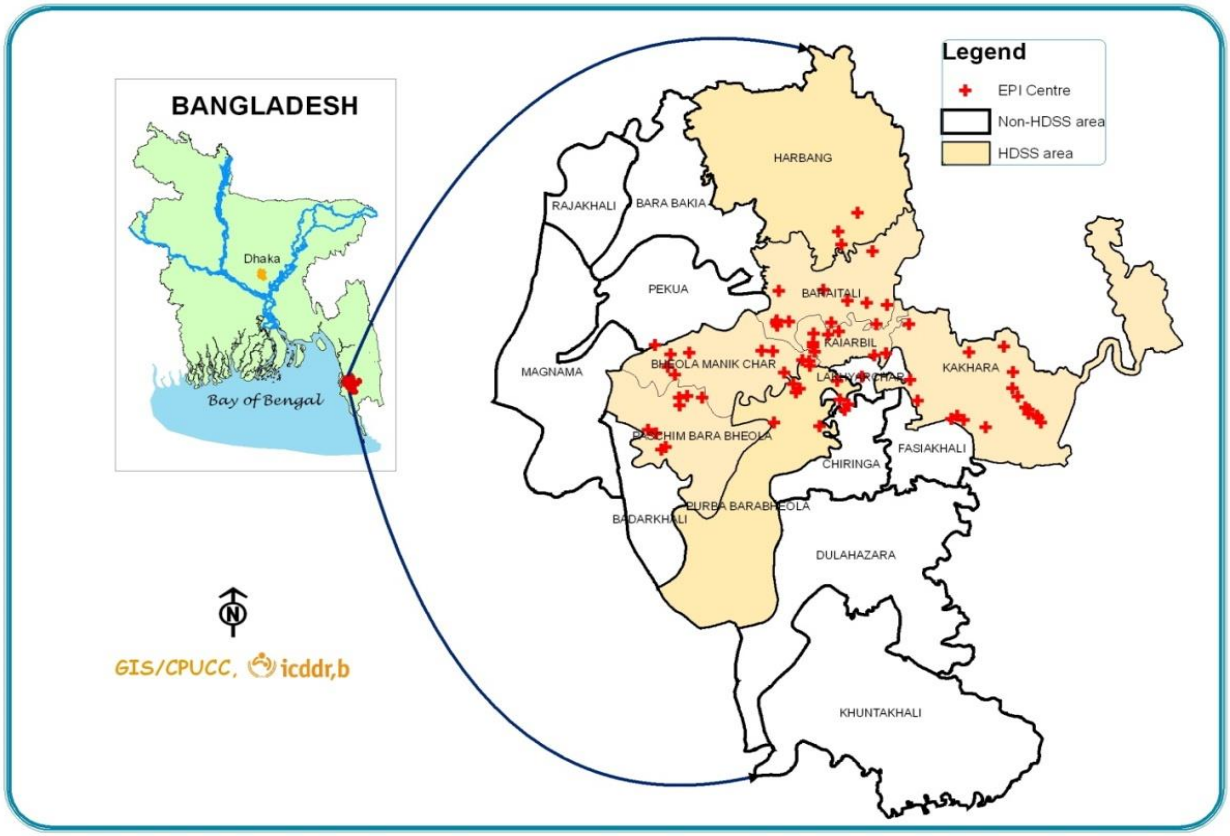
Figure 1 The flow chart of inclusion for Chakaria 2012-14 5
Figure 2 Histogram of visits from flow chart 6
Figure 3 FIC coverage by year of visit 8
Figure 4 FIC coverage by key factors 10
Figure 5 Coverage curves for each vaccine among FIC, NOT FIC, and combined 11
Figure 6 Comparison of median vaccination age of FIC and NOT FIC 13
Figure 7 Among NOT FIC percent of missing a particular vaccine 14
Figure 8 Coverage of FIC-in-sequence among FIC 15
Figure 9 Coverage of FIC-in-sequence among FIC 16
Figure 10 Reason for out-of-sequence among FICOS 17
Figure 11 FIC15 Coverage curves for each vaccine among FIC, NOT FIC, and combined 18
Figure 12 Vaccination card used 25

Chakaria HDSS

Study area

Chakaria HDSS is located in the southeastern coast of the Bay of Bengal and is one of the field sites of International Centre for Diarrhoeal Disease Research, district Bangladesh (icddr,b).The site belongs to Chakaria Upazila, which is a subdistrict in the Cox's Bazar district of Bangladesh. The total HDSS area is about 288 km^2. About half of the HDSS area belongs to low-lying area and the rest of the area is inland. The map below shows the location of Chakaria.

Map of Chakaria HDSS area showing EPI centers



Population

The surveillance covers 87,079 residents living in 16,167 households of 49 villages in 2014 and it represents one-fourth of the population of Chakaria Upazila. The majority of the population is Muslim making up about 94% of the population, Hindus constitute about 4% and the remaining are Buddhist. The average household size is 5.4 people. Agriculture is the main sources of income for males and females are mostly housewives. About 25% of the households have electricity connection. The adult literacy rate of 15-24 years old was 77% (male 74% and female 79%) in 2014.

Health care system

The health-care delivery system in the HDSS area comprises of public, private and non-governmental organizations (NGOs). At present, the Upazila Health Complex of the government and four private hospitals provide health-care services at the headquarters of Chakaria. At the union level, 14 community clinics, seven Union Health and Family Welfare Centres (UHFWCs) and one rural dispensary (RD) of the government provide health-care services in HDSS area.

Immunization services

The expanded programme on immunization (EPI) in Chakaria was launched in 1990 with 6 conventional vaccines; BCG, DTP, OPV, and measles. In 2005 the national EPI programme incorporated the hepatitis B vaccine. In January 2009, the Bangladesh EPI programme introduced the hemophilus influenza type B (Hib) vaccine. This was done in the form of the pentavalent vaccine that included the DPT and hepatitis B vaccine and the new HIB vaccine. In September 2012 Bangladesh EPI has introduced a combination MR (Measles and Rubella) at 9 month and Measles containing vaccine at 15 month. It is noted that providing Vitamin A Supplementation with measles vaccine was stopped since September 2012. The vaccination schedule is presented here:

Currrent vaccination schedule in Chakaria

<table>
<tr><td colspan="2">Sequence of vaccination</td></tr>
<tr><td colspan="2">Receive BCG and OPV0 if baby visit within 2 wk of age. Receive only BCG if s/he visit after 2 wk of age to maintain the minimum recommended distance between two doses of OPV.</td></tr>
<tr><td>Receive Penta1 and OPV1 at 6 wk of age.</td><td rowspan="3">Penta and OPV are administered with a minimum gap of 4 wk.</td></tr>
<tr><td>Receive Penta2 and OPV2 at 10 wk of age.</td></tr>
<tr><td>Receive Penta3 and OPV3 at 14 wk of age.</td></tr>
<tr><td colspan="2">Receive first dose of MR, VAS, and OPV4 at age of 9 mo .</td></tr>
<tr><td colspan="2">Receive MCV2 at age of 15-18 mo</td></tr>
</table>

The routine EPI services in HDSS areas have been provided through 95 EPI centres with monthly session for a catchments of approximately 1,000 population. Vaccination is provided primarily by 28 Health Assistants (HAs) (20 male and 8 females), an employee of the health wing of Ministry of Health and Family Welfare (MOHFW) and is usually assisted by Family Welfare Assistant (FWA), an employee of family planning wing of MOHFW. Porters deliver vaccines from the Upazila Health Complex to the vaccination site/distribution points where the field workers collect and deliver the vaccines to vaccination sites. Almost all EPI centres are within 15-20 minutes walking distance, and field workers are instructed to conduct home visits to register new-borns in the EPI registration book and invite parents to bring their target children to come to vaccination sessions prior to the day of

session. Usually, each EPI center covers 42 children below 2 years of age. On average, 10 children receive vaccine from a EPI session.

Campaigns

Apart from routine vaccination, National Immunization Days (NIDs) have been implemented in Bangladesh since 1995 with an aim to eradicate poliomyelitis by the year of 2000. NIDs are held on two particular days in a year known as Round 1 and Round 2. In each round, OPV is administered to the children less than five years of age. Vitamin A Capsule (VAC) is given to children 1-5 years of age during either round of OPV. In addition, VAC campaign (first 2008) and Deworming (first 2009) have been conducted periodically. Also, Measles follow-up and Measles-Rubella campaigns were conducted in February 2010 and during January/February 2014.

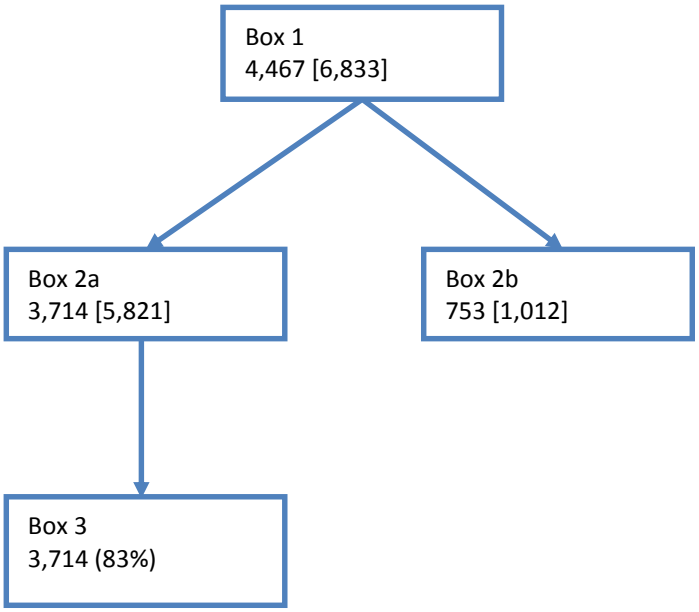
Data collection, data management, and quality control

All households were mapped using GPS. The 49 villages were divided into 14 work areas and 14 SWs (surveillance worker) were recruited from the 14 work areas where they resided. Each SW was assigned a work area covering approximately 1200 households. Each SW is provided with a sketch map of their assigned work area to help collect data sequentially. A supervisor guides and monitors their activities and checks collected data for one in every 20 households of an SW.

Chakaria HDSS records vital events, use of maternal health services, morbidity and occurrence of hospitalization, and vaccination information with structured questionnaires through quarterly household visits with the wife of the household head. Information on pregnancy is collected from respective pregnant women. The asset list of the households, education and occupation of individuals is updated annually from the household head or his wife.

For each SW, 5% of their assigned households are chosen randomly to be re-interviewed either over the phone or through a home visit by an external interviewer within 2 days of data collection. Data are then compared and checked for inconsistencies and feedback is provided to the SWs in the team. Based on the feedback, necessary corrections are made. Data are store in a relational database, developed in MySQL maintaining 15 tables for data entry.

Figure 1 The flow chart of inclusion for Chakaria 2012-14



Box 1
Number of children alive at an HDSS home visit between 12 and 23 months of age
[Number of visits asking for vaccine card]

Box 2a
Number of children from box 1 having at least one visit with card seen
[Number of visits for these children including those where card not seen]

Box 2b
Number of children from box 1 having no seen card at any visit between 12 and 23 months of age
[Number of visits]

Box 3
Number of children included in analyses

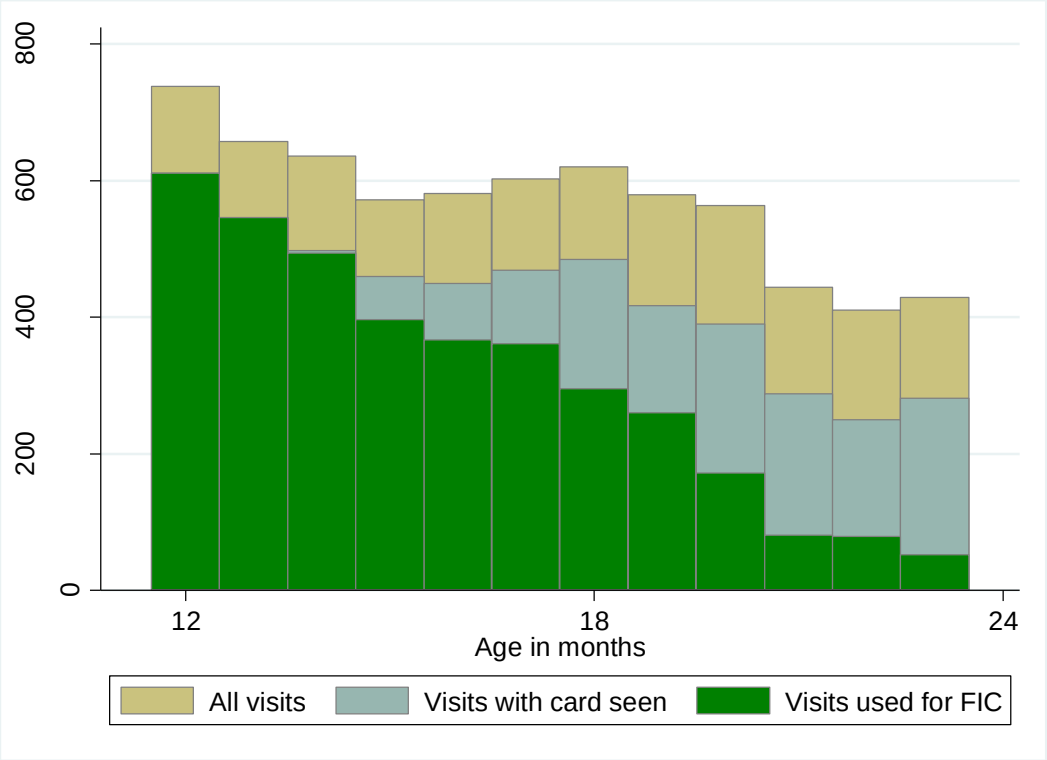
Table 1 Inclusion per year of visit

Year of Visit	Inclusion % (n/total)
2012	91 (1111/1218)
2013	83 (1467/1766)
2014	77 (1136/1483)
Total	83 (3714/4467)

Table 2 Percent of children per year having no vaccination card

Year of Visit	No card % (n/total)
2012	5 (57/1218)
2013	4 (70/1766)
2014	7 (100/1483)
Total	5 (227/4467)

Figure 2 Histogram of visits from flow chart



All visits = Visits from Box 1
Visits with card seen = Visits from Box 2a
Visits used for FIC = Visits from Box 3

Table 3 Representativeness – comparison children included and excluded from the analyses

	Included	Excluded	
	n (%)	n (%)	P-Value
Sex			0.234
Male	1928 (52)	373 (50)	
Female	1786 (48)	380 (50)	
Year of visit			<0.001
2012	1111 (30)	107 (14)	
2013	1467 (39)	299 (40)	
2014	1136 (31)	347 (46)	
Study area			<0.001
Plain and hilly	2167 (58)	358 (48)	
Low-lying	1547 (42)	395 (52)	
Parity			0.002
1	1105 (30)	274 (36)	
2	990 (27)	198 (26)	
3	700 (19)	121 (16)	
4+	906 (24)	157 (21)	
Missing	13 (0)	3 (0)	
Place of birth			0.001
Home	3051 (82)	555 (74)	
Facility	490 (13)	129 (17)	
Missing	173 (5)	69 (9)	
Mother's education			0.029
None	670 (18)	155 (21)	
1-5	1091 (29)	197 (26)	
6-8	995 (27)	165 (22)	
9+	804 (22)	168 (22)	
Missing	154 (4)	68 (9)	
Mother's age			0.486
<20	597 (16)	125 (17)	
20-24	1386 (37)	276 (37)	
25-29	953 (26)	166 (22)	
30+	624 (17)	118 (16)	
Missing	154 (4)	68 (9)	
ANC			0.723
No	728 (20)	136 (18)	
Yes	2832 (76)	549 (73)	
Missing	154 (4)	68 (9)	
Wealth Index			0.232
Poorest	729 (20)	155 (21)	
Poorer	700 (19)	144 (19)	
Poor	717 (19)	126 (17)	
Less poor	704 (19)	115 (15)	
Least poor	675 (18)	136 (18)	
Missing	189 (5)	77 (10)	
Season of birth			0.003
Dry	1759 (47)	402 (53)	
Rainy	1955 (53)	351 (47)	

* The assets used for the wealth index is found in the next table

Assets used for the wealth index

Phone (Mobile or land)
Almira
Showcase
Khat (Bed frame)
Television
Sofa sets
Electricity connection
Ownership of land by households
Electric fan

Table 4 FIC coverage by year of visit

Year of Visit	FIC % (n/total)
2012	84 (938/1111)
2013	88 (1298/1467)
2014	85 (970/1136)
Total	86 (3206/3714)

Figure 3 FIC coverage by year of visit

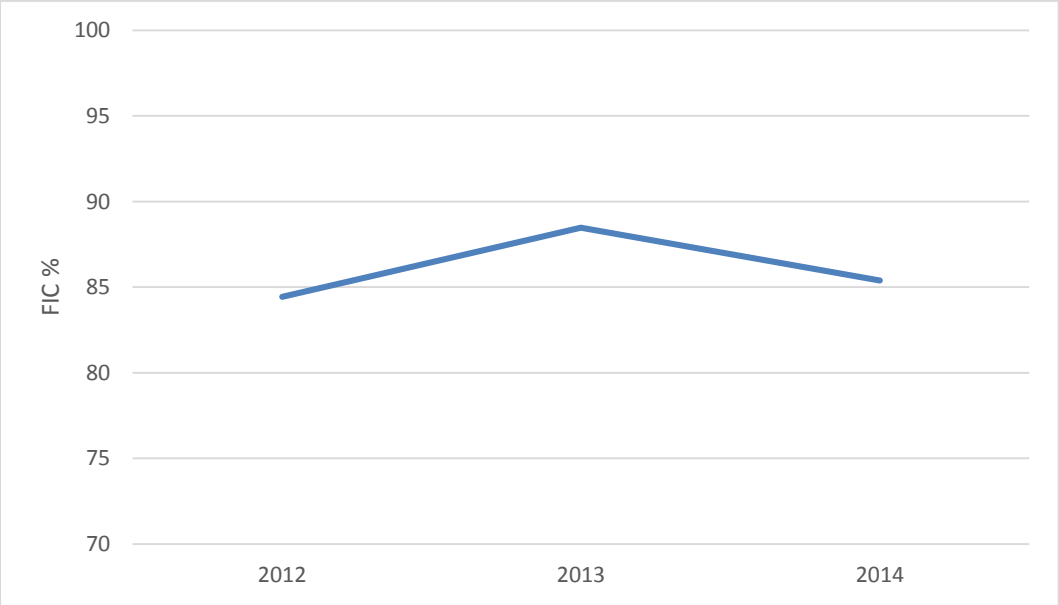


Table 5 Coverage of FIC by year of visit and sex

Year of Visit	Sex		
	Females	Males	Total
2012	85 (444/525)	84 (494/586)	84 (938/1111)
2013	87 (615/708)	90 (683/759)	88 (1298/1467)
2014	85 (469/553)	86 (501/583)	85 (970/1136)
Total	86 (1528/1786)	87 (1678/1928)	86 (3206/3714)

Table 6 Coverage of FIC by year and Place of residence

Year of Visit	Study Area		
	Low-lying	Plain and hilly	Total
2012	82 (379/460)	86 (559/651)	84 (938/1111)
2013	85 (540/634)	91 (758/833)	88 (1298/1467)
2014	81 (369/453)	88 (601/683)	85 (970/1136)
Total	83 (1288/1547)	89 (1918/2167)	86 (3206/3714)

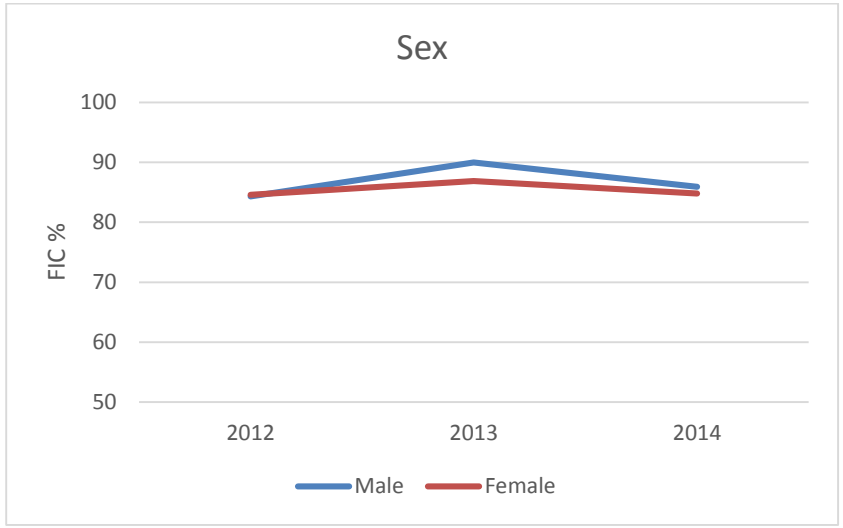
Table 7 Coverage of FIC by year of visit and Socio-economic status (wealth index)

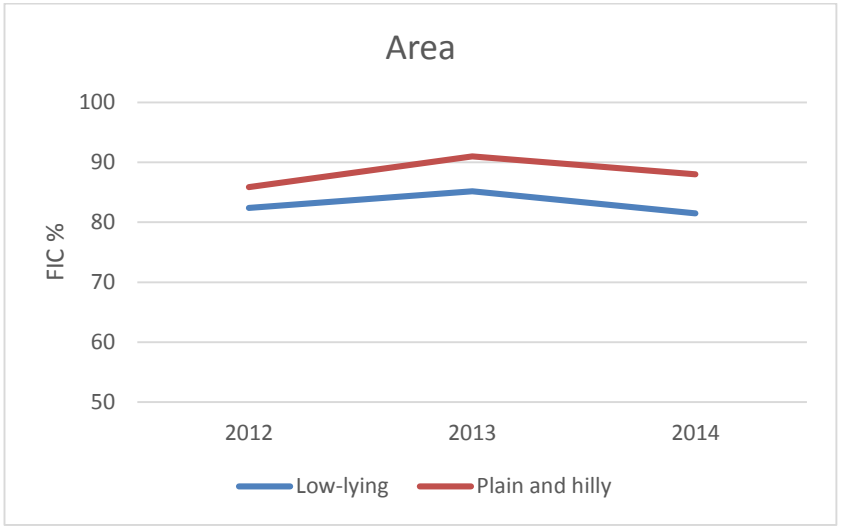
Year of Visit	Wealth index						
	Poorest	Poorer	Poor	Less poor	Least poor	Missing	Total
2012	77 (190/247)	79 (178/225)	88 (191/217)	90 (194/216)	91 (165/181)	80 (20/25)	84 (938/1111)
2013	86 (255/298)	85 (231/271)	90 (249/277)	92 (235/255)	93 (261/280)	78 (67/86)	88 (1298/1467)
2014	76 (140/184)	83 (170/204)	86 (191/223)	92 (215/233)	89 (191/214)	81 (63/78)	85 (970/1136)
Total	80 (585/729)	83 (579/700)	88 (631/717)	91 (644/704)	91 (617/675)	79 (150/189)	86 (3206/3714)

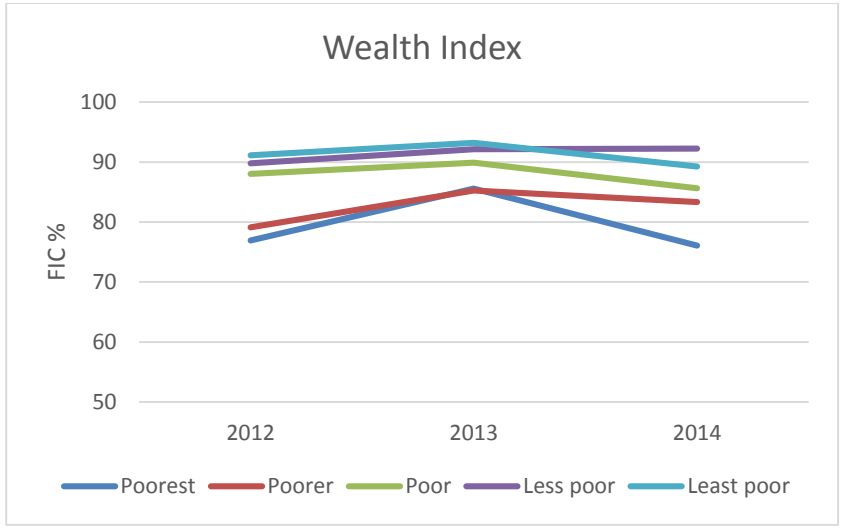
Table 8 Coverage of FIC by year of visit and maternal education

Year of Visit	Maternal education					
	None	1-5	6-8	9+	Missing	Total
2012	79 (187/238)	82 (288/352)	87 (242/277)	92 (205/223)	76 (16/21)	84 (938/1111)
2013	84 (217/259)	89 (386/433)	90 (341/378)	92 (294/319)	77 (60/78)	88 (1298/1467)
2014	73 (126/173)	84 (258/306)	91 (310/340)	89 (234/262)	76 (42/55)	85 (970/1136)
Total	79 (530/670)	85 (932/1091)	90 (893/995)	91 (733/804)	77 (118/154)	86 (3206/3714)

Figure 4 FIC coverage by key factors







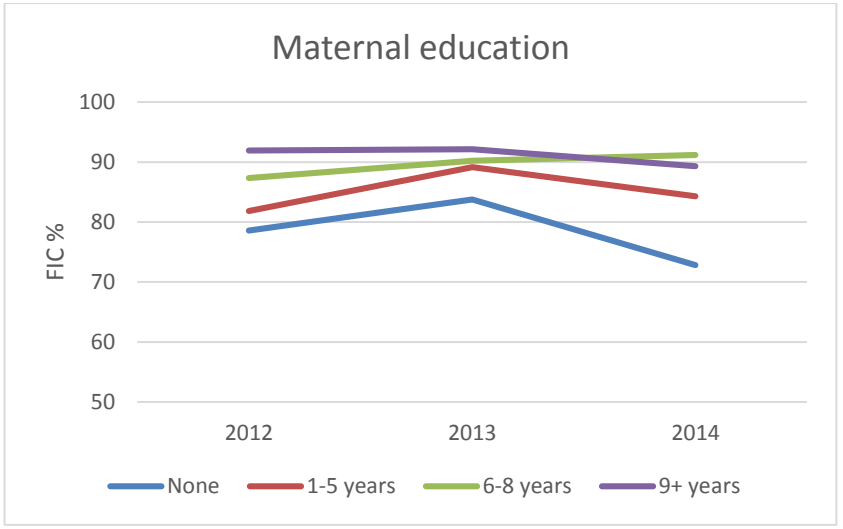
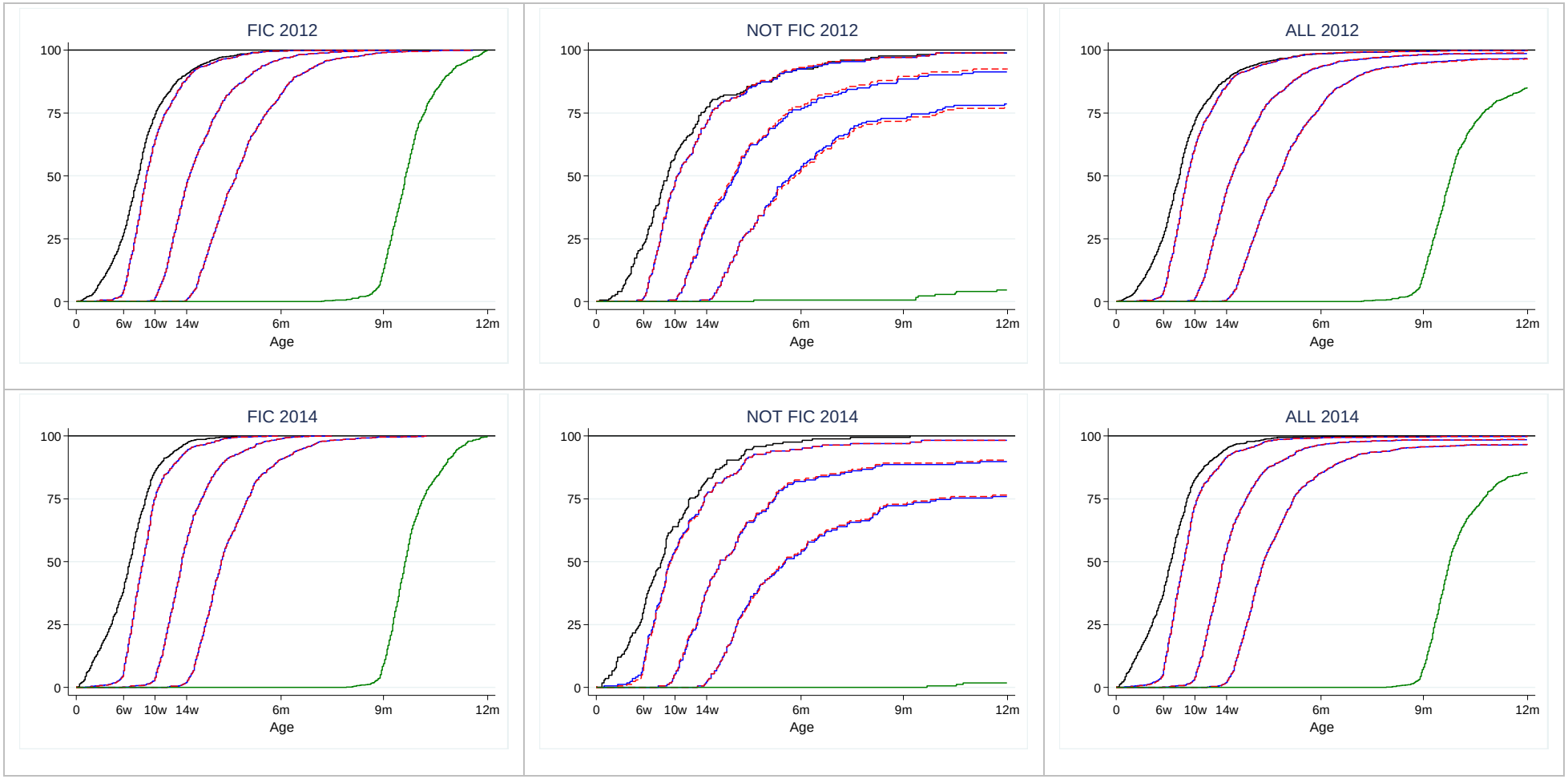


Figure 5 Coverage curves for each vaccine among FIC, NOT FIC, and combined



BCG is black; Penta is blue; OPV is dashed and red; MCV is green

Table 9 Median vaccination age (days) and lower and upper quartiles for FIC

Year of Visit	BCG			Penta 1			Penta 2			Penta 3			OPV 1			OPV 2			OPV 3			MCV		
	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
2012	41	55	71	52	63	80	86	101	125	121	142	169	52	62	80	86	101	125	121	142	169	280	293	309
2013	36	52	67	50	62	74	84	96	113	116	131	155	50	62	74	84	96	113	116	131	155	281	293	307
2014	31	48	62	50	59	70	82	94	112	115	129	152	50	59	70	82	94	111	115	129	152	281	293	308
Total	36	51	66	51	61	74	84	96	117	117	133	158	51	61	74	84	96	117	117	133	158	281	293	308

Table 10 Median vaccination age (days) and lower and upper quartiles for NOT FIC with a vaccine

Year of Visit	BCG			Penta 1			Penta 2			Penta 3			OPV 1			OPV 2			OPV 3			MCV		
	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
2012	44	63	93	57	71	102	92	117	156	125	155	196	57	71	102	92	118	154	125	155	196	284	294	320
2013	46	66	103	57	74	121	94	114	159	132	157	200	57	74	121	94	113	159	133	157	201	283	288	311
2014	39	58	83	51	65	96	85	106	141	121	144	188	51	65	96	86	105	141	121	143	188	294	320	326
Total	42	62	93	55	70	101	91	112	153	125	152	196	54	70	101	91	112	153	125	152	196	284	293	320

Figure 6 Comparison of median vaccination age of FIC and NOT FIC

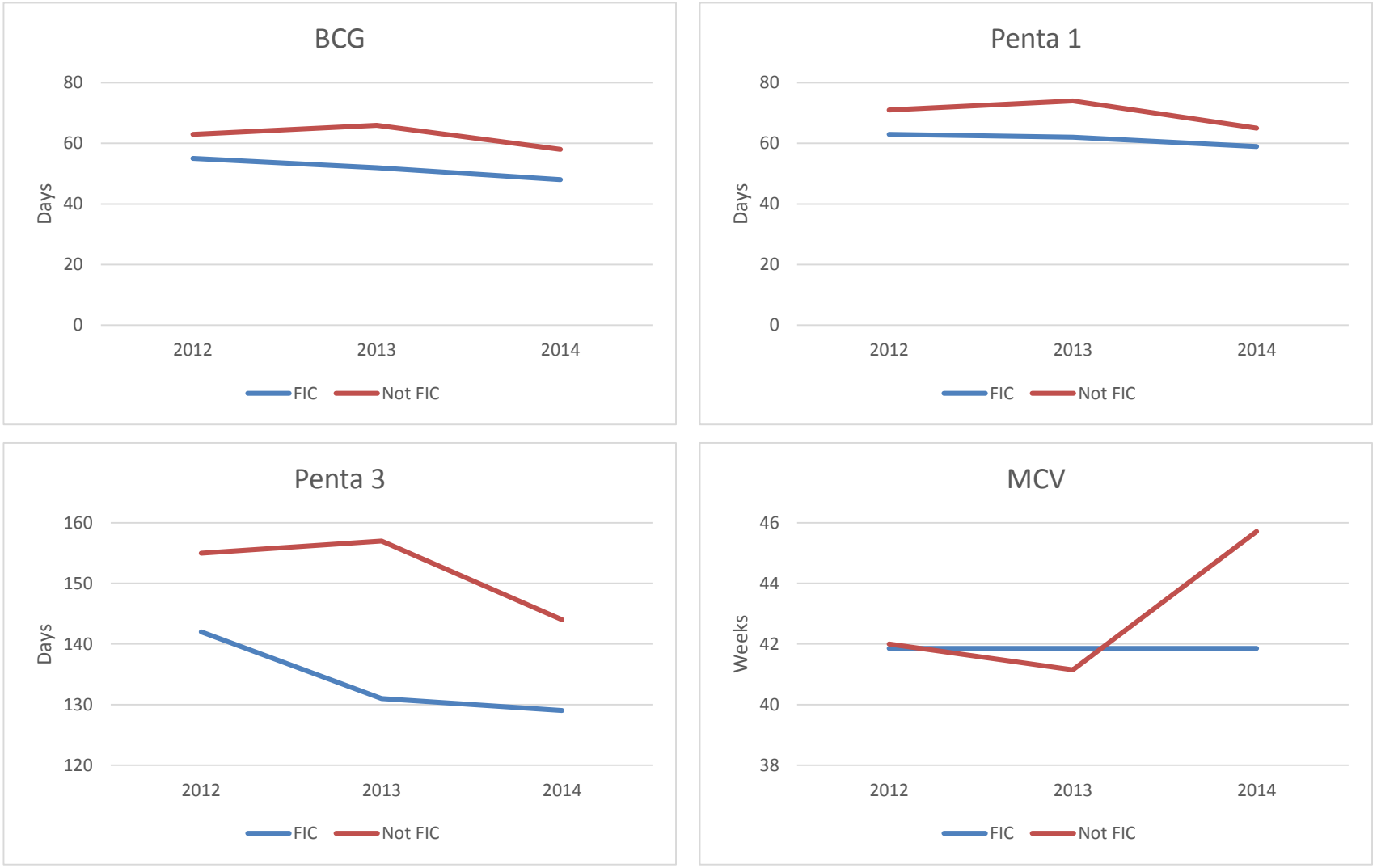


Table 11 Among children NOT FIC, missing a specific vaccine

Year of visit	BCG	Penta1	Penta2	Penta3	OPV 1	OPV 2	OPV 3	MCV	Number NOT FIC
2012	1.2 (2)	1.2 (2)	7.5 (13)	22.5 (39)	1.2 (2)	8.7 (15)	21.4 (37)	95.4 (165)	173
2013	1.8 (3)	0.0 (0)	5.9 (10)	16.0 (27)	0.0 (0)	6.5 (11)	17.2 (29)	94.7 (160)	169
2014	0.0 (0)	1.8 (3)	9.6 (16)	23.5 (39)	1.8 (3)	10.2 (17)	24.1 (40)	98.2 (163)	166
Total	**1.0 (5)**	**1.0 (5)**	**7.7 (39)**	**20.7 (105)**	**1.0 (5)**	**8.5 (43)**	**20.9 (106)**	**96.1 (488)**	**508**

Figure 7 Among NOT FIC percent of missing a particular vaccine

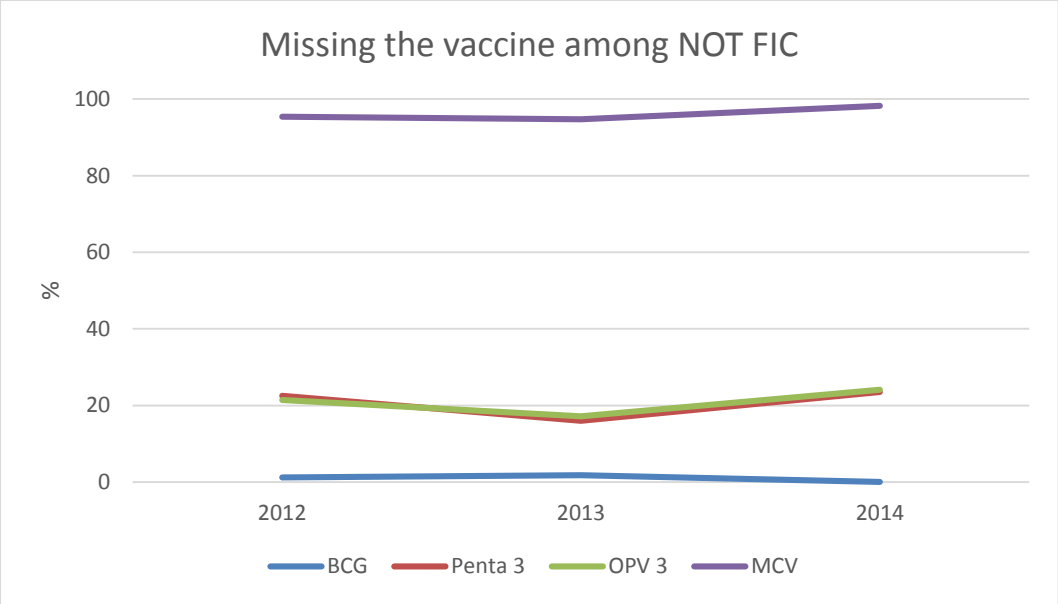


Table 12 Among children NOT FIC, missing only the particular vaccine

Year of visit	BCG	Penta 3	OPV 3	MCV
2012	0.6 (1)	0.0 (0)	0.0 (0)	75.7 (131)
2013	0.6 (1)	0.6 (1)	1.8 (3)	80.5 (136)
2014	0.0 (0)	0.0 (0)	0.6 (1)	75.9 (126)
Total	**0.4 (2)**	**0.2 (1)**	**0.8 (4)**	**77.4 (393)**

Table 13 Among children NOT FIC, number of vaccines missing

	Number of vaccines missing							
Year of visit	1	2	3	4	5	6	7	8
2012	77.5 (134)	2.3 (4)	12.7 (22)	1.2 (2)	5.2 (9)	0.0 (0)	1.2 (2)	0.0 (0)
2013	84.0 (142)	1.8 (3)	8.3 (14)	0.6 (1)	4.7 (8)	0.6 (1)	0.0 (0)	0.0 (0)
2014	76.5 (127)	1.2 (2)	12.1 (20)	0.6 (1)	7.8 (13)	0.0 (0)	1.8 (3)	0.0 (0)
Total	**79.3 (403)**	**1.8 (9)**	**11.0 (56)**	**0.8 (4)**	**5.9 (30)**	**0.2 (1)**	**1.0 (5)**	**0.0 (0)**

Table 14 Full immunization coverage in sequence (FICIS) among FIC

Year of visit	FICIS % (n/FIC)
2012	27 (255/938)
2013	30 (385/1298)
2014	38 (370/970)
Total	32 (1010/3206)

FICIS is defined as the WHO recommended sequence of vaccinations, i.e. BCG before OPV1, OPV1=Penta1, OPV2=Penta2, OPV3=Penta3 and Penta3 before MCV.

Figure 8 Coverage of FIC-in-sequence among FIC

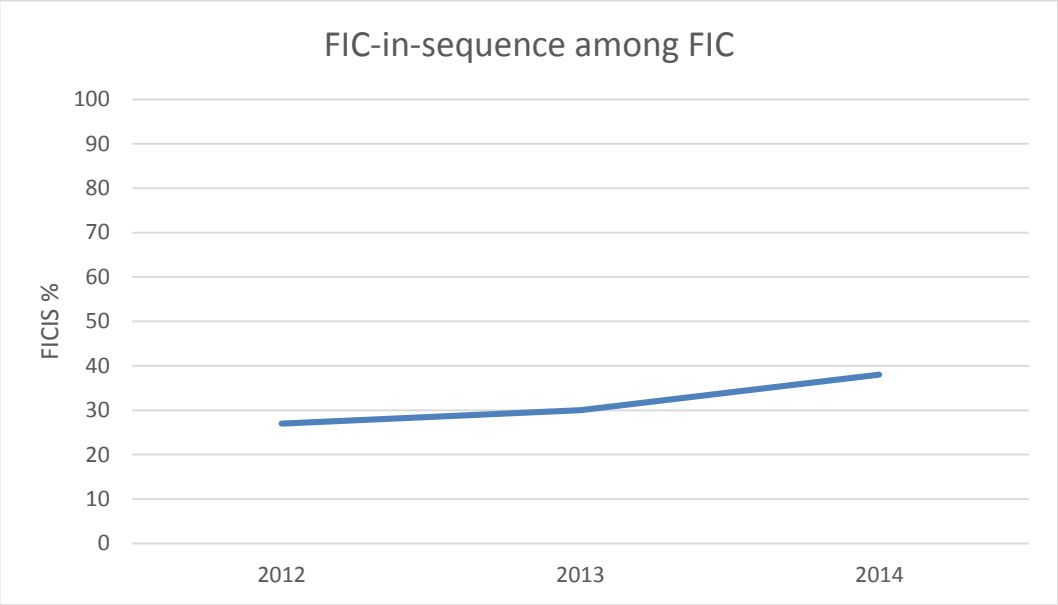


Figure 9 Coverage of FIC-in-sequence among FIC

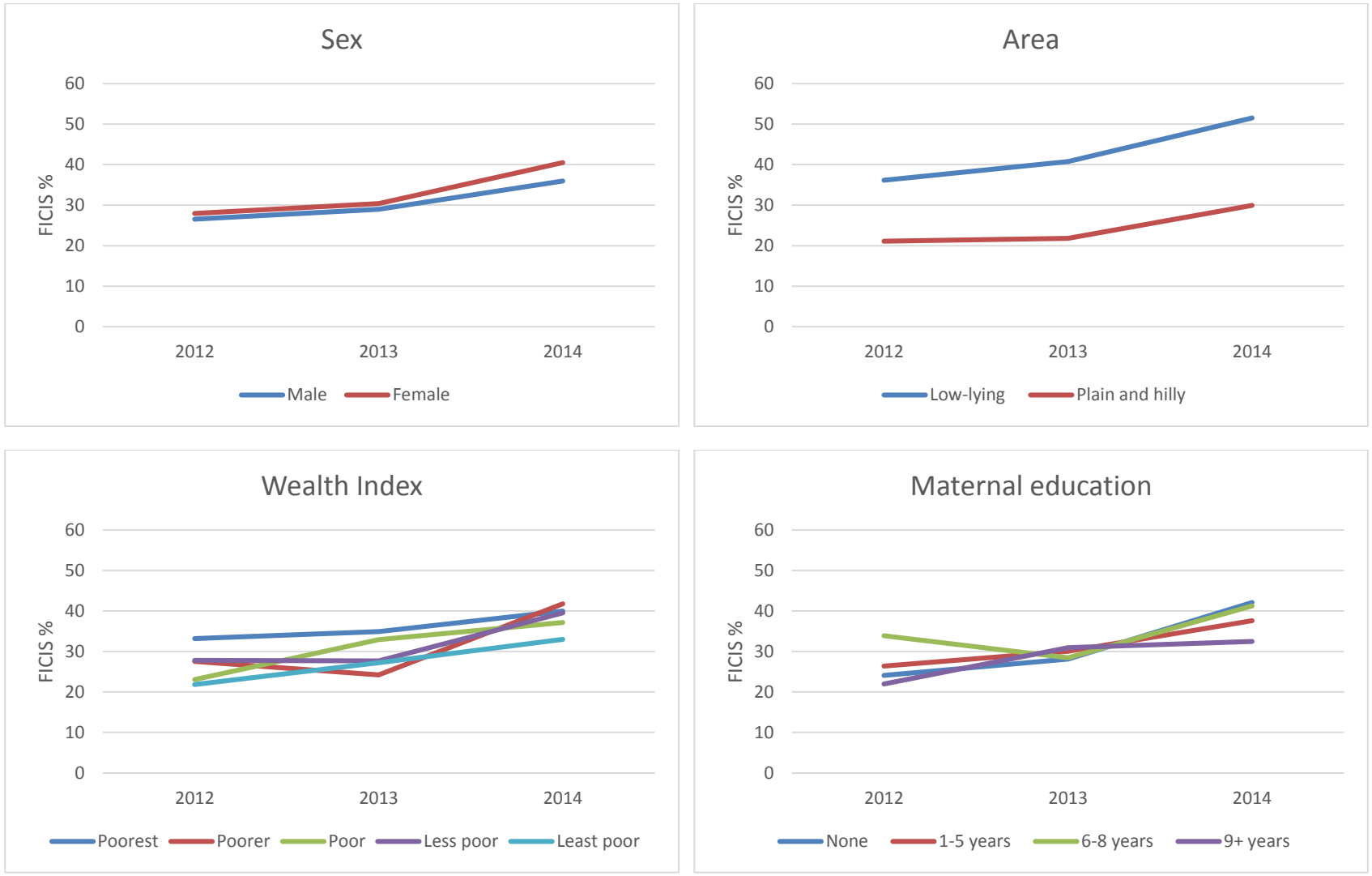


Table 15 Main reasons for out-of-sequence for FIC who are out-of-sequence (FICOS)

Year of Visit	Type of out-of-sequence % (n)			
	BCG ≥ Penta1 or MCV	OPV ≠ Penta	Penta ≥ MCV	Total FICOS
2012	98.7 (674)	1.8 (12)	0.4 (3)	683
2013	99.6 (909)	1.2 (11)	0.6 (5)	913
2014	99.5 (597)	1.0 (6)	0.2 (1)	600
Total	99.3 (2180)	1.3 (29)	0.4 (9)	2196

Note: Percentages do not sum to 100 as children may contribute to more than one type of out-of-sequence

Figure 10 Reason for out-of-sequence among FICOS

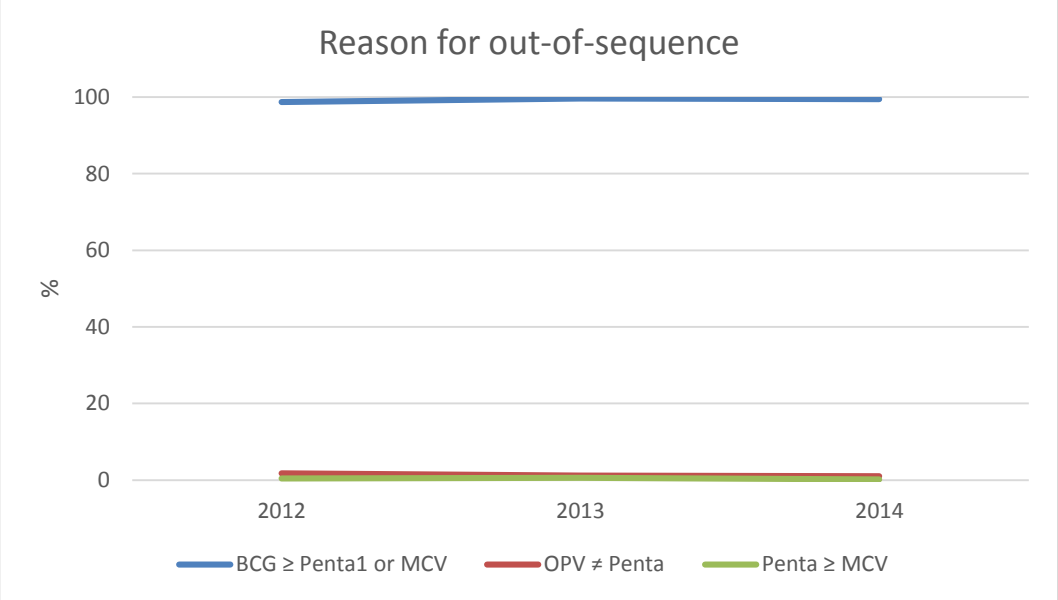
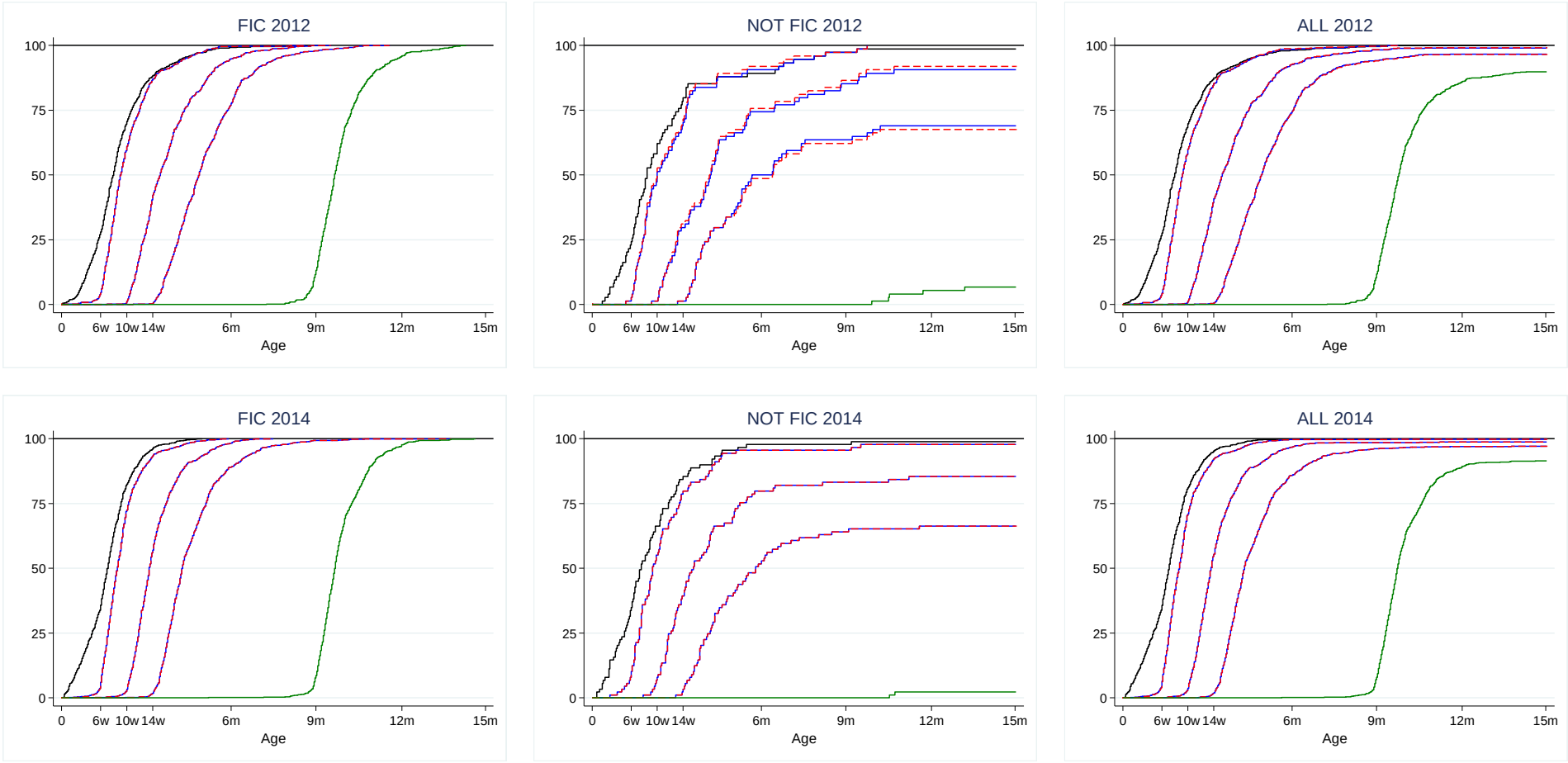


Table 16 Fully Vaccination coverage at 24 months (FIC24) for NOT FIC at 12 months of age

Year of FIC12 visit	FIC at 24 months % (n/N)
2012	74 (75/102)
2013	55 (41/74)
2014	*NA*
Total	66 (116/176)

Figure 11 FIC15 Coverage curves for each vaccine among FIC, NOT FIC, and combined



N=2994 children included, i.e. 81% (2994/3714) of the children in the overall FIC analyses (cf. Figure 1)

Table 17 Analyses of association between background factors and FIC

Variable	N	%	FIC %	Unadjusted P-value PR (95% CI)	Adjusted P-value PR (95% CI)
Sex				0.191	0.110
Male	1928	52	87	Ref	Ref
Female	1786	48	86	0.98 (0.96-1.01)	0.98 (0.95-1.00)
Year of visit				0.006	0.001
2012	1111	30	84	Ref	Ref
2013	1467	39	88	1.05 (1.02-1.08)	1.03 (1.00-1.07)
2014	1136	31	85	1.01 (0.98-1.05)	0.97 (0.94-1.01)
Study area				<0.001	<0.001
Plain and hilly	2167	58	89	Ref	Ref
Low-lying	1547	42	83	0.94 (0.92-0.97)	0.95 (0.93-0.98)
Parity				0.815	0.472
1	1105	30	86	Ref	Ref
2	990	27	86	1.00 (0.96-1.03)	1.02 (0.97-1.06)
3	700	19	87	1.01 (0.97-1.05)	1.04 (0.99-1.09)
4+	906	24	86	0.99 (0.96-1.03)	1.02 (0.96-1.08)
Missing	13	0	92		
Place of birth				<0.001	0.072
Home	3051	82	86	Ref	Ref
Facility	490	13	92	1.07 (1.04-1.10)	1.04 (1.00-1.08)
Missing	173	5	78		
Mother´s education				<0.001	<0.001
None	670	18	79	Ref	Ref
1-5	1091	29	85	1.08 (1.03-1.13)	1.08 (1.03-1.13)
6-8	995	27	90	1.13 (1.09-1.19)	1.12 (1.06-1.18)
9+	804	22	91	1.15 (1.10-1.20)	1.10 (1.03-1.17)
Missing	154	4	77		
Mother´s age				0.666	0.200
<20	597	16	87	Ref	Ref
20-24	1386	37	87	1.01 (0.97-1.05)	1.01 (0.97-1.06)
25-29	953	26	86	0.99 (0.95-1.03)	1.00 (0.94-1.06)
30+	624	17	87	1.01 (0.96-1.05)	1.05 (0.98-1.11)
Missing	154	4	77		
ANC				0.002	0.231
No	728	20	83	Ref	Ref
Yes	2832	76	88	1.06 (1.02-1.10)	1.02 (0.99-1.06)
Missing	154	4	77		
Wealth Index				<0.001	<0.001
Poorest	729	20	80	Ref	Ref
Poorer	700	19	83	1.03 (0.98-1.08)	1.01 (0.96-1.05)
Poor	717	19	88	1.10 (1.05-1.15)	1.06 (1.01-1.11)
Less Poor	704	19	91	1.14 (1.09-1.19)	1.09 (1.05-1.14)
Least Poor	675	18	91	1.14 (1.09-1.19)	1.08 (1.02-1.14)
Missing	189	5	79		
Season of birth				<0.001	<0.001
Dry	1759	47	89	Ref	Ref
Rainy	1955	53	84	0.94 (0.91-0.96)	0.94 (0.92-0.97)

Table 18 Analyses of association between background factors and FICIS among FIC

Variable	N	%	FICIS %	Unadjusted P-value PR (95% CI)	Adjusted P-value PR (95% CI)
Sex				0.135	0.245
Male	1678	52	30	Ref	Ref
Female	1528	48	33	1.08 (0.98-1.20)	1.07 (0.96-1.19)
Year of visit				<0.001	<0.001
2012	938	30	27	Ref	Ref
2013	1298	40	30	1.09 (0.95-1.25)	1.08 (0.94-1.25)
2014	970	30	38	1.40 (1.23-1.60)	1.44 (1.24-1.67)
Study area				<0.001	<0.001
Plain and hilly	1918	60	24	Ref	Ref
Low-lying	1288	40	42	1.76 (1.59-1.95)	1.81 (1.62-2.02)
Parity				0.299	0.719
1	954	30	33	Ref	Ref
2	853	27	33	1.01 (0.89-1.16)	1.06 (0.90-1.24)
3	611	19	29	0.90 (0.77-1.05)	1.01 (0.83-1.23)
4+	776	24	30	0.92 (0.80-1.06)	1.10 (0.88-1.38)
Missing	12	0	17		
Place of birth				0.259	0.776
Home	2620	82	32	Ref	Ref
Facility	451	14	29	0.91 (0.78-1.07)	1.02 (0.87-1.21)
Missing	135	4	35		
Mother´s education				0.094	0.431
None	530	17	30	Ref	Ref
1-5	932	29	31	1.03 (0.88-1.21)	0.98 (0.82-1.17)
6-8	893	28	34	1.15 (0.98-1.34)	1.08 (0.89-1.31)
9+	733	23	29	0.96 (0.81-1.15)	0.97 (0.77-1.22)
Missing	118	4	36		
Mother´s age				0.005	0.038
<20	517	16	33	Ref	Ref
20-24	1211	38	34	1.02 (0.88-1.18)	0.98 (0.83-1.16)
25-29	816	25	28	0.85 (0.72-1.00)	0.79 (0.63-0.98)
30+	544	17	27	0.81 (0.68-0.98)	0.76 (0.58-1.00)
Missing	118	4	36		
ANC				0.831	0.971
No	603	19	32	Ref	Ref
Yes	2485	78	31	0.99 (0.86-1.12)	1.00 (0.87-1.16)
Missing	118	4	36		
Wealth Index				0.054	0.279
Poorest	585	18	36	Ref	Ref
Poorer	579	18	30	0.85 (0.73-1.01)	0.89 (0.75-1.05)
Poor	631	20	31	0.88 (0.75-1.03)	0.90 (0.76-1.07)
Less Poor	644	20	32	0.89 (0.76-1.04)	0.95 (0.80-1.14)
Least Poor	617	19	28	0.77 (0.65-0.92)	0.81 (0.65-1.00)
Missing	150	5	37		
Season of birth				0.001	0.093
Dry	1570	49	34	Ref	Ref
Rainy	1636	51	29	0.85 (0.76-0.94)	0.91 (0.81-1.02)

Table 19 Survival analysis of FIC vs NOT FIC, Children followed to 3 years of age

Factor	Rate/ 1000PYO	D	PYO	N	Crude HR (95%-CI)
FIC					p=0.820
No	4.7	2	423	342	Ref
Yes	4.0	11	2722	2234	0.84 (0.19-3.77)

Table 20 Hospitalization analysis of FIC vs NOT FIC, Children followed to 3 years of age

Variable	Rate/100PYO	H	PYO	N	Unadjusted P-value HRR (95% CI)	Adjusted P-value HRR (95% CI)
FIC					0.885	0.544
No	6.7	26	389.5	342	Ref	Ref
Yes	7	176	2521.7	2234	1.03 (0.68-1.56)	0.87 (0.56-1.35)
Sex					0.005	0.009
Male	8.3	125	1511.1	1344	Ref	Ref
Female	5.5	77	1400.2	1232	0.67 (0.50-0.89)	0.68 (0.50-0.91)
Year of visit					0.621	0.107
2012	6.3	106	1669.8	1111	Ref	Ref
2013	7.7	96	1241.5	1465	0.93 (0.69-1.24)	0.77 (0.56-1.06)
2014	NA	NA	NA	0	*NA*	*NA*
Study area					0.171	0.279
Plain and hilly	7.5	125	1669	1482	Ref	Ref
Low-lying	6.2	77	1242.3	1094	0.82 (0.62-1.09)	0.85 (0.63-1.14)
Parity					0.889	0.862
1	7.3	62	853.7	778	Ref	Ref
2	6.9	52	757.1	666	0.96 (0.66-1.38)	1.04 (0.68-1.59)
3	7.3	39	532	468	1.01 (0.68-1.51)	1.23 (0.74-2.05)
4+	6.3	48	758.4	654	0.88 (0.60-1.28)	1.10 (0.61-1.98)
Missing	9.9	1	10.2	10		
Place of birth					0.039	0.376
Home	6.4	158	2454.7	2146	Ref	Ref
Facility	9.8	34	345.3	316	1.50 (1.04-2.18)	1.20 (0.80-1.80)
Missing	9	10	111.3	114		
Mother´s education					0.003	0.111
None	5.9	34	580.2	497	Ref	Ref
1-5	4.7	43	915.9	784	0.80 (0.51-1.26)	0.78 (0.48-1.27)
6-8	8.3	60	726.2	655	1.40 (0.92-2.14)	1.30 (0.79-2.15)
9+	9.2	55	597.4	541	1.56 (1.01-2.39)	1.21 (0.68-2.13)
Missing	10.9	10	91.6	99		
Mother´s age					0.859	0.733
<20	7.8	37	475.9	433	Ref	Ref
20-24	6.5	71	1093.1	958	0.85 (0.57-1.26)	0.81 (0.52-1.28)
25-29	6.6	49	745.1	646	0.85 (0.56-1.30)	0.82 (0.46-1.46)
30+	6.9	35	505.7	440	0.89 (0.56-1.42)	0.97 (0.49-1.91)
Missing	10.9	10	91.6	99		
ANC					0.003	0.032
No	4.2	28	665.5	550	Ref	Ref
Yes	7.6	164	2154.2	1927	1.77 (1.19-2.64)	1.58 (1.04-2.40)
Missing	10.9	10	91.6	99		
Wealth Index					0.019	0.555
Poorest	5.5	34	618.5	545	Ref	Ref
Poorer	4.6	27	584.1	496	0.85 (0.51-1.41)	0.80 (0.48-1.33)
Poor	6.9	39	562.6	492	1.27 (0.80-2.01)	1.14 (0.71-1.84)
Less Poor	8	43	539.5	471	1.46 (0.93-2.30)	1.16 (0.70-1.91)
Least Poor	9.5	48	504.6	461	1.72 (1.11-2.66)	1.23 (0.71-2.11)
Missing	10.8	11	102	111		
Season of birth					0.269	0.164
Dry	7.9	88	1116	1057	Ref	Ref
Rainy	6.4	114	1795.3	1519	0.85 (0.65-1.13)	0.81 (0.60-1.09)

Table 21 Hospitalization analyses: Interactions between FIC and sex and between FIC and area

FIC	Adjusted HR (95%-CI)	Test of no interaction p-value
Sex		
Males	0.87 [0.49-1.53]	0.976
Females	0.88 [0.45-1.73]	
Study area		
Plain and hilly	0.88 [0.49-1.58]	0.974
Low-lying	0.87 [0.45-1.66]	

Table 22 Hospitalization analyses – splitting FIC into FICIS and FICOS

					Unadjusted	Adjusted
	Rate/100PYO	**H**	**PYO**	**N**	**HRR (95% CI)**	**HRR (95% CI)**
FIC					[P=0.598]	[P=0.419]
Not FIC	6.7	26	389.5	342	Ref	Ref
FICOS	6.6	120	1812.3	1594	0.98 (0.64-1.50)	0.82 (0.52-1.29)
FICIS	7.9	56	709.5	640	1.16 (0.73-1.84)	1.00 (0.61-1.64)

FIC	Adjusted HR (95%-CI)	Test of no interaction p-value
Male		0.150
FICOS	0.88 [0.50-1.57]	
FICIS	0.82 [0.43-1.58]	
Female		
FICOS	0.72 [0.35-1.45]	
FICIS	1.30 [0.62-2.72]	

FIC	Adjusted HR (95%-CI)	Test of no interaction p-value
Plain and hilly		0.995
FICOS	0.84 [0.46-1.52]	
FICIS	1.03 [0.52-2.01]	
Low-lying		
FICOS	0.80 [0.41-1.58]	
FICIS	0.98 [0.48-2.00]	

Table 23 Hospitalization analyses – NOT FIC split into "FIC without MCV" and otherwise

					Unadjusted	Adjusted
	Rate/100PYO	**H**	**PYO**	**N**	**HRR (95% CI)**	**HRR (95% CI)**
FIC					[P=0.353]	[P=0.495]
Not FIC	3.4	3	88.2	75	Ref	Ref
FIC without MCV	7.6	23	301.4	267	2.22 (0.67-7.39)	1.81 (0.54-6.07)
FIC	7.0	176	2521.7	2234	2.01 (0.64-6.28)	1.44 (0.45-4.53)

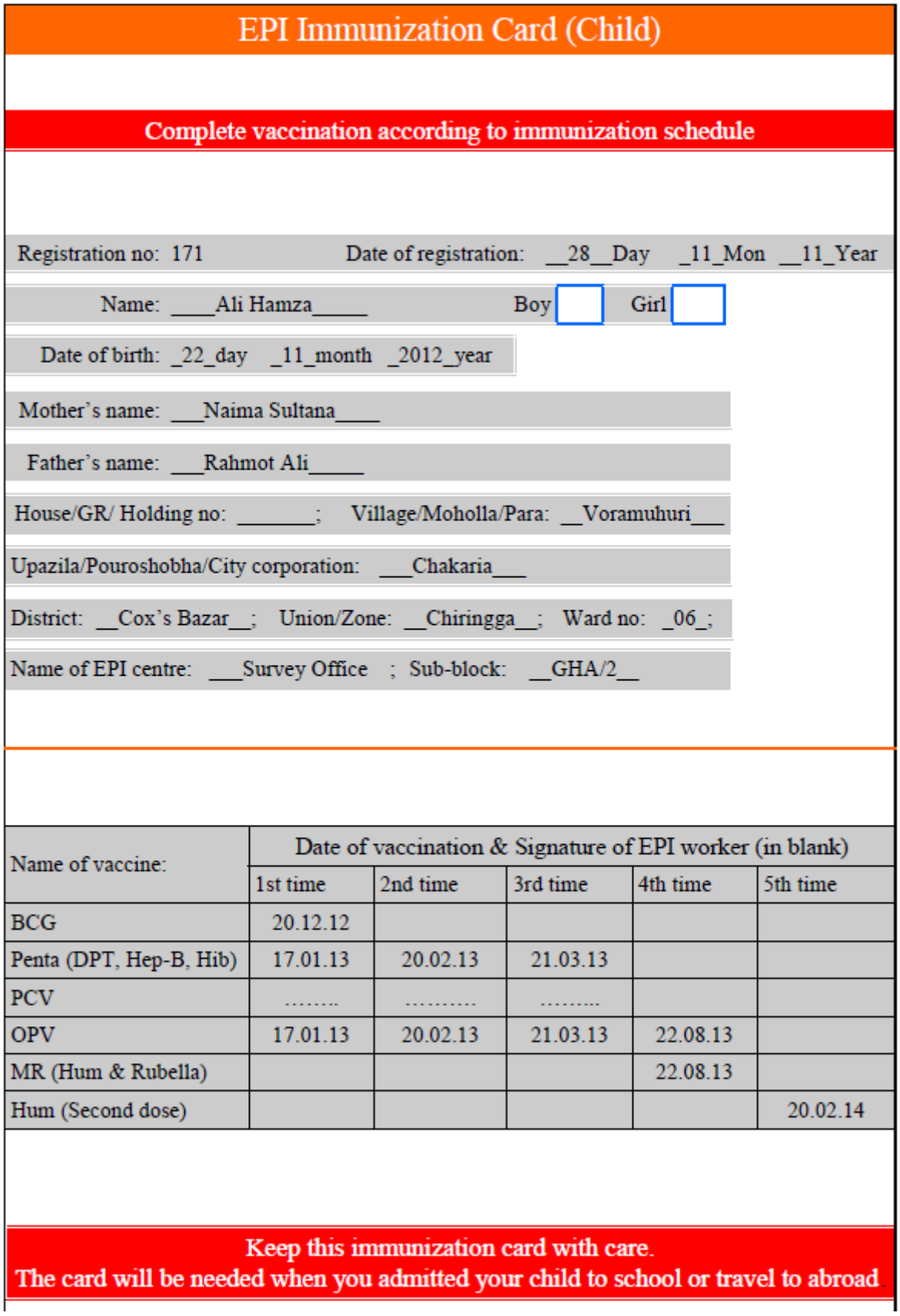
FIC	**Adjusted HR (95%-CI)**	**Test of no interaction p-value**
Male		*NA*
FIC without MCV	0.87 [0.24-3.15]	
FIC	0.78 [0.25-2.49]	
Female		
FIC without MCV	*NA**	
FIC	*NA**	

* Zero hospitalizations in the reference group "Not FIC" for female

FIC	**Adjusted HR (95%-CI)**	**Test of no interaction p-value**
Plain and hilly		*NA*
FIC without MCV	0.86 [0.23-3.13]	
FIC	0.78 [0.24-2.49]	
Low-lying		
FIC without MCV	*NA**	
FIC	*NA**	

* Zero hospitalizations in the reference group "Not FIC" for the low-lying area

Figure 12 Vaccination card used



EPI Immunization Card (Child)

Complete vaccination according to immunization schedule

Registration no: 171 Date of registration: __28__Day _11_Mon __11_Year

Name: ____Ali Hamza_____ Boy ☐ Girl ☐

Date of birth: _22_day _11_month _2012_year

Mother's name: ___Naima Sultana____

Father's name: ___Rahmot Ali_____

House/GR/ Holding no: _____; Village/Moholla/Para: __Voramuhuri___

Upazila/Pouroshobha/City corporation: ___Chakaria___

District: __Cox's Bazar__; Union/Zone: __Chiringga__; Ward no: _06_;

Name of EPI centre: ___Survey Office ; Sub-block: __GHA/2__

Name of vaccine:	Date of vaccination & Signature of EPI worker (in blank)				
	1st time	2nd time	3rd time	4th time	5th time
BCG	20.12.12				
Penta (DPT, Hep-B, Hib)	17.01.13	20.02.13	21.03.13		
PCV	……..	……..	……..		
OPV	17.01.13	20.02.13	21.03.13	22.08.13	
MR (Hum & Rubella)				22.08.13	
Hum (Second dose)					20.02.14

Keep this immunization card with care.
The card will be needed when you admitted your child to school or travel to abroad.

Appendix 6: Bandim 2001-13

List of Tables

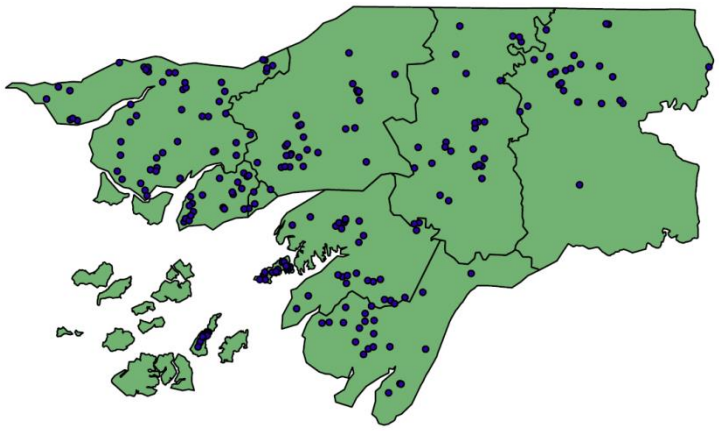
Table 1 Inclusion per year of visit 4
Table 2 Percent of children per year having no vaccination card 4
Table 3 Representativeness – comparison children included and excluded from the analyses 6
Table 4 Overall FIC by year of visit 7
Table 5 Coverage of FIC by year of visit and sex 8
Table 6 Coverage of FIC by year and Place of residence 8
Table 7 Coverage of FIC by year of visit and place of birth 9
Table 8 Coverage of FIC by year of visit and maternal education 9
Table 9 Median vaccination age (days) and lower and upper quartiles for FIC 12
Table 10 Median vaccination age (days) and lower and upper quartiles for NOT FIC with a vaccine 12
Table 11 Among children NOT FIC, missing a specific vaccine 14
Table 12 Among children NOT FIC, missing only the particular vaccine 15
Table 13 Among children NOT FIC, number of vaccines missing 15
Table 14 Full immunization coverage (FIC) in sequence, FICIS among FIC 16
Table 15 Main reasons for out-of-sequence for FIC who are out-of-sequence (FICOS) 18
Table 16 Fully Vaccination coverage at 24 months (FIC24) for NOT FIC at 12 months of age 20
Table 17 Analyses of association between background factors and FIC 21
Table 18 Analyses of association between background factors and FICIS among FIC 22
Table 19 Survival analysis of FIC vs NOT FIC, Children followed to 3 years of age 23
Table 20 Interactions 24
Table 21 Survival analysis – splitting FIC into FICIS and FICOS 24
Table 22 Survival analysis – NOT FIC split into “FIC without MCV” and otherwise 25
Table 23 Survival and alternative FIC calculations: FIC at visit and FIC15 26

List of Figures

Figure 1 Flow chart of inclusion for Bandim 2001-13 4
Figure 2 Histogram of visits from flow chart 5
Figure 3 Coverage in percent of FIC by year of visit 7
Figure 4 FIC Coverage by key factors 10
Figure 5 Coverage curves for each vaccine among FIC, NOT FIC, and combined 11
Figure 6 Comparison of median vaccination age of FIC and NOT FIC 13
Figure 7 Among NOT FIC percent of missing a particular vaccine 14
Figure 8 Coverage of FIC-in-sequence among FIC 16
Figure 9 Coverage of FIC-in-sequence among FIC for key factors 17
Figure 10 Reason for out-of-sequence among FICOS 18
Figure 11 FIC15 Coverage curves for each vaccine among FIC, NOT FIC, and combined 19
Figure 12 Coverage of FIC24 among NOT FIC at 12 months 20
Figure 13 Vaccination card used 27

Bandim Health Project, Guinea-Bissau

The Bandim Health Project (BHP) (www.bandim.org) runs a rural Health and Demographic Surveillance System (HDSS) site in Guinea-Bissau. The rural HDSS covers village clusters throughout the 9 health regions of the country. BHP surveys women and their children below 5 years of age in 182 clusters in the 9 health regions in Guinea-Bissau. In 1990 the study population in 20 clusters in each of the 5 most populous regions (83% of the country's population) was registered. In 2006 the surveillance system was expanded to cover the rest of the country. Six regions each have 20 clusters, one health region which was formerly divided into two regions has 40 clusters and the two smallest regions have 12 and 10 clusters.



Map: Villages followed through the Bandim Health Projects rural surveillance system

In each of the village clusters, originally 100 women of fertile age and all their children less than 5 years of age are followed. Women are registered at 14-16 years of age or when they move into the village. Newly registered women are interviewed about their age, obstetric history, ethnicity and whether they have attended school. At all visits the women are asked whether they are pregnant. When a pregnancy is registered; the woman's nutritional status is accessed by measurement of a mid-upper-arm-circumference (MUAC); information on antenatal care is collected prior to giving birth, as well as at the first visit after delivery. After the delivery, information on the place of delivery (home, health facility) and who assisted the delivery is collected.

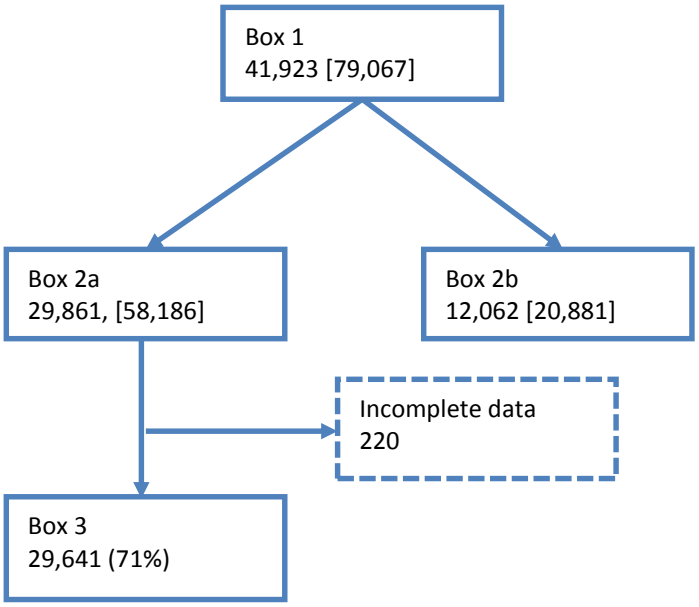
Throughout the BHP data collection vaccinations have been registered. At all visits it is registered whether the child has a vaccination card and whether the card was seen. When a vaccination card is seen, the information is copied. In addition, for all children below 5 years of age information is collected on vital status, breastfeeding status, supplementary feeding, MUAC, hospital admissions and whether the child has received interventions provided in campaigns.

Socio-economic factors (type of roofing, type of bathroom, possession of a mobile phone, radio and generator) are registered since 2009. Bi-annual survey visits have been conducted to all 182 village clusters since the baseline registration in 1990/2006; more frequent visits have been conducted in three regions closest to Bissau since 2012.

Prior to 2008 the vaccination schedule was BCG and oral polio vaccine (OPV) at birth, 3 doses of diphtheria-tetanus-pertussis vaccine (DTP) and OPV at 6, 10 and 14 weeks of age. In September 2008 pentavalent (DTP-Hepatitis B-H. influenza type B) vaccines replaced the DTP vaccine and yellow fever vaccine was added to be given with measles vaccine.

Vaccines are available to infants free of charge at health centres and some hospitals throughout the country. The national EPI programme organises outreach vaccination sessions when funding is available, but the frequency has been low until the introduction of new vaccines in 2008 where GAVI support for the vaccination programme made the outreach visits more common.

Figure 1 Flow chart of inclusion for Bandim 2001-13



Box 1
Number of children alive at an HDSS home visit between 12 and 23 months of age
[Number of visits asking for vaccine card]

Box 2a
Number of children from box 1 having at least one visit with card seen
[Number of visits for these children including those where card not seen]

Box 2b
Number of children from box 1 having no seen card at any visit between 12 and 23 months of age
[Number of visits]

Box 3
Number of children included in analyses

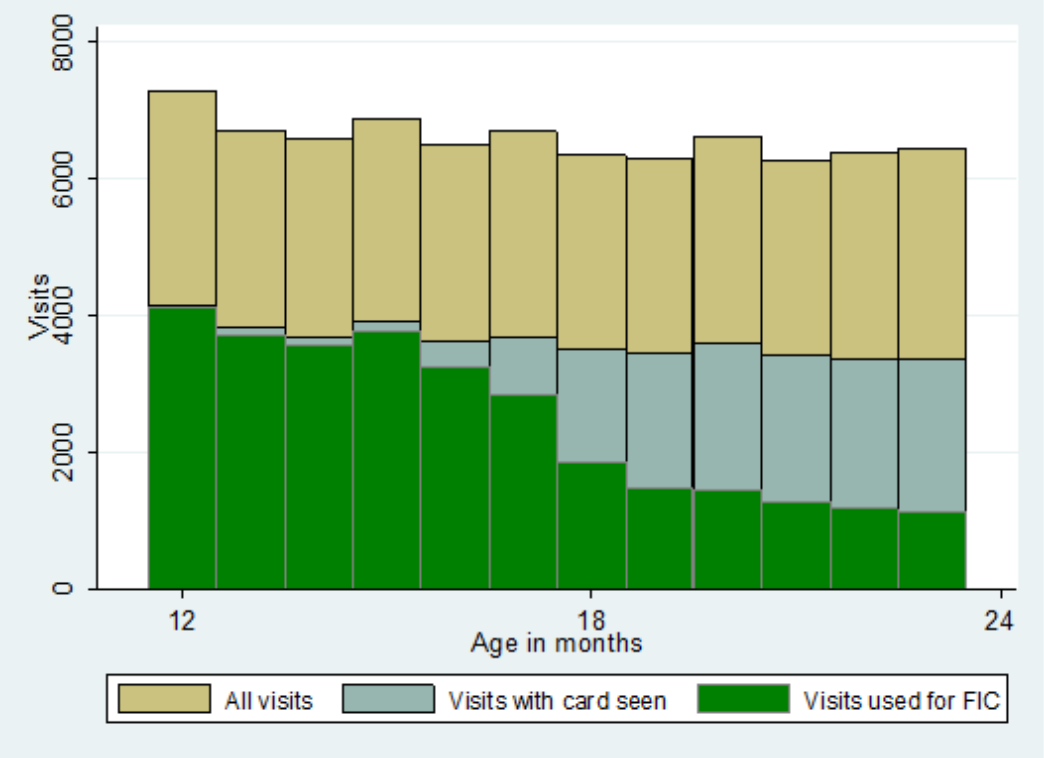
Table 1 Inclusion per year of visit

Year of Visit	Inclusion % (n/total)
2001	58 (1549/2690)
2002	63 (1268/2027)
2003	67 (1323/1986)
2004	68 (1414/2073)
2005	68 (1505/2221)
2006	69 (2694/3925)
2007	72 (2888/3985)
2008	75 (2479/3311)
2009	71 (2871/4032)
2010	76 (2626/3460)
2011	74 (2831/3825)
2012	76 (2664/3500)
2013	72 (3529/4888)
Total	71 (29641/41923)

Table 2 Percent of children per year having no vaccination card

Year of Visit	No card % (n/total)
2001	6% (148/2690)
2002	6% (120/2027)
2003	3% (67/1986)
2004	2% (45/2073)
2005	2% (50/2221)
2006	2% (85/3925)
2007	1% (50/3985)
2008	1% (22/3311)
2009	0% (14/4032)
2010	0% (4/3460)
2011	1% (23/3825)
2012	0% (3/3500)
2013	0% (5/4888)
Total	2% (636/41923)

Figure 2 Histogram of visits from flow chart



All visits = Visits from Box 1
Visits with card seen = Visits from Box 2a
Visits used for FIC = Visits from Box 3

Table 3 Representativeness – comparison children included and excluded from the analyses

Variable	Included n (%)	Excluded n (%)	P-Value
Sex			
Male	14800 (50%)	6062 (49%)	0.003
Female	14840 (50%)	6214 (51%)	
Missing	1 (0%)	6 (0%)	
Region of residence			
Oio	4687 (16%)	1946 (16%)	<0.001
Biombo	4588 (15%)	2260 (18%)	
Gabu	4771 (16%)	1348 (11%)	
Cacheu	5571 (19%)	2488 (20%)	
Bafata	4033 (14%)	1447 (12%)	
Quinara	2492 (8%)	925 (8%)	
Tombali	2210 (7%)	1011 (8%)	
Bubaque	698 (2%)	504 (4%)	
Bolama	591 (2%)	353 (3%)	
Ethnicity			
Balanta	6801 (23%)	3744 (30%)	<0.001
Fula	6567 (22%)	1910 (16%)	
Manjaco/Mancanha	2263 (8%)	1096 (9%)	
Pepel	3896 (13%)	2006 (16%)	
Mandinga	5327 (18%)	1524 (12%)	
Beafada	1687 (6%)	478 (4%)	
Other	2904 (10%)	1423 (12%)	
Missing	196 (1%)	101 (1%)	
Place of delivery			
Health Facility	5888 (20%)	2387 (19%)	<0.001
Home	15095 (51%)	5729 (47%)	
Elsewhere	194 (1%)	197 (2%)	
Missing	8464 (29%)	3969 (32%)	
Maternal education			
None	20714 (70%)	8450 (69%)	<0.006
1-4 years	5235 (18%)	2190 (18%)	
>4 years	2729 (9%)	1166 (9%)	
Missing	963 (3%)	476 (4%)	
Maternal age			
<20	6493 (22%)	2664 (22%)	<0.001
20-24	8199 (28%)	3597 (29%)	
25-29	6792 (23%)	2856 (23%)	
>=30	7854 (26%)	2983 (24%)	
Missing	303 (1%)	182 (1%)	

Table 4 Overall FIC by year of visit

Year of Visit	FIC coverage (n/total)
2001	19 (301/1549)
2002	27 (337/1268)
2003	45 (591/1323)
2004	56 (790/1414)
2005	47 (703/1505)
2006	44 (1192/2694)
2007	53 (1545/2888)
2008	52 (1284/2479)
2009	41 (1178/2871)
2010	54 (1422/2626)
2011	56 (1572/2831)
2012	61 (1631/2664)
2013	72 (2547/3529)
Total	51 (15093/29641)

Figure 3 Coverage in percent of FIC by year of visit

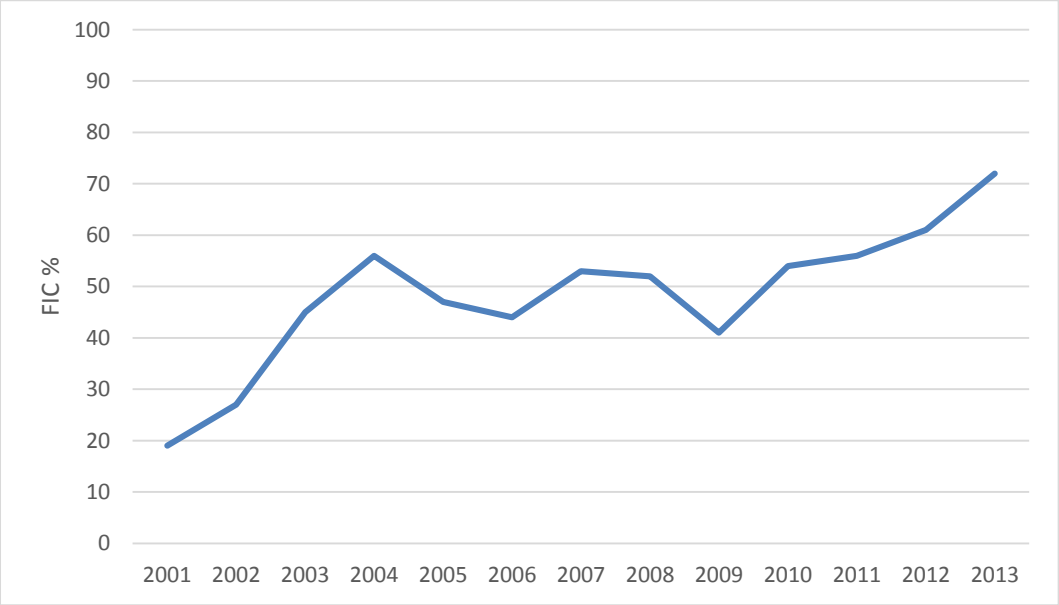


Table 5 Coverage of FIC by year of visit and sex

Year of Visit	Sex		
	Females	**Males**	Total
2001	19 (142/746)	20 (159/803)	19 (301/1549)
2002	26 (165/642)	27 (172/626)	27 (337/1268)
2003	43 (286/668)	47 (305/655)	45 (591/1323)
2004	56 (392/705)	56 (398/709)	56 (790/1414)
2005	45 (342/753)	48 (361/752)	47 (703/1505)
2006	43 (577/1332)	45 (615/1362)	44 (1192/2694)
2007	53 (774/1472)	54 (771/1416)	53 (1545/2888)
2008	52 (645/1243)	52 (639/1236)	52 (1284/2479)
2009	41 (586/1441)	41 (592/1430)	41 (1178/2871)
2010	54 (693/1281)	54 (729/1345)	54 (1422/2626)
2011	56 (779/1400)	55 (792/1430)	56 (1571/2830)
2012	62 (837/1345)	60 (794/1319)	61 (1631/2664)
2013	71 (1283/1812)	74 (1264/1717)	72 (2547/3529)
Total	51 (7501/14840)	51 (7591/14800)	51 (15092/29640)

Table 6 Coverage of FIC by year and Place of residence

Year of visit	Place of residence				
	Oio	**Biombo**	**Gabu**	**Cacheu**	**Bafata**
2001	12% (45/374)	34% (110/320)	6% (19/311)	28% (66/239)	20% (61/305)
2002	25% (65/261)	45% (131/293)	7% (17/246)	45% (90/201)	13% (34/267)
2003	59% (160/272)	47% (142/300)	21% (61/295)	54% (129/239)	46% (99/217)
2004	44% (135/306)	50% (138/278)	60% (199/332)	61% (144/235)	66% (174/263)
2005	28% (84/295)	33% (98/298)	60% (216/359)	44% (104/239)	64% (201/314)
2006	25% (79/317)	36% (118/326)	70% (232/332)	54% (311/574)	62% (187/302)
2007	39% (130/331)	59% (190/323)	69% (275/401)	65% (302/465)	71% (243/340)
2008	30% (58/195)	49% (193/393)	47% (209/448)	64% (335/520)	62% (210/338)
2009	25% (102/411)	43% (165/388)	26% (105/400)	51% (259/510)	61% (201/330)
2010	45% (172/386)	47% (172/369)	59% (216/369)	63% (318/505)	64% (253/396)
2011	52% (201/384)	59% (268/455)	46% (178/385)	68% (323/478)	55% (173/312)
2012	56% (315/560)	68% (260/383)	54% (217/405)	70% (417/595)	53% (119/225)
2013	80% (474/595)	90% (418/462)	66% (323/488)	86% (663/771)	60% (253/424)
Total	43% (2020/4687)	52% (2403/4588)	48% (2267/4771)	62% (3461/5571)	55% (2208/4033)

Year of visit	Place of residence			
	Quinara	**Tombali**	**Bubaque**	**Bolama**
2006	29% (101/346)	10% (21/220)	58% (83/143)	45% (60/134)
2007	46% (196/426)	24% (108/449)	68% (55/81)	64% (46/72)
2008	51% (172/337)	28% (39/141)	61% (38/62)	67% (30/45)
2009	42% (99/235)	22% (69/313)	68% (106/156)	56% (72/128)
2010	49% (126/255)	41% (104/253)	60% (35/58)	74% (26/35)
2011	53% (177/336)	47% (150/321)	56% (35/63)	69% (67/97)
2012	69% (159/229)	51% (82/162)	53% (41/77)	75% (21/28)
2013	58% (190/328)	47% (165/351)	53% (31/58)	58% (30/52)
Total	49% (1220/2492)	33% (738/2210)	61% (424/698)	60% (352/591)

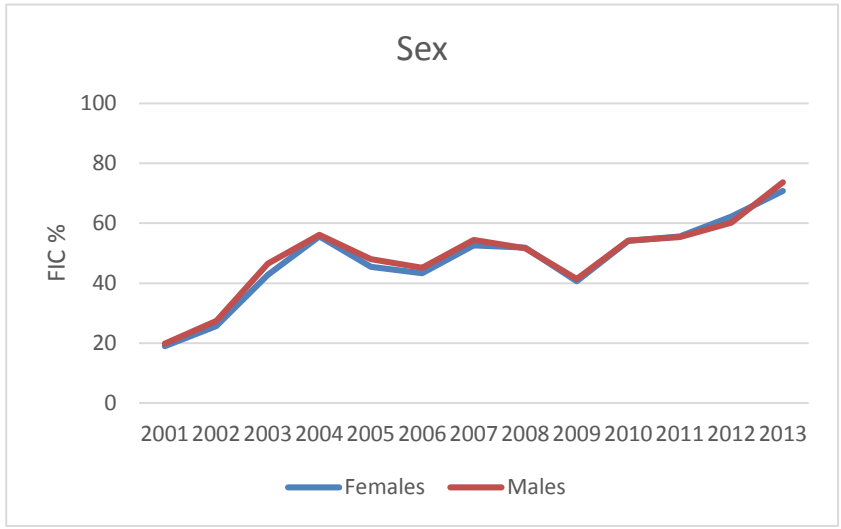
Table 7 Coverage of FIC by year of visit and place of birth

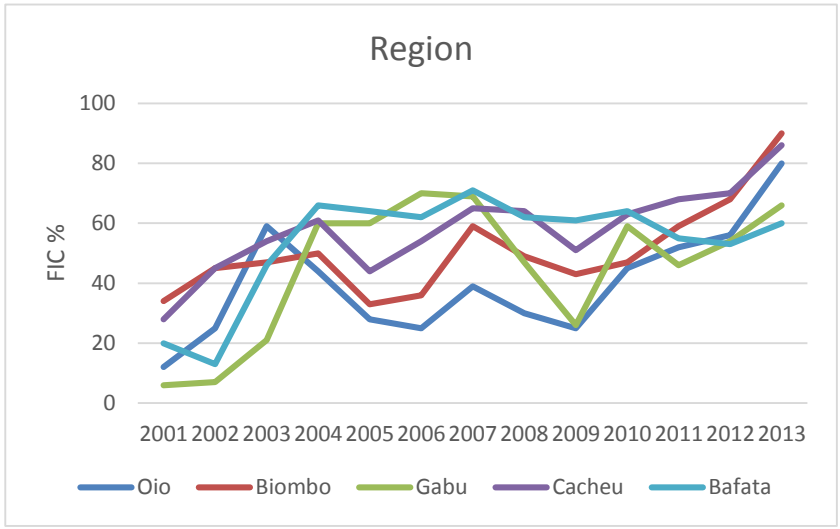
Year of visit	Place of birth			
	Health Facility	Home	Other	Total
2001	35% (85/246)	14% (93/670)	25% (3/12)	20% (181/928)
2002	36% (80/225)	23% (147/651)	25% (3/12)	26% (230/888)
2003	54% (102/189)	40% (264/662)	47% (7/15)	43% (373/866)
2004	64% (133/207)	55% (380/697)	43% (3/7)	57% (516/911)
2005	50% (111/224)	47% (330/708)	46% (6/13)	47% (447/945)
2006	47% (128/272)	50% (367/733)	23% (3/13)	49% (498/1018)
2007	68% (305/448)	51% (617/1202)	44% (4/9)	56% (926/1659)
2008	63% (294/470)	48% (624/1293)	29% (2/7)	52% (920/1770)
2009	51% (306/600)	38% (539/1433)	56% (9/16)	42% (854/2049)
2010	65% (400/615)	52% (811/1554)	50% (9/18)	56% (1220/2187)
2011	63% (493/779)	53% (877/1660)	48% (15/31)	56% (1385/2470)
2012	69% (458/666)	59% (985/1658)	50% (8/16)	62% (1451/2340)
2013	79% (747/947)	72% (1561/2174)	72% (18/25)	74% (2326/3146)
Total	62% (3642/5888)	50% (7595/15095)	46% (90/194)	53% (11327/21177)

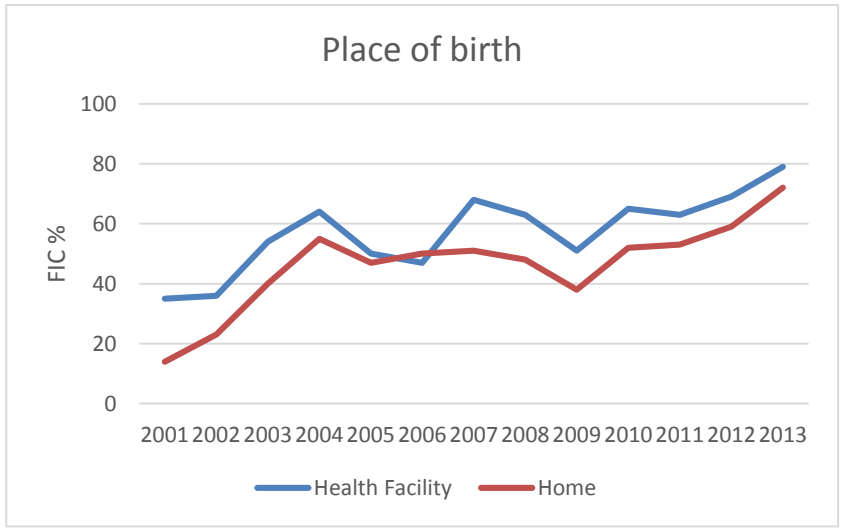
Table 8 Coverage of FIC by year of visit and maternal education

Year of visit	Maternal education			
	None	1-4 years	>4 years	Total
2001	16 (207/1268)	30 (54/178)	48 (32/66)	19 (293/1512)
2002	24 (253/1063)	44 (62/142)	36 (16/44)	27 (331/1249)
2003	42 (450/1063)	51 (87/170)	64 (37/58)	44 (574/1291)
2004	56 (641/1152)	49 (77/156)	68 (46/68)	56 (764/1376)
2005	45 (552/1221)	55 (91/165)	61 (43/71)	47 (686/1457)
2006	42 (799/1888)	48 (220/462)	56 (137/245)	45 (1156/2595)
2007	51 (1072/2122)	58 (260/452)	71 (173/244)	53 (1505/2818)
2008	48 (843/1748)	59 (267/452)	64 (140/218)	52 (1250/2418)
2009	37 (708/1905)	46 (254/548)	56 (176/316)	41 (1138/2769)
2010	52 (911/1751)	57 (289/508)	63 (170/269)	54 (1370/2528)
2011	52 (926/1789)	61 (390/643)	69 (208/302)	56 (1524/2734)
2012	58 (970/1681)	66 (368/557)	71 (220/312)	61 (1558/2550)
2013	70 (1442/2063)	74 (592/802)	78 (404/516)	72 (2438/3381)
Total	47 (9774/20714)	58 (3011/5235)	66 (1802/2729)	51 (14587/28678)

Figure 4 FIC Coverage by key factors







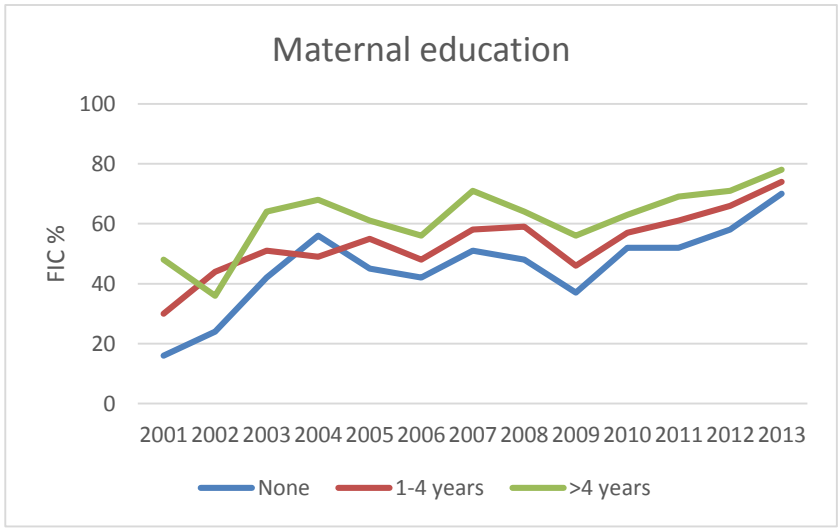
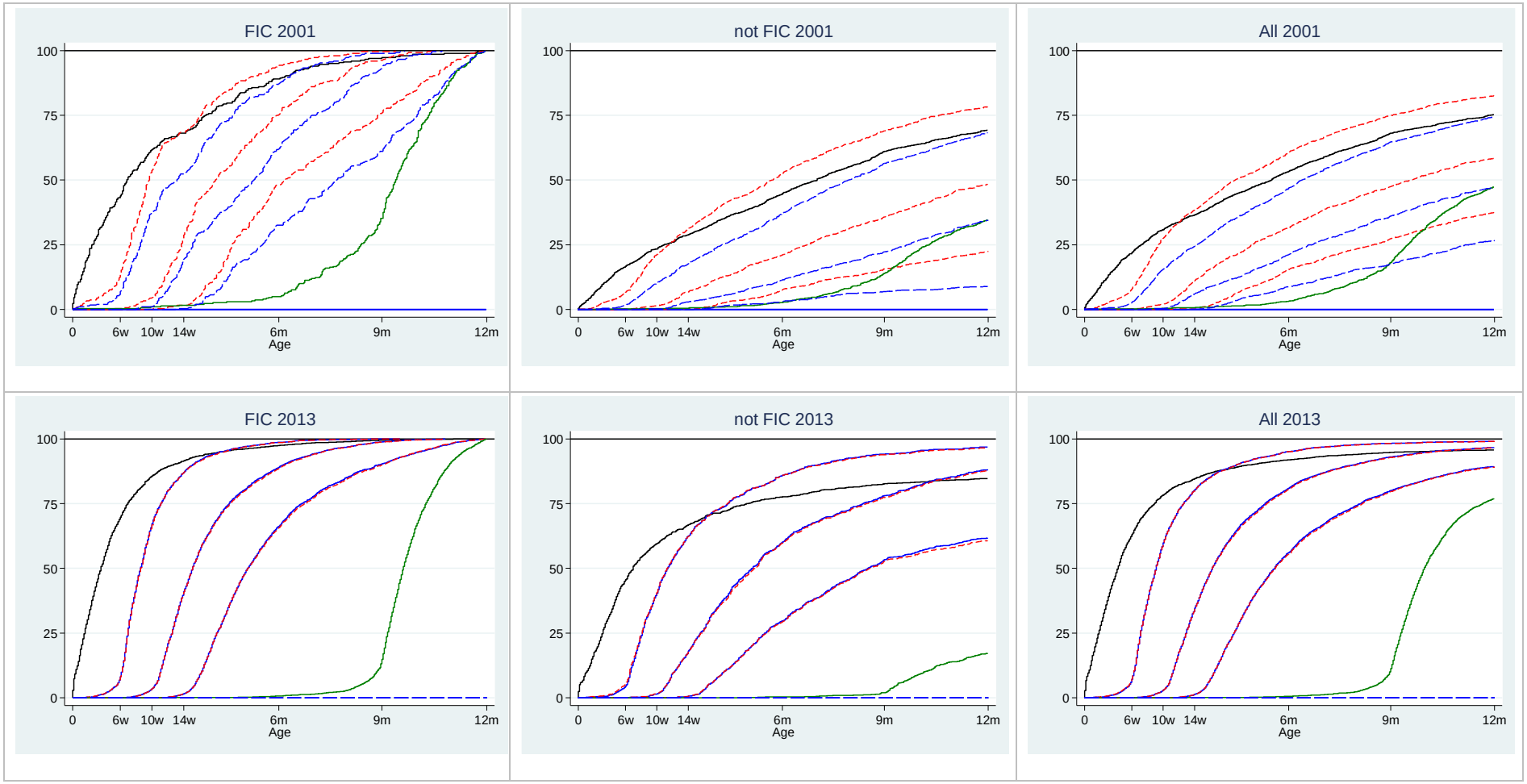


Figure 5 Coverage curves for each vaccine among FIC, NOT FIC, and combined



BCG is black; DTP/Penta is blue; OPV is dashed and red; MCV is green

Table 9 Median vaccination age (days) and lower and upper quartiles for FIC

Year of visit	BCG			DTP 1			DTP 2			DTP 3			OPV 1			OPV 2			OPV 3			MCV		
	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
2001	18	48	117	60	92	141	106	160	211	168	233	304	51	68	113	96	126	180	141	188	269	255	285	314
2002	12	32	67	50	67	102	96	128	183	147	203	279	48	63	96	91	124	168	136	188	261	267	285	311
2003	20	48	103	54	71	111	96	132	192	147	202	277	53	70	109	95	130	190	145	197	273	272	289	311
2004	16	39	87	51	70	105	98	132	179	153	197	265	51	70	103	98	132	179	154	199	265	263	284	310
2005	21	57	110	52	70	107	98	139	196	150	203	277	55	80	123	104	154	209	165	228	293	266	287	315
2006	16	42	89	50	65	92	93	118	158	138	178	239	50	65	92	93	118	159	138	180	241	274	291	318
2007	16	42	84	51	69	101	96	125	174	142	187	246	51	69	101	96	126	176	142	189	252	274	288	312
2008	13	34	72	49	63	87	88	112	152	130	166	231	49	63	89	89	114	154	132	170	237	275	289	314
2009	14	34	71	Penta 1			Penta 2			Penta 3			49	65	98	91	119	169	134	179	248	277	292	315
2010	14	34	67	51	66	92	93	120	162	137	175	240	50	66	90	93	119	160	137	177	244	277	291	316
2011	14	36	71	52	66	92	96	121	159	142	181	248	51	66	91	95	120	159	142	181	246	279	295	320
2012	14	34	68	51	65	92	94	123	164	139	179	246	51	64	89	93	122	162	138	177	244	278	293	318
2013	10	25	49	49	60	78	88	106	138	127	155	202	49	60	78	88	106	139	127	155	205	278	292	312

Table 10 Median vaccination age (days) and lower and upper quartiles for NOT FIC with a vaccine

Year of visit	BCG			DTP 1			DTP 2			DTP 3			OPV 1			OPV 2			OPV 3			MCV		
	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
2001	45	127	222	96	169,5	247	158	230,5	298	165,5	214	269,5	66	124	213	126	198	276,5	170	219	289	244	285	315
2002	24	59	156	65	124	210	123	207	290	156	196	272	62	114	183	122	199	270	162	218	298	266	297	334
2003	31	95	196	69	122	216	121	198	287	150	201	247	65	116	202	118	195	277	148	201	252	263	299	331
2004	23	54	117	60	92	151	116	171	248	165	220	284	59	91	151	116	168	249	151	203	251	260	291	322
2005	20	61	152	60	92	162	110	166	257	151	203	268	65	108	185	125	191	273	155	206	260	262	287	313
2006	25	64	135	56	84	140	101	143	224	137	174	238	55	84	141	102	145	227	138	177	242	273	293	318
2007	26	62	134	61	96	179	110	159	249	143	187	241	61	95	179	108	163	253	141	183	241	280	301	334
2008	20	47	109	60	94	150	112	159	230	149	192	245	60	94	156	112	160	239	146	187	237	280	301	325
2009	19	44	98	Penta 1			Penta 2			Penta 3			59	91	161	114	175	261	156	219	278	282	303	328
2010	18	40	83	58	83	139	106	154	232	150	201	255	56	80	130	106	155	227	149	205	256	280	304	330
2011	18	40	87	59	84	131	108	149	224	154	198	248	59	84	132	110	153	228	161	206	260	283	302	329
2012	20	46	93	58	79	128	108	151	213	149	193	251	57	77	120	108	148	208	151	198	255	280	299	327
2013	19	37	83	57	78	125	104	141	203	144	187	244	56	77	122	104	143	204	144	186	242	282	302	326

Figure 6 Comparison of median vaccination age of FIC and NOT FIC

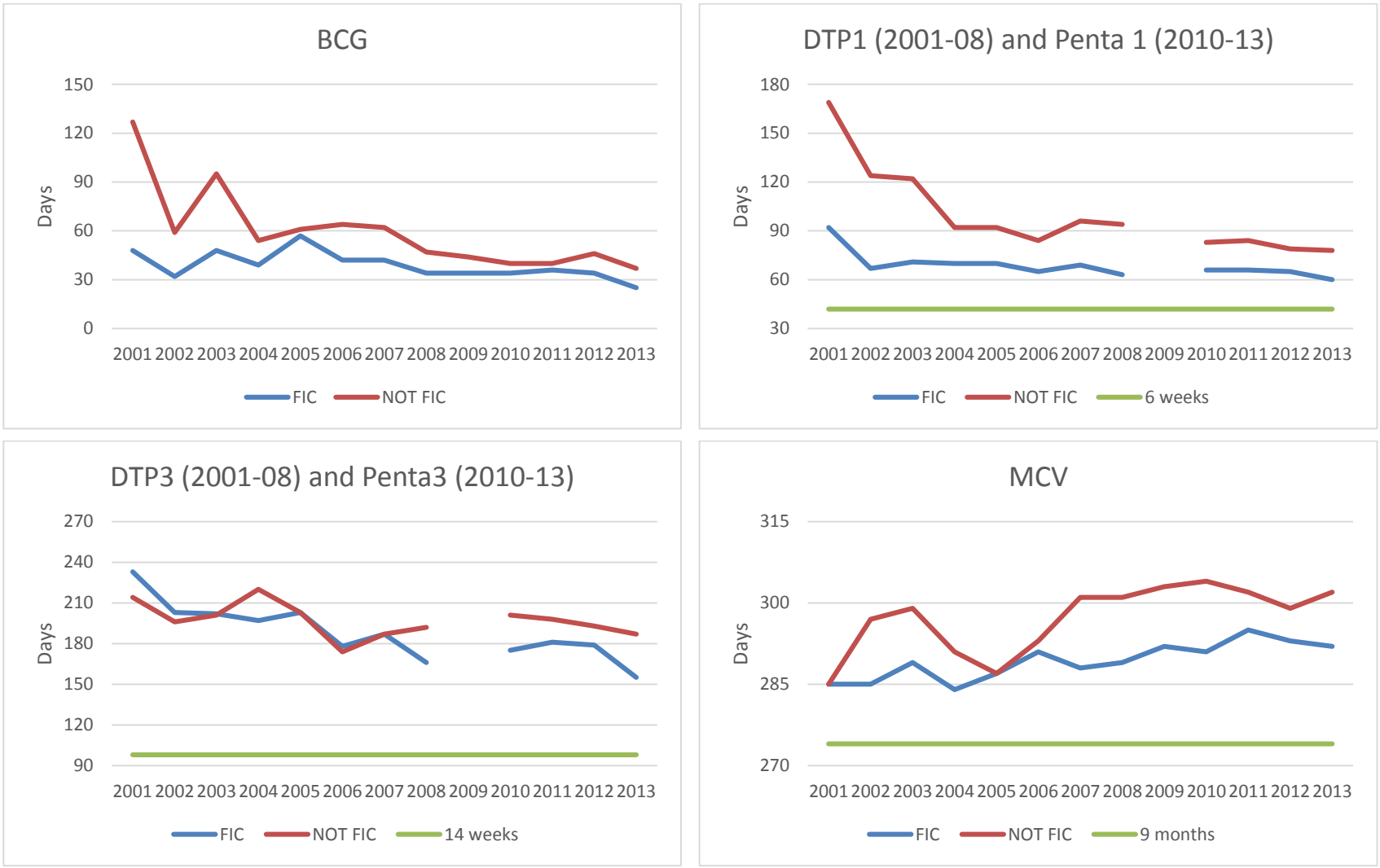


Table 11 Among children NOT FIC, missing a specific vaccine

Year of visit	BCG	DTP 1	DTP 2	DTP 3	Penta 1	Penta 2	Penta 3	OPV 1	OPV 2	OPV 3	MCV	Number NOT FIC
2001	30.7 (383)	31.6 (394)	65.5 (818)	91.0 (1136)	-	-	-	21.6 (270)	51.6 (644)	77.6 (968)	65.4 (816)	1,248
2002	26.7 (249)	25.3 (236)	58.9 (548)	84.9 (790)	-	-	-	21.1 (196)	51.0 (475)	78.2 (728)	79.5 (740)	931
2003	20.9 (153)	17.8 (130)	44.0 (322)	77.0 (564)	-	-	-	16.1 (118)	41.4 (303)	75.4 (552)	70.6 (517)	732
2004	12.3 (77)	7.7 (48)	25.3 (158)	60.1 (375)	-	-	-	9.1 (57)	28.0 (175)	68.3 (426)	63.6 (397)	624
2005	19.5 (156)	8.1 (65)	25.9 (208)	59.4 (476)	-	-	-	11.8 (95)	33.4 (268)	73.8 (592)	58.4 (468)	802
2006	17.6 (265)	9.6 (144)	30.2 (453)	59.5 (894)	-	-	-	10.1 (151)	31.0 (466)	61.7 (926)	81.6 (1225)	1,502
2007	19.4 (261)	15.4 (207)	37.2 (500)	67.3 (904)	-	-	-	15.6 (209)	38.0 (511)	70.4 (946)	75.2 (1010)	1,343
2008	16.7 (199)	7.9 (95)	25.6 (306)	55.1 (658)	98.8 (1181)	99.7 (1192)	100.0 (1195)	8.4 (100)	28.2 (337)	62.6 (748)	73.5 (878)	1,195
2009	16.7 (282)	49.6 (840)	70.0 (1185)	87.4 (1479)	41.1 (696)	62.7 (1062)	85.5 (1448)	6.9 (116)	26.8 (454)	59.4 (1005)	57.2 (968)	1,693
2010	23.7 (285)	99.6 (1199)	99.8 (1201)	99.9 (1203)	4.6 (55)	17.4 (209)	48.1 (579)	4.5 (54)	17.9 (215)	50.0 (602)	69.4 (835)	1,204
2011	21.5 (271)	-	-	-	5.0 (63)	18.7 (235)	48.3 (608)	3.9 (49)	17.5 (220)	46.1 (581)	73.6 (926)	1,259
2012	20.3 (210)	-	-	-	4.7 (49)	16.5 (170)	41.6 (430)	4.4 (45)	14.9 (154)	39.5 (408)	77.5 (801)	1,033
2013	15.3 (150)	-	-	-	3.2 (31)	11.7 (115)	38.2 (375)	3.5 (34)	12.1 (119)	39.2 (385)	82.7 (812)	982
Total*	20.2 (2941)	21.4 (2159)	44.7 (4498)	72.3 (7276)	4.4 (198)	16.3 (729)	44.5 (1992)	10.3 (1494)	29.8 (4341)	60.9 (8867)	71.4 (10393)	14,548

Note: Total, DTP for year <2010, Penta: year>2009

Figure 7 Among NOT FIC percent of missing a particular vaccine

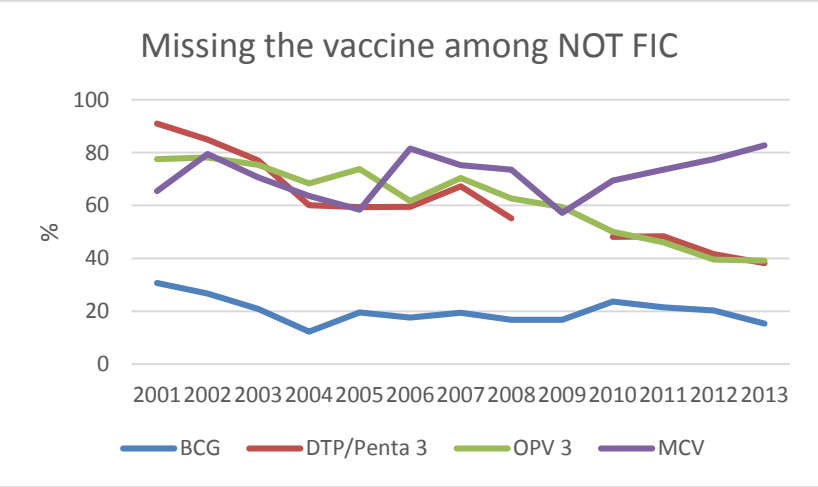


Table 12 Among children NOT FIC, missing only the particular vaccine

Year of visit	BCG	DTP 3	Penta 3	OPV 3	MCV
2001	0 (3)	6 (70)		1 (12)	7 (92)
2002	0 (1)	3 (28)		0 (4)	14 (128)
2003	1 (5)	2 (12)		1 (6)	21 (153)
2004	3 (16)	1 (9)		8 (48)	25 (157)
2005	2 (20)	3 (21)		8 (63)	18 (142)
2006	2 (35)	1 (14)		2 (30)	32 (484)
2007	2 (28)	1 (14)		3 (36)	25 (335)
2008	3 (32)	2 (21)		6 (67)	31 (374)
2009	0 (7)	6 (96)		1 (20)	9 (158)
2010	7 (80)		4 (50)	5 (59)	32 (384)
2011	6 (76)		4 (48)	3 (40)	38 (474)
2012	8 (84)		3 (29)	2 (21)	45 (463)
2013	6 (59)		1 (8)	1 (12)	52 (506)
Total	3 (446)	3 (285)	3 (135)	3 (418)	26 (3850)

Note: Total, DTP for year <2010, Penta: year>2009

Table 13 Among children NOT FIC, number of vaccines missing

	Number of vaccines missing							
Year of visit	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8=unvaccinated**
2001	14 (177)	12 (150)	15 (183)	12 (149)	17 (214)	7 (92)	6 (79)	16 (204)
2002	17 (161)	11 (102)	15 (142)	8 (73)	20 (185)	7 (69)	6 (52)	16 (147)
2003	24 (176)	15 (107)	17 (126)	10 (74)	14 (104)	4 (27)	4 (31)	12 (87)
2004	37 (230)	19 (118)	17 (106)	7 (43)	11 (69)	3 (16)	3 (20)	4 (22)
2005	31 (246)	24 (190)	15 (121)	9 (75)	10 (80)	3 (27)	3 (27)	4 (36)
2006	37 (563)	13 (197)	16 (245)	6 (88)	15 (218)	3 (48)	3 (42)	7 (101)
2007	31 (413)	15 (205)	15 (200)	7 (94)	15 (195)	3 (38)	3 (38)	12 (160)
2008	41 (494)	15 (181)	15 (184)	5 (61)	11 (137)	4 (49)	2 (22)	6 (67)
2009	17 (281)	11 (188)	15 (249)	25 (417)	16 (266)	10 (175)	3 (59)	3 (58)
2010	48 (573)	17 (207)	15 (179)	7 (83)	6 (74)	3 (39)	1 (18)	3 (31)
2011	51 (638)	13 (166)	15 (192)	7 (88)	6 (76)	4 (51)	1 (15)	3 (33)
2012	58 (597)	11 (114)	13 (135)	4 (39)	7 (77)	3 (28)	2 (16)	3 (27)
2013	60 (585)	9 (93)	17 (167)	3 (34)	6 (55)	2 (18)	1 (10)	2 (20)
Total	35 (5134)	14 (2018)	15 (2229)	9 (1318)	12 (1750)	5 (677)	3 (429)	7 (993)

Table 14 Full immunization coverage (FIC) in sequence, FICIS among FIC

Year of visit	FICIS % (n/FIC)
2001	19 (57/301)
2002	38 (128/337)
2003	37 (218/591)
2004	39 (312/790)
2005	21 (150/703)
2006	42 (499/1192)
2007	39 (610/1545)
2008	45 (577/1284)
2009	36 (426/1178)
2010	41 (584/1422)
2011	41 (651/1572)
2012	47 (772/1631)
2013	63 (1598/2547)
Total	44 (6582/15093)

FICIS is defined as the WHO recommended sequence of vaccinations, i.e. BCG before OPV1, OPV1=Penta1, OPV2=Penta2, OPV3=Penta3 and Penta3 before MCV.

Figure 8 Coverage of FIC-in-sequence among FIC

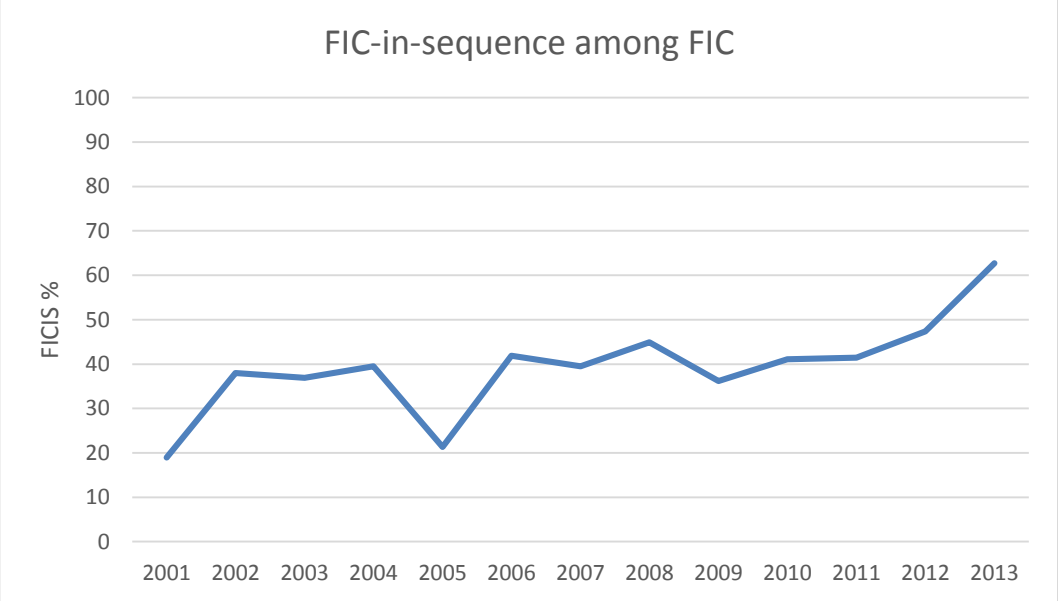


Figure 9 Coverage of FIC-in-sequence among FIC for key factors

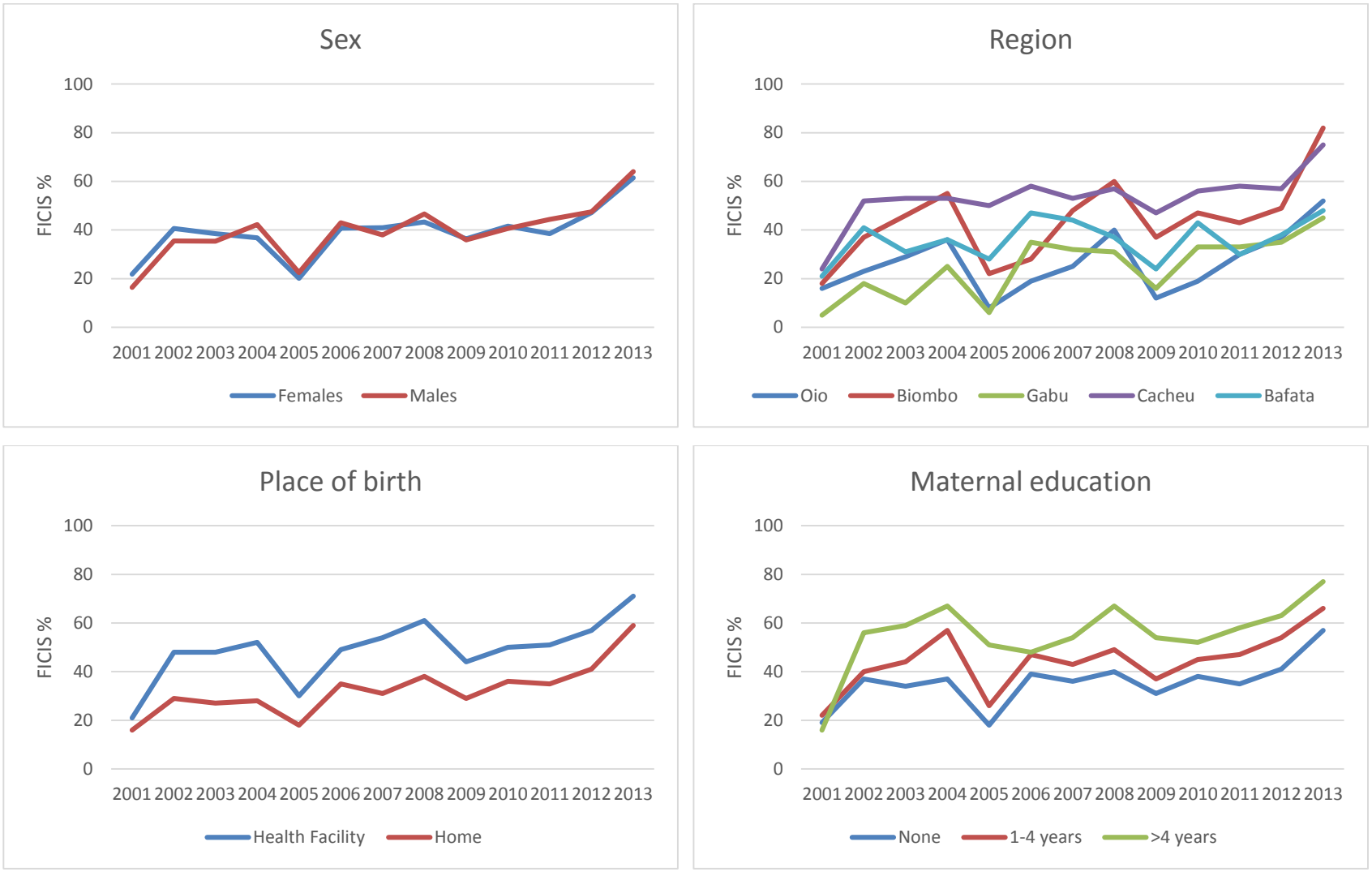


Table 15 Main reasons for out-of-sequence for FIC who are out-of-sequence (FICOS)

Year of Visit	Type of out-of-sequence % (n)			
	BCG ≥ Penta1 or MCV	OPV ≠ Penta	Penta ≥ MCV	Total FICOS
2001	57 (140)	53 (130)	59 (144)	244
2002	61 (128)	34 (71)	56 (116)	209
2003	80 (299)	14 (51)	48 (180)	373
2004	74 (354)	9 (42)	53 (253)	478
2005	74 (407)	29 (163)	41 (228)	553
2006	83 (578)	10 (71)	35 (244)	693
2007	81 (755)	16 (146)	34 (315)	935
2008	76 (538)	23 (162)	28 (195)	707
2009	54 (404)	58 (437)	36 (274)	752
2010	61 (509)	42 (353)	28 (238)	838
2011	68 (623)	32 (297)	30 (272)	921
2012	72 (619)	21 (178)	30 (254)	859
2013	76 (723)	16 (155)	25 (235)	949
Total	71 (6077)	27 (2256)	35 (2948)	8511

Note: Percentages do not sum to 100 as children may contribute to more than one type of out-of-sequence

Figure 10 Reason for out-of-sequence among FICOS

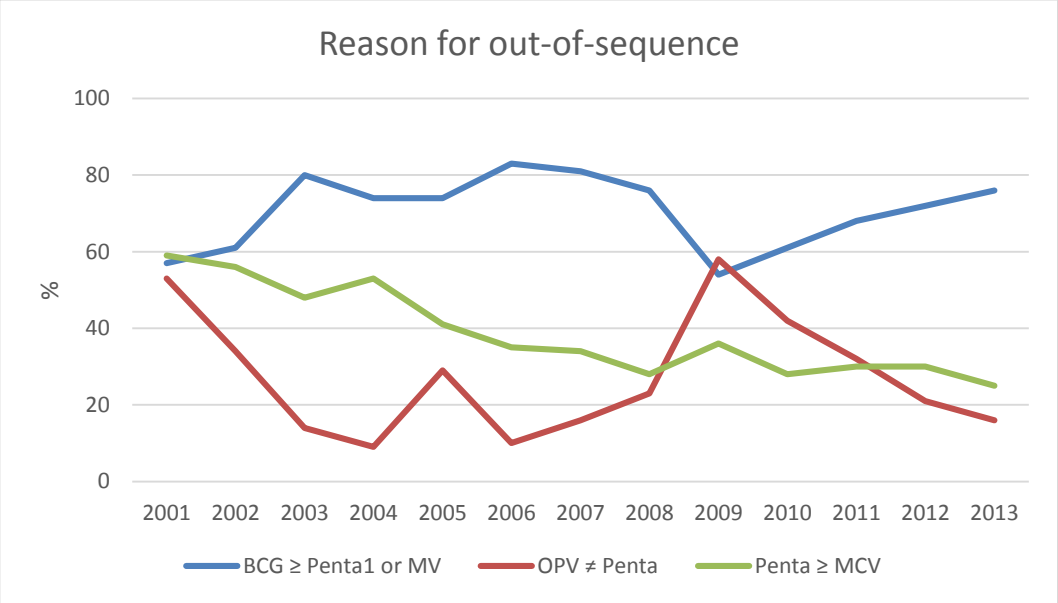
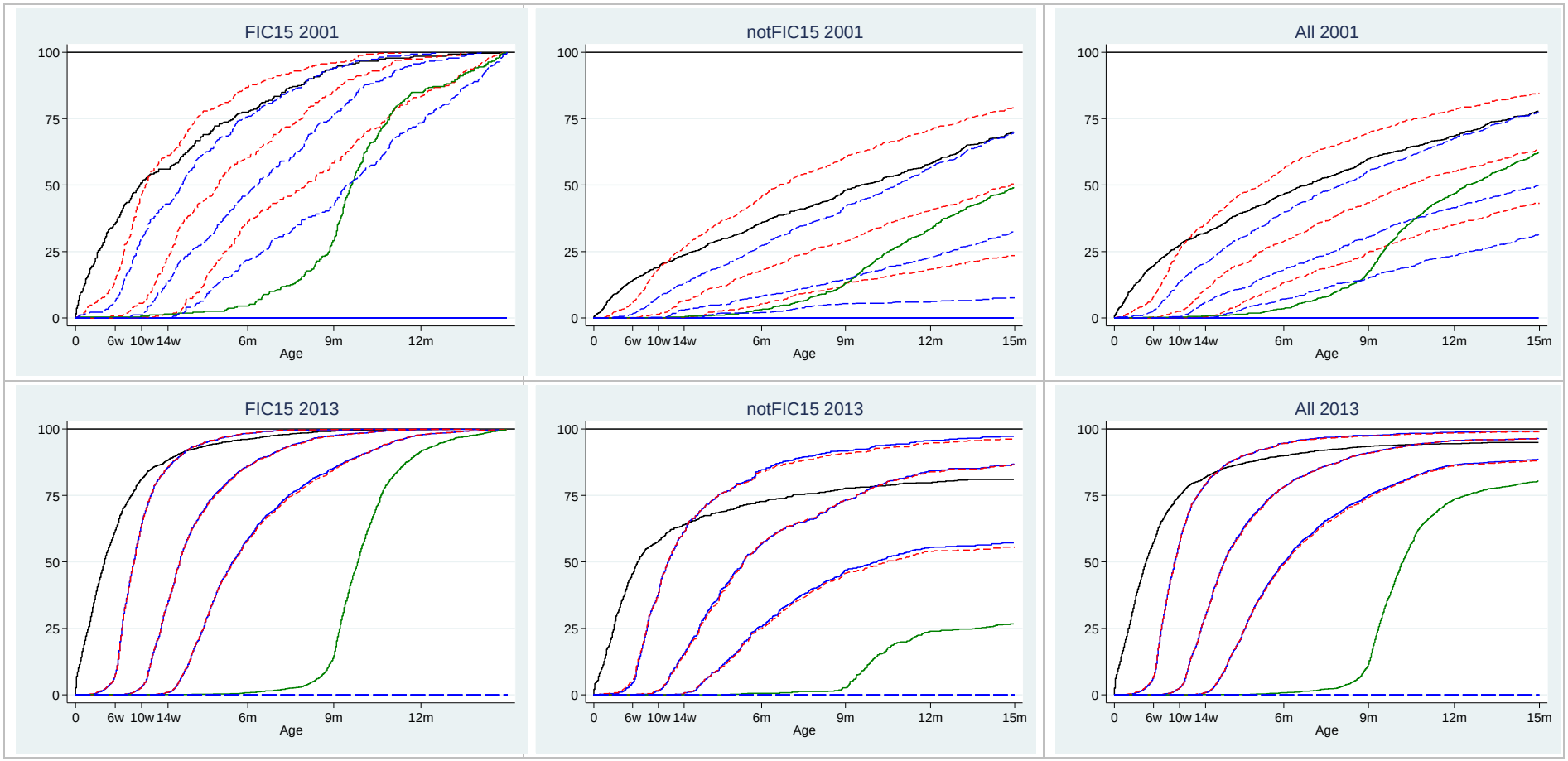


Figure 11 FIC15 Coverage curves for each vaccine among FIC, NOT FIC, and combined



N=18,077 children included, thus 61% (18,077/29,641) of the children in the overall FIC analyses (see. Figure 1)

Table 16 Fully Vaccination coverage at 24 months (FIC24) for NOT FIC at 12 months of age

Year of visit for FIC12 status	Percent (FIC24/N)
2001	37% (247/673)
2002	48% (265/551)
2003	50% (227/451)
2004	48% (185/383)
2005	38% (196/512)
2006	41% (393/952)
2007	52% (427/814)
2008	49% (380/772)
2009	33% (380/1150)
2010	47% (384/811)
2011	44% (377/848)
2012	41% (264/645)
2013	43% (45/105)
Total	44% (3770/8667)

Figure 12 Coverage of FIC24 among NOT FIC at 12 months

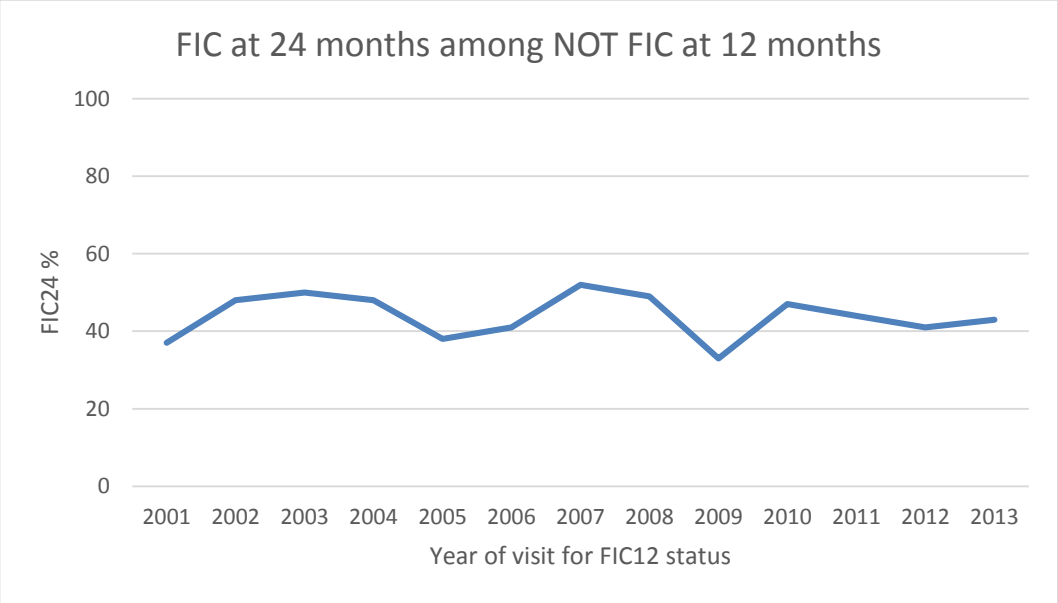


Table 17 Analyses of association between background factors and FIC

Factor	N (%)	FIC %	Unadjusted P-value* PR (95% CI)	Adjusted P-value* aPR (95% CI)	Adjusted P-value* aPR (95% CI)
Sex			0.20	0.89	0.27
Male	14800 (50)	51	Ref	Ref	Ref
Female	14840 (50)	51	0.99 (0.96-1.01)	1.00 (0.98-1.02)	0.99 (0.97-1.01)
Missing	1 (0)	100			
Year of visit			<0.001	<0.001	<0.001
2001-2005	7059 (24)	39	Ref	Ref	Ref
2006-2007	5582 (19)	49	1.27 (1.15-1.40)	1.41 (1.27-1.56)	1.34 (1.22-1.47)
2008-2011	10807 (36)	50	1.31 (1.21-1.42)	1.36 (1.24-1.48)	1.33 (1.23-1.45)
2012-2013	6193 (21)	67	1.75 (1.61-1.90)	1.74 (1.58-1.91)	1.72 (1.58-1.87)
Region			<0.001	<0.001	<0.001
Oio	4687 (16)	43	Ref	Ref	Ref
Biombo	4588 (15)	52	1.22 (1.06-1.40)	1.15 (1.03-1.29)	1.21 (1.06-1.38)
Gabu	4771 (16)	48	1.10 (0.97-1.25)	1.03 (0.91-1.17)	1.10 (0.97-1.25)
Cacheu	5571 (19)	62	1.44 (1.26-1.64)	1.25 (1.12-1.39)	1.32 (1.18-1.49)
Bafata	4033 (14)	55	1.27 (1.11-1.45)	1.12 (1.00-1.26)	1.24 (1.09-1.41)
Quinara	2492 (8)	49	1.14 (0.94-1.37)	1.01 (0.86-1.19)	1.02 (0.85-1.22)
Tombali	2210 (7)	33	0.77 (0.64-0.94)	0.76 (0.64-0.90)	0.70 (0.58-0.85)
Bubaque	698 (2)	61	1.41 (1.21-1.64)	1.04 (0.93-1.18)	1.17 (1.02-1.34)
Bolama	591 (2)	60	1.38 (1.19-1.60)	1.10 (0.96-1.25)	1.16 (1.01-1.33)
Ethnicity			<0.001	*Excluded due to collinearity with region*	*Excluded due to collinearity with region*
Balanta	6801 (23)	44	Ref		
Fula	6567 (22)	50	1.12 (0.99-1.26)		
Manjaco/Mancanha	2263 (8)	67	1.50 (1.32-1.71)		
Pepel	3896 (13)	53	1.20 (1.04-1.39)		
Mandinga	5327 (18)	49	1.11 (0.96-1.28)		
Beafada	1687 (6)	58	1.31 (1.14-1.50)		
Other	2904 (10)	53	1.20 (1.05-1.36)		
Missing	196 (1)	48			
Place of birth			<0.001	<0.001	*Excl. Due to many missing (only recorded for children registered <12months)*
Home	15095 (51)	50	Ref	Ref	
Health facility	5888 (20)	62	1.23 (1.17-1.29)	1.12 (1.08-1.16)	
Other	194 (1)	46	0.92 (0.79-1.08)	0.92 (0.79-1.05)	
Missing	8464 (29)	44			
Maternal Education			<0.001	<0.001	<0.001
None	20714 (70)	47	Ref	Ref	Ref
1-4 grade	5235 (18)	58	1.22 (1.17-1.27)	1.10 (1.06-1.14)	1.12 (1.08-1.17)
5+ grade	2729 (9)	66	1.40 (1.33-1.47)	1.13 (1.08-1.19)	1.19 (1.13-1.25)
Missing	963 (3)	53			
Maternal Age			0.01	0.96	0.98
<20	6493 (22)	53	Ref	Ref	Ref
20-24	8199 (28)	51	0.97 (0.94-1.00)	1.00 (0.97-1.03)	1.00 (0.97-1.03)
25-29	6792 (23)	50	0.95 (0.92-0.99)	0.99 (0.96-1.03)	1.00 (0.96-1.03)
30+	7854 (26)	50	0.94 (0.91-0.98)	1.00 (0.96-1.04)	1.00 (0.96-1.03)
Missing	303 (1)	44			

* Overall p-value

Missing group is not included in the regression.

Table 18 Analyses of association between background factors and FICIS among FIC

Factor	N (%)	FICIS %	Unadjusted P-value* PR (95% CI)	Adjusted P-value* aPR (95% CI)	Adjusted P-value* aPR (95% CI)
Sex			0.31	0.31	0.14
Male	7591 (50)	44	Ref	Ref	Ref
Female	7501 (50)	43	0.98 (0.94-1.02)	0.97 (0.92-1.03)	0.97 (0.94-1.01)
Missing	1 (0)	0			
Year of visit			<0.001	<0.001	<0.001
2001-2005	2722 (18)	32	Ref	Ref	Ref
2006-2007	2737 (18)	41	1.28 (1.11-1.47)	1.32 (1.13-1.54)	1.19 (1.05-1.35)
2008-2011	5456 (36)	41	1.29 (1.13-1.47)	1.27 (1.12-1.46)	1.20 (1.08-1.35)
2012-2013	4178 (28)	57	1.79 (1.57-2.03)	1.86 (1.63-2.10)	1.63 (1.45-1.83)
Region			<0.001	<0.001	<0.001
Oio	2020 (13)	33	Ref	Ref	Ref
Biombo	2403 (16)	50	1.53 (1.31-1.79)	1.57 (1.34-1.82)	1.57 (1.35-1.83)
Gabu	2267 (15)	30	0.91 (0.75-1.11)	1.01 (0.84-1.22)	0.98 (0.81-1.19)
Cacheu	3461 (23)	58	1.78 (1.52-2.08)	1.75 (1.49-2.05)	1.69 (1.45-1.97)
Bafata	2208 (15)	37	1.14 (0.93-1.41)	1.22 (0.99-1.51)	1.23 (0.99-1.52)
Quinara	1220 (8)	40	1.21 (1.02-1.45)	1.16 (0.97-1.39)	1.19 (1.00-1.41)
Tombali	738 (5)	32	0.97 (0.79-1.19)	0.96 (0.76-1.20)	0.96 (0.78-1.17)
Bubaque	424 (3)	63	1.93 (1.59-2.33)	1.90 (1.60-2.25)	1.80 (1.52-2.14)
Bolama	352 (2)	65	1.98 (1.67-2.36)	1.88 (1.54-2.32)	1.78 (1.51-2.10)
Ethnicity			<0.001	*Excluded due to collinearity with region*	*Excluded due to collinearity with region*
Balanta	3017 (20)	48	Ref		
Fula	3252 (22)	33	0.70 (0.59-0.83)		
Manjaco/Mancanha	1509 (10)	58	1.22 (1.04-1.44)		
Pepel	2081 (14)	49	1.04 (0.87-1.24)		
Mandinga	2617 (17)	36	0.75 (0.61-0.92)		
Beafada	980 (6)	43	0.91 (0.76-1.09)		
Other	1543 (10)	49	1.02 (0.88-1.20)		
Missing	94 (1)	47			
Place of birth			<0.001	<0.001	*Excl. Due to many missing (only recorded for children registered <12months)*
Home	7595 (50)	39	Ref	Ref	
Health facility	3642 (24)	55	1.42 (1.32-1.53)	1.28 (1.20-1.38)	
Other	90 (1)	56	1.44 (1.15-1.80)	1.32 (1.03-1.70)	
Missing	3766 (25)	42			
Maternal Education			<0.001	<0.001	<0.001
None	9774 (65)	39	Ref	Ref	Ref
1-4 grade	3011 (20)	49	1.27 (1.20-1.35)	1.09 (1.03-1.17)	1.11 (1.05-1.17)
5+ grade	1802 (12)	61	1.57 (1.45-1.71)	1.25 (1.15-1.36)	1.21 (1.12-1.31)
Missing	506 (3)	44			
Maternal Age			0.37	0.96	0.77
<20	3428 (23)	44	Ref	Ref	Ref
20-24	4206 (28)	44	1.00 (0.95-1.04)	0.99 (0.93-1.06)	1.02 (0.97-1.06)
25-29	3423 (23)	43	0.98 (0.93-1.03)	0.99 (0.93-1.06)	1.01 (0.97-1.06)
30+	3902 (26)	42	0.96 (0.90-1.01)	0.98 (0.91-1.05)	1.00 (0.94-1.05)
Missing	134 (1)	46			

* Overall p-value

Missing group is not included in the regression.

Table 19 Survival analysis of FIC vs NOT FIC, Children followed to 3 years of age

Factor	Mortality Rate/ 1000 pyrs &	Deaths/pyrs &	Number of children ¤	Crude P-value* Hazard ratio (95%-CI)	Adjusted P-value* Hazard ratio (95%-CI)
FIC				<0.001	0.002
No	28	592 / 21231	14547	Ref	Ref
Yes	21	452 / 21717	15091	0.74 (0.65-0.84)	0.81 (0.71-0.93)
Sex				0.68	0.50
Male	24	521 / 21635	14799	Ref	Ref
Female	25	523 / 21312	14838	1.03 (0.91-1.16)	1.04 (0.92-1.18)
Year of visit				<0.001	<0.001
2001-2005	40	424 / 10509	7059	Ref	Ref
2006-2007	21	178 / 8338	5582	0.65 (0.54-0.79)	0.68 (0.56-0.82)
2008-2011	20	327 / 16643	10807	0.55 (0.48-0.64)	0.58 (0.49-0.68)
2012-2013	15	115 / 7459	6190	0.44 (0.35-0.54)	0.49 (0.39-0.61)
Region				<0.001	Adjusted for using stratification for village cluster
Oio	19	126 / 6782	4687	Ref	
Biombo	34	223 / 6654	4588	1.83 (1.37-2.43)	
Gabu	37	261 / 6961	4771	2.03 (1.56-2.63)	
Cacheu	16	126 / 8007	5570	0.85 (0.65-1.11)	
Bafata	34	197 / 5867	4033	1.83 (1.37-2.44)	
Quinara	14	50 / 3620	2492	0.75 (0.54-1.04)	
Tombali	12	38 / 3231	2210	0.64 (0.40-1.02)	
Bubaque	18	18 / 991	696	1.07 (0.59-1.94)	
Bolama	6	5 / 836	591	0.32 (0.14-0.77)	
Ethnicity				0.56	0.31
Balanta	17	164 / 9608	6800	Ref	Ref
Fula	31	299 / 9553	6567	0.93 (0.56-1.54)	0.92 (0.55-1.55)
Manjaco/Mancanha	15	51 / 3326	2263	1.06 (0.63-1.80)	1.24 (0.73-2.11)
Pepel	34	193 / 5704	3895	0.91 (0.43-1.94)	0.94 (0.44-2.02)
Mandinga	29	229 / 7824	5327	1.21 (0.74-1.97)	1.25 (0.75-2.07)
Beafada	12	30 / 2508	1687	1.15 (0.56-2.36)	1.26 (0.60-2.64)
Other	17	70 / 4164	2903	1.36 (0.85-2.18)	1.46 (0.89-2.37)
Place of birth				0.94	Excl. from multivariate analysis due to missing information for 29% (registered only for infants)
Health facility	21	178 / 8493	5887	Ref	
Home	24	536 / 21993	15095	1.02 (0.85-1.23)	
Other	21	6 / 290	194	0.92 (0.40-2.08)	
Maternal Education				0.12	0.60
None	27	807 / 30346	20727	Ref	Ref
1-4 grade	20	152 / 7474	5235	0.90 (0.75-1.07)	0.97 (0.80-1.17)
5+ grade	13	50 / 3814	2727	0.75 (0.55-1.01)	0.85 (0.62-1.16)
Maternal Age				0.47	0.62
<20	27	247 / 9249	6491	Ref	Ref
20-24	23	276 / 11851	8200	0.89 (0.75-1.06)	0.90 (0.75-1.07)
25-29	23	231 / 9880	6791	0.90 (0.75-1.08)	0.92 (0.77-1.11)
30+	24	279 / 11564	7854	0.88 (0.74-1.05)	0.90 (0.75-1.07)

Note: Cox model is stratified by cluster (village)

& pyrs = person years of observation; ¤ Number of children contributing to rate calculation

* Overall p-value;

Table 20 Interactions

	Adjusted HR (95%-CI)	Test of no Interaction p-value
Males	0.83 (0.69-1.00)	0.66
Females	0.79 (0.66-0.95)	
2001-2005	0.78 (0.63-0.97)	0.21
2006-2007	1.07 (0.78-1.45)	
2008-2011	0.71 (0.57-0.90)	
2012-2013	0.87 (0.59-1.29)	

Table 21 Survival analysis – splitting FIC into FICIS and FICOS

Factor	Mortality Rate/1000 pyrs	Deaths/pyrs	Number of children	Crude Hazard ratio (95%-CI)	Adjusted Hazard ratio (95%-CI)
FIC				p<0.001	p=0.006
NOTFIC	28	592 / 21231	14547	Ref	Ref
FICIS	18	162 / 9175	6581	0.67 (0.56-0.81)	0.77 (0.63-0.93)
FICOS	23	290 / 12542	8510	0.77 (0.67-0.89)	0.83 (0.72-0.96)

	Adjusted HR (95%-CI)	Test of no interaction p-value
Male		0.40
FICIS	0.85 (0.66-1.10)	
FICOS	0.82 (0.66-1.01)	
Female		
FICIS	0.68 (0.52-0.90)	
FICOS	0.85 (0.69-1.04)	
2001-2005		0.05
FICIS	0.50 (0.33-0.75)	
FICOS	0.89 (0.71-1.12)	
2006-2007		
FICIS	1.05 (0.70-1.58)	
FICOS	1.08 (0.76-1.52)	
2008-2011		
FICIS	0.81 (0.60-1.10)	
FICOS	0.65 (0.50-0.85)	
2012-2013		
FICIS	0.84 (0.53-1.32)	
FICOS	0.89 (0.57-1.41)	

Table 22 Survival analysis – NOT FIC split into "FIC without MCV" and otherwise

Factor	Mortality Rate/1000 pyrs	Deaths/pyrs	Number of children	Crude Hazard ratio (95%-CI)	Adjusted Hazard ratio (95%-CI)
FIC				p<0.001	p=0.001
Not FIC	30	462 / 15391	10561	Ref	Ref
FIC without MCV	22	130 / 5840	3986	0.71 (0.58-0.87)	0.81 (0.66-1.00)
FIC	21	452 / 21717	15091	0.67 (0.59-0.77)	0.76 (0.66-0.88)

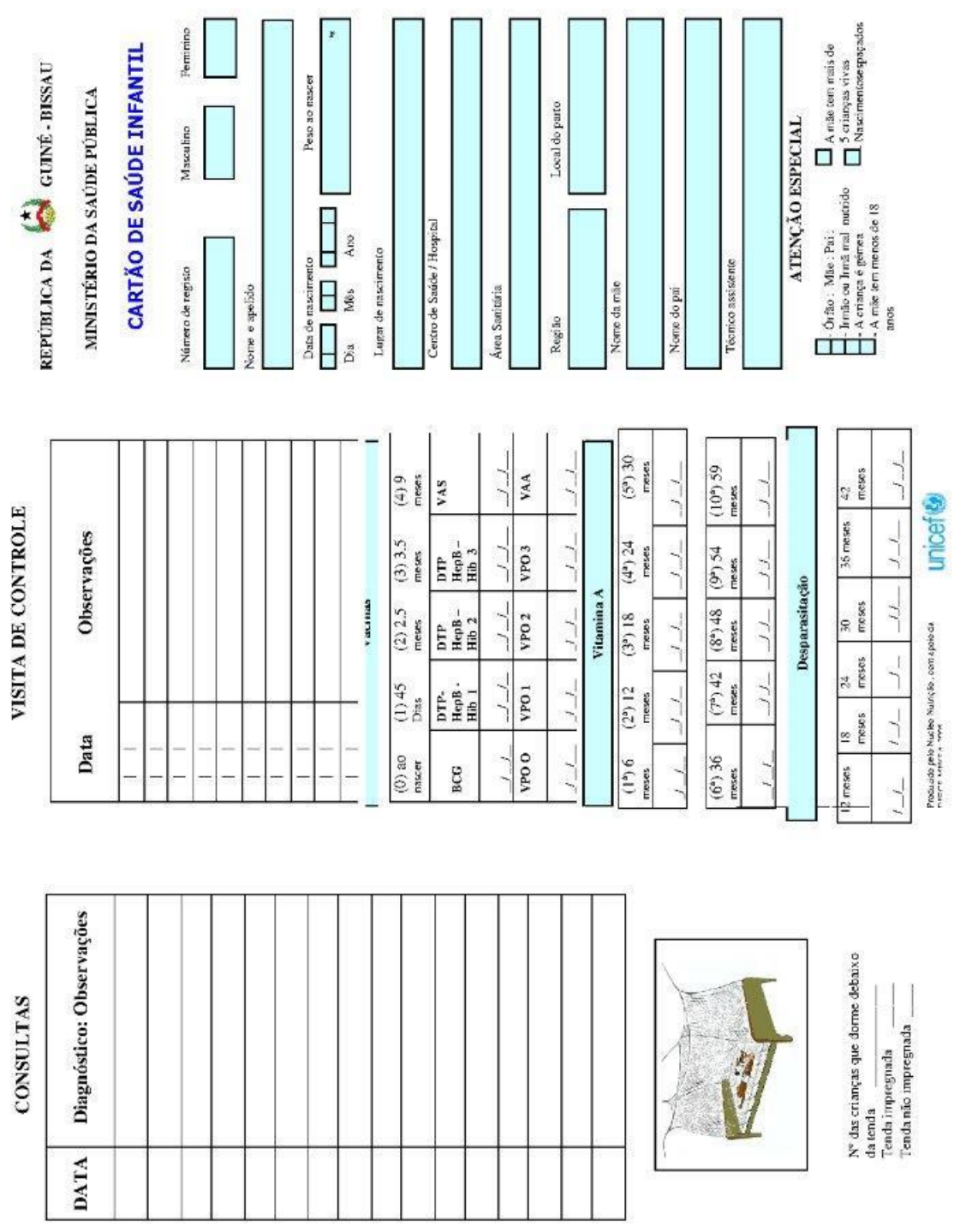
	Adjusted HR (95%-CI)	Test of no interaction p-value
Male		0.33
FIC without MCV	0.67 (0.49-0.91)	
FIC	0.76 (0.62-0.92)	
Female		
FIC without MCV	1.00 (0.76-1.30)	
FIC	0.78 (0.64-0.95)	
2001-2005		0.21
FIC without MCV	0.92 (0.65-1.29)	
FIC	0.77 (0.62-0.96)	
2006-2007		
FIC without MCV	1.09 (0.67-1.78)	
FIC	1.09 (0.77-1.55)	
2008-2011		
FIC without MCV	0.70 (0.49-0.99)	
FIC	0.64 (0.50-0.82)	
2012-2013		
FIC without MCV	0.72 (0.39-1.34)	
FIC	0.74 (0.46-1.20)	

Table 23 Survival and alternative FIC calculations: FIC at visit and FIC15

	FIC at visit * Number of deaths =1044		FIC15 # Number of deaths = 574	
Factor	**Crude Hazard ratio (95%-CI)**	**Adjusted Hazard ratio (95%-CI)**	**Crude Hazard ratio (95%-CI)**	**Adjusted Hazard ratio (95%-CI)**
FIC	p<0.001	P<0.001	P=0.001	p=0.038
No	Ref	Ref	Ref	Ref
Yes	0.70 (0.62-0.80)	0.78 (0.69-0.89)	0.74 (0.62-0.88)	0.83 (0.69-0.99)

* FIC at visits means that vaccines given between 12 months of age and first visit (after 12 months of age) are included in the calculation of FIC status
# FIC15 is FIC at 15 months of age, i.e. only visits after 15 months of age is used and all vaccines until 15 months of age are used in the calculation of FIC15 status

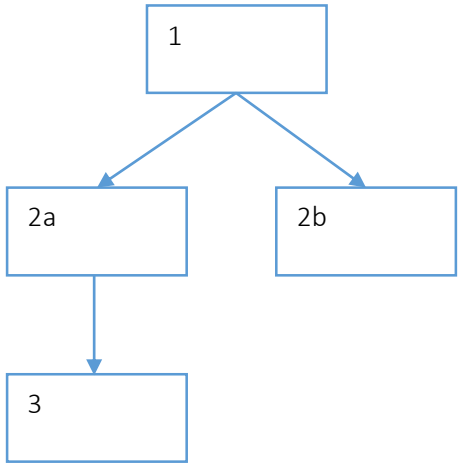
Figure 13 Vaccination card used



Appendix 7 Data check tool

Detailed data check tool (called Check-20) developed during inception workshop in Accra, Ghana (3-8 March 2014).

Flow chart



Box 1
Number of children alive at an HDSS home visit between 12 and 23 months of age
[Number of visits asking for vaccine card]

Box 2a
Number of children from box 1 having at least one visit with card seen
[Number of visits for these children including those where card not seen]

Box 2b
Number of children from box 1 having no seen card at any visit between 12 and 23 months of age
[Number of visits]

Box 3
Number of children included in analyses

First step:

Check and clean DOB (date of birth) and visit dates for all children in the vaccine database to get Box 1 (using check 1-6). See flow chart for definition of boxes.

Second step:

Clean vaccination card status to define who goes into Box 2a and Box 2b (using check 7)

Third step:

Clean all the other vaccination dates for children in Box 2a (using check 8-15)

Fourth step:

Clean background factors (16-17) and follow-up information (using check 18-20) for children in Box 3.

The Check 20 list

1) Date of birth (DOB): All must have a DOB. Check for missing

2) Date of visit/interview (DOV): Check for missing and be sure that DOB <= DOV

DOB and Date of visit correct – essential information
Imprecise date of birth – coded as the 15th in many datasets? How frequent is this – all to make a histogram of DOB. Would be nice to have information on the precision of DOB – available in Nairobi and Bandim (recent years)

3) DOB <= BCG

BCG vaccines registered prior to the DOB will be investigated (questionnaire). Where other sources of DOB are available, the information will be compared. The day of the week may provide inputs as to where to look for the errors if the vaccines are not normally given during weekends.

4) DOB <= OPV0 (OPV at birth)

Same rationale as above

5) Check number of days between visits. Should not be too small

Check if the interval less than planned interval minus 1 month.

6) All date variables (DOB, vaccinations, date of death, etc) must be before date of the database

Check that all dates are before the data was extracted from the HDSS database. Use Stata command "codebook" which returns a range.

No dates in the future are allowed. Similarly, data from a particular round should lie within the round dates or date of data entry has to be larger than vaccine dates / visit dates /*etc*.

7) Health/vaccination card. This is VERY important.

a. All visits must have corresponding card information

b. Be sure your coding is correct.

c. Check if vaccinations have been collected at a visit where card was NOT seen. Is this possible?

8) All other dates of vaccination must be greater that DOB

Rationale as above – return to questionnaire – logical errors such as penta1->polio2->polio3 in sequence but if the polio1->polio2 (one year before)->polio3.

9) Vaccines given as dose must be ordered:

a. DTP1 < DTP2 < DTP3

b. PENTA1 < PENTA2 < PENTA3

c. OPV1 < OPV2 < OPV3

d. PCV1 < PCV2 < PCV3

e. MV1 < MV2

etc.

10) Vaccines given as doses must not be missing intermediate dose

E.g. missing PENTA2 while having PENTA1 and PENTA3 [you may by looking at OPV doses get help on possible dates of missing intermediate PENTA doses]

a. PENTA1 given, PENTA2 missing, PENTA3 given

b. PENTA1 missing, PENTA2 given

11) Important that no intermediate doses are missing

No child can have Penta1 + Penta3 – without having penta2. If this is how the nurses record it, we need to recode in the analysis.

12) Check distance between doses and investigate very short distances

Distance between doses must be reasonable. For example not have PENTA2 given the day after PENTA1. Check whether feasible to examine all intervals less than 24 days on the forms. Keep all in the dataset, regardless of the interval – report how many have received the doses with too short intervals.

13) Age at vaccination

Check if age for vaccine is not far from the scheduled age. E.g. Penta1 given the day after birth is most likely wrong. MCV given at 2 months of age is most likely wrong.
Some sites e.g. Nairobi, MCV1 is given early for children of HIV-positive mothers? These are few.
MCV: Check at least children who have received MCV before 6 months of age.
Penta1: Check all children who have received penta1 before 1 month of age.

14) Be aware of special values (dates) for missing vaccination dates

For example it seems like Navrongo uses 05-05-1905 and Nairobi 01-01-1901 for some missing dates.

15) Check vaccination dates across visits for each child

If BCG for example is recorded more than once for a child (at each visit) check that it is the same date. See Stata note how this can be done.

16) Sex is important – check for missing.

17) Check missingness of other “core group of determinants” as defined in protocol

18) Date of death (DOD) and date of exit (DOE), i.e. last seen alive or out-migration

Must be clearly defined and checked against ALL other dates. You cannot have vaccinations given after DOD or DOE.

a. DOB <= DOD/E

b. Check if status for death corresponds to a date of death. If the status is "dead" a date of death must exist.

c. Vaccination dates <= DOD/E

d. Hospitalisation dates <= DOD/E

19) Check a 5% sample of all the deaths for vaccine information on the original forms

20) All children who according to databases are *completely unvaccinated* should be checked