USAID Integrated Health Program Evaluation Report

Year 3 Impact Evaluation Results

April 2023

USAID FROM THE AMERICAN PEOPLE

DATA FOR impact

USAID Integrated Health Program Evaluation Report

Year 3 Impact Evaluation Results

Matt Worges, PhD
David Hotchkiss, PhD
Janna Wisniewski, PhD
Paul-Samson Lusamba-Dikassa, MD, PhD
Lauren Blum, PhD
Eva Silvestre, PhD

Data for Impact
University of North Carolina at Chapel Hill
123 West Franklin Street, Suite 330
Chapel Hill, NC 27516 USA
Phone: 919-445-9350 | Fax: 919-445-9353
D4I@unc.edu
http://www.data4impactproject.org

This publication was produced with the support of the United States Agency for International Development (USAID) under the terms of the Data for Impact (D4I) associate award 7200AA18LA00008, which is implemented by the Carolina Population Center at the University of North Carolina at Chapel Hill, in partnership with Palladium International, LLC; ICF Macro, Inc.; John Snow, Inc.; and Tulane University. The views expressed in this publication do not necessarily reflect the views of USAID or the United States government. TR-23-36 D4I

D4I is committed to local partner engagement and individual and institutional strengthening. Local authorship is important, and we urge you to engage local partners in analysis and reporting.

Abstract

This report presents results from an impact evaluation conducted by Data for Impact (D4I) following three years of implementation of the United States Agency for International Development (USAID) Integrated Health Program (IHP) in nine provinces of the Democratic Republic of the Congo (DRC). The IHP focuses, in part, on increasing the use of health facility-based maternal and child healthcare and family planning services. The impact evaluation investigated the extent to which changes in healthy behaviors and health outcomes were attributable to the USAID IHP.

The primary analysis for the evaluation used a quasi-experimental design based on a propensity score matched difference-in-differences (DID) model fit to data collected through the DRC's routine health information system (RHIS). The matching process was successful in balancing the distribution of all selected RHIS indicators across comparison and intervention sites. Restricting the propensity scores to a region of common support led to the exclusion of only 2.0 percent (96 of 4,794) of intervention facilities and 1.3 percent (91 of 7,188) of comparison facilities. The common trends assumption suggested no significant differences between the comparison and intervention groups in the preintervention time series trends for all but three of the RHIS indicators (i.e., new acceptors of modern contraceptive methods, bed net distribution during first antenatal care clinic visits, and measles vaccinations). Not satisfying the common trends assumption served to reduce the stringency of the analysis and undermined the ability to appropriately interpret the results for implicated indicators.

Given the time series nature of the available RHIS data, we conducted a secondary analysis that used a controlled interrupted time series approach. This analysis was conducted on selected indicators only for which suitable RHIS data elements were available to serve as comparator values (i.e., denominators). Another secondary analysis was done that compared intervention health zone (HZ) facilities that had received intensified support from the IHP with other intervention HZs that had not received this intensified support (the latter group served as comparison facilities).

Based on adjusted p-values from the primary analysis, minimal and nonsignificant changes were observed in the DID estimates for all twelve indicators. The only indicator to demonstrate significance (in an intended direction) for the unadjusted and corrected p-values was complicated diarrhea/dehydration cases per 1,000 children under five years. Even so, this significant change amounted to less than 1 additional and appropriately treated complicated diarrhea/dehydration case per 1,000 children among intervention sites relative to comparison sites. Although slight, there were two indicators whose DID estimators suggested movement in an unanticipated direction when comparing intervention sites with comparison sites (i.e., more instances of moderate acute malnutrition and fewer instances of complicated malaria treatment), neither of which were significant based on adjusted p-values. No results from the analysis that compared IHP HZs receiving intensified support with IHP HZs receiving the standard intervention package were found to be significant. The controlled interrupted time series analysis showed that treatment of *uncomplicated* malaria, diarrhea, and pneumonia increased over the longer-term trend among intervention sites relative to comparison sites. However, again, the incidence rate ratios for these three analyses were small (~1.04). Overall, the results highlighted areas that may warrant additional program focus, such as treatment of severe childhood illnesses and prevention/treatment of moderate acute malnutrition in children.

Because this impact analysis is expected to occur on an annual basis, year-over-year results need to be interpreted in the proper context. In the interim, the USAID IHP should draw its attention to those indicators that showed little to no movement in the anticipated direction (severe childhood illnesses and prevention and treatment of moderate acute malnutrition in children) and consider whether any course adjustments are warranted.

Acknowledgments

The authors wish to thank the USAID Mission in the DRC and the Congolese Ministry of Health for supporting this work.

We acknowledge our colleagues at Tulane University (Dr. Josh Yukich and Dr. Charles Stoecker) and the University of North Carolina at Chapel Hill (Dr. Gustavo Angeles, Dr. Kristen Brugh, and Dr. Sean Sylvia) who provided technical guidance for the impact evaluation analysis.

We also thank the D4I Knowledge Management team for editorial, design, and production services.

Suggested citation

Data for Impact. (2023). USAID Integrated Health Program Evaluation Report: Year 3 Impact Evaluation Results. Chapel Hill, NC, USA: Data for Impact, University of North Carolina.

Contents

Figures

Tables

Abbreviations

ANC	antenatal care
ASMD	absolute standardized mean difference
ASSP	Access to Primary Health Care [program]
CI	confidence interval
cITS	controlled interrupted time series
D4I	Data for Impact
DID	difference-in-differences
DRC	Democratic Republic of the Congo
EVD	Ebola virus disease
HZ	health zone
IHP	Integrated Health Program
IRR	incidence rate ratio
ITN	insecticide-treated bed net
NDVI	normalized difference vegetation index
PSM	propensity score matching
RHIS	routine health information system
SP	sulfadoxine/pyrimethamine
Tx	treatment
USAID	United States Agency for International Development
WCB	wild cluster bootstrap
WRA	women of reproductive age

Program Background

As part of its strategy to improve health outcomes in the Democratic Republic of the Congo (DRC), the United States Agency for International Development (USAID) funded the Integrated Health Program (IHP) in 2018. The program began operations in July 2018 and is being implemented by Abt Associates and several partner organizations. The purpose of USAID IHP is to strengthen the capacity of Congolese institutions and communities to deliver quality, integrated health services to sustainably improve the health status of the Congolese population. The project focuses on the following specific health, population, and nutrition areas: maternal health; neonatal, infant, and child health; tuberculosis; malaria; child nutrition; water, sanitation, and hygiene; and family planning.

USAID IHP seeks to reach its goal through the achievement of the following overall performance objectives:

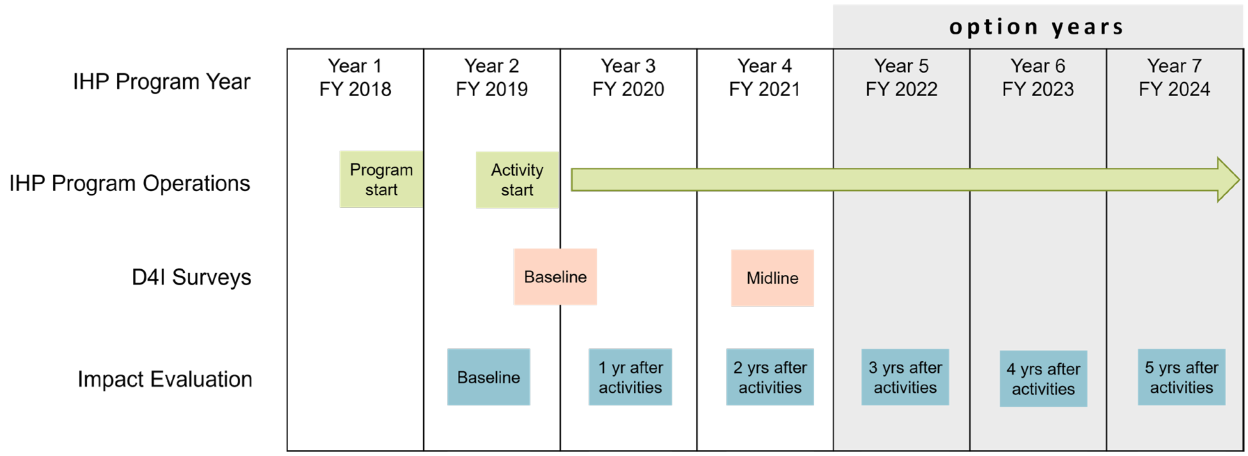
- **Objective 1:** Strengthen health systems, governance, and leadership at the provincial, health zone (HZ), and facility levels in target HZs.
- **Objective 2**: Increase access to quality, integrated health services in target HZs.
- **Objective 3:** Increase the adoption of healthy behaviors, including use of health services, in target HZs.

USAID IHP works in nine contextually diverse provinces in the regions of Eastern Congo, Katanga, and Kasai, and implements a wide array of interventions.

Given the breadth and depth of IHP's interventions, the USAID Mission in DRC requested that Data for Impact (D4I) conduct an independent third-party evaluation of the performance and impact of USAID IHP on key health systems-related outcomes: the uptake of family planning and healthcare services; health systems functioning (i.e., improved disease surveillance, the availability of essential commodities, and health worker motivation); and the practice of key healthy behaviors.

Figure 1 shows program rollout timing and D4I evaluation time points. The nearly one-year gap between program start and activity implementation allowed the IHP to staff up across the nine provinces and begin program implementation after administrative delays with the donor and Ministry of Health had been resolved.

Figure 1. Timeline of IHP rollout and D4I survey and evaluation time points



Intensification of activities

In addition to essential activities across all program-supported provinces and HZs, USAID IHP provides more comprehensive support to a limited subset of 60 HZs across the nine provinces. These 60 HZs have a high potential to improve the health status of their populations due to their location in economic corridors, high mortality rates, and/or baseline levels of maternal, newborn, and child health service offerings already available. The strategic selection of the 60 HZs also considered the presence of other technical and financial partner support so that USAID—through USAID IHP—can best leverage resources to improve health outcomes. This activity stratification in the IHP target provinces was used as the basis for a secondary analysis, as described in the methods section.

Methods and Limitations

Methods

D4I is carrying out two types of evaluation components for this study: (1) a performance evaluation and (2) an impact evaluation. Performance evaluations incorporate before and after comparisons, but generally lack a rigorously defined counterfactual to control for factors other than the project or intervention that might account for the observed change. Impact evaluations assess the extent to which changes in health outcomes or service use over time are attributable to an intervention. The specific research questions that are addressed in the evaluation are the following:

1. Did the expected changes in outcomes and impact occur?
    a. Strengthened health systems, governance, and leadership at provincial, HZ, and facility levels in target HZs.
    b. Increased access to quality, integrated health services in target HZs.
    c. Increased adoption of healthy behaviors, including health service use, in target HZs.
2. If there were changes in healthy behaviors over the course of the study period, to what extent were they attributable to USAID IHP?
3. Did the project contribute to gender equity in health services and in the health system?

4. What factors enabled or limited the success of USAID IHP?

The performance evaluation aspect of the study addresses Research Questions 1, 3, and 4. Data for this component of the study are collected from multiple sources, including the DRC's routine health information system (RHIS); household surveys; surveys of healthcare facilities, HZ offices, and provincial health offices; and key informant and in-depth interviews, observations of patient-health worker interactions, and focus group discussions. The impact evaluation aspect of the study—the focus of this report—addresses Research Question 2. The impact evaluation used a quasi-experimental design based on a propensity score matched difference-in-differences (DID) model fit to the RHIS data. Ethical approval for this work was given by the institutional review boards of Tulane University and the Kinshasa School of Public Health.

Analysis of Impact Using a DID Model Two Years After IHP Program Implementation

The propensity score matching difference-in-differences (PSM-DID) method is a quasi-experimental approach that attempts to mimic an experimental research design. The PSM-DID method can facilitate causal inference even when randomization is not possible. The approach compares changes in outcomes between populations located in areas undergoing an intervention (the intervention group) and similar populations located in areas without the intervention (the comparison group) using time points before and after the start of the intervention. Simply put, the DID analysis first calculates the before-after difference of an outcome in the intervention group and then calculates the before-after difference of the same outcome for the same period in the comparison group. Next, the difference noted in the comparison group is subtracted from the difference noted in the intervention group (i.e., difference-in-differences), which provides an impact estimation of the IHP intervention.

A doubly robust model that combines PSM with a DID model was used to estimate the impact[1] of the USAID IHP on the provision of maternal and child healthcare and family planning services (as identified in Research Question 2). The data used for this analysis came from the in-country RHIS that collects health facility data monthly. The unit of analysis was the facility, and because the program was implemented at the province level, a random effect was included to account for this in regression modeling. In addition, due to the low number of provinces included in the analysis (24 total; 9 intervention and 15 comparison) and high variation in the number of health facilities per province (a low of 204 and a high of 1,298), wild cluster bootstrapping (WCB) was used. Given the multiple outcomes we tested, all of which are hypothesized to be an effect of IHP activity implementation, we adjusted the DID regression p-values for the number of hypothesis tests performed using the Bonferroni correction procedure.

The intervention arm included facilities from HZs in USAID IHP provinces (including both hospitals and health centers) in the preintervention (June 2018–May 2019) and postintervention (June 2019–

[1] In health evaluation research literature, the term "impact" typically refers to the effects on health outcomes, such as lives saved or disability-adjusted life years averted. In health systems strengthening evaluation literature, "impact" is also often used to refer to the effects on service delivery or other aspects of health systems functioning (Adam, et al., 2012). For the purposes of this evaluation, we use "impact" in the latter sense, unless otherwise noted.

September 2022) periods. All facilities in IHP-targeted provinces were exposed to IHP activities. The comparison arm included facilities in comparable and non-excluded HZs in provinces not receiving USAID IHP support. Excluded HZs were those that were part of a previous and intensive health systems strengthening project (the Access to Primary Health Care program, known by the French acronym *ASSP*), which was active in Kasaï, Nord Ubangi, and Sud Ubangi provinces. Moreover, HZs that experienced Ebola virus disease (EVD) outbreaks (N=33) were removed from consideration because certain policies were enacted in these affected HZs that were designed to increase health service use. Only one of the 33 HZs affected by EVD was in an IHP target province. Nearly 85 percent of the EVD-affected HZs were in Ituri and North Kivu provinces. We conducted an analysis of a free care policy on service volumes in North Kivu province, which showed that the enacted policy dramatically increased total clinic visits for an extended period, driven in large part by malaria and pneumonia cases, which encompassed two of our outcomes of interest. A previous analysis showed similar findings following the enactment of a free care policy across EVD-affected HZs in Equateur province.

Additional data cleaning included removal of anomalous data points from each individual health facility time series if these values exceeded ±4.5 standard deviations from the median facility value. Missing data in health facility time series were managed using a flexible interpolation process that took seasonality into account where it was detected; otherwise, simple linear interpolation was conducted to fill in gaps. Specifically, the “na.interp” function from the forecast package (Hyndman & Khandakar, 2008; Hyndman, et al., 2023) of R (R Core Team, 2018) was used to interpolate the health facility time series. Note that each successive analysis took advantage of a longer time series than predecessor analyses. This scenario could help establish a more robust seasonal component to individual health facility time series trends, which was exploited during the interpolation process. Health facility time series with seven or more missing values in a row were dropped from analysis. See **Table 1** for a summary of the data cleaning process, which details the extent of missing data and anomalous data points.

Following the data cleaning process, rates per 1,000 population were calculated for each data element of interest. We obtained overall population statistics for health areas and HZs directly from the RHIS. Because they were overall population counts, we calculated the size of sub-populations (women of reproductive age [15–49 years], children 6–59 months, and children <6 months) from population pyramids estimated by the Population Division of the Department of Economic and Social Affairs in the United Nations. Hospital-based rates were calculated using their respective HZ as the catchment population. All other health facility-based rates were calculated using their respective health area as the catchment population.

Baseline measures included in the DID analyses reflected three-month averages for March 2019 through May 2019, which were compared with averages spanning the same three months in 2022. These three months were specifically chosen because they immediately preceded the onset of IHP activity implementation (June 2019). Due to the variable nature of data availability in the RHIS and taking into consideration the interpolation procedure used to establish fuller health facility-level time series, a three-month average was taken.

Comparison facilities were identified through PSM, coupled with the use of a gradient boosted model. Propensity score methods were used to adjust for observed confounders to produce more valid causal effect estimates. This covariate balancing was the degree to which the distribution of covariates was similar across intervention assignment. Covariate balancing requires proper model specification to avoid biased estimates. Researchers can swap covariates in and out of their logistic models or manually add polynomial and/or interaction terms to these models to balance covariates, but this process can be tedious and inefficient. Use of gradient boosted models involves a machine learning process that captures the flexible and nonlinear relationships between intervention assignment and the preintervention covariates in an automated fashion, do not need to exclude collinear or insignificant covariates, and can automatically assign polynomial and interaction terms without overfitting the data. McCaffrey, et al. (2004) provide supplemental materials with annotated R code for estimating propensity scores with boosted regression that we used to build our gradient boosted model. The receiver operating characteristic curve for gradient boosted model used to estimate propensity scores is shown in Appendix 1, Figure 3.

The objective of the PSM process was to match a pool of health facilities from the comparison provinces with those in the intervention provinces such that the distributions of selected RHIS indicators were similar between the two groups. This process helped ensure similar baseline characteristics between these two pools of facilities. The 13 selected RHIS indicators used in the PSM process were:

1) Total clinic visits
2) New cases
3) Confirmed uncomplicated malaria
4) Suspected malaria
5) Uncomplicated diarrhea
6) Uncomplicated pneumonia
7) New pregnancies
8) Sulfadoxine/pyrimethamine (SP) dose 1
9) Antenatal care (ANC) clinic visits 1, 2, and 3
10) Births
11) Live births

An underlying assumption of the DID analysis is the common trends assumption. This was initially explored for each outcome indicator of interest by plotting the overall average case incidence per 1,000 target population for the preintervention time series for both the comparison and intervention areas. Satisfying this assumption inferred that the comparison units provided the appropriate counterfactual trend that the treated units would have followed if they had not been exposed to the intervention (i.e., in the absence of the IHP package of interventions, the two groups of health facilities would have had similar trends). In addition, a formal statistical test was used to assess equality of trends using a 12-month preintervention period.

Before the DID analyses were run, it was necessary to compile covariates that would be useful in the DID linear regression models. Remote sensing data from the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration were leveraged to create three-month average measures of the normalized difference vegetation index (NDVI)—a measure of greenness in the environment—and monthly rainfall. The vegetation index and rainfall measures were pulled for the three-month periods in 2019 and 2022 that corresponded to the timeframe for which average estimates were taken for the outcome indicators identified for use in the DID analyses. HZ-level estimates were obtained for 2015 prevalence of improved housing and for 2014 educational attainment of women of reproductive age (WRA), the last time such published measures were estimated. HZ values for educational attainment and prevalence of improved housing were held constant across all time points. A binary variable describing urbanicity (rural and urban) was also assigned to each HZ.

The DID linear regression model can be defined as follows:

$$\mathbf{Y}_{it} = \boldsymbol{\alpha} + \boldsymbol{\beta}\mathbf{T}_{i} + \boldsymbol{\gamma}\mathbf{A}_{t} + \boldsymbol{\delta}(\mathbf{T}_{i}\times\mathbf{A}_{t}) + \mathbf{COVS}_{it} + \mathbf{COVS}_{i} + \boldsymbol{\epsilon}_{it}$$

where *Yit* is the outcome of interest for facility *i* at time *t*, *Ti* indexes health facilities in the intervention HZs, *At* distinguishes between pre- and postintervention values, *COVSit* represents time-varying covariates, *COVSi* represents time-invariant covariates, and *ϵit* is a normal random variable with mean zero. The Greek letters are the parameters to be estimated. The null hypothesis $\delta=0$ was tested to determine whether the IHP intervention had an effect because δ represented the change in the intervention group from pre- to postintervention relative to the comparison group. Inverse probability weights calculated from the propensity scores (ps/(1-ps)) for comparison facilities were also used in these models (note: intervention facilities were ascribed a weight of one).

Secondary Analyses

The primary analysis made use of population denominators to calculate rates per 1,000 population for each data element of interest. Given the time series nature of the available RHIS data, we conducted a secondary analysis that used a controlled interrupted time series (cITS) approach (Appendix 1, Figure 10). The difference between the PSM-DID and the cITS analyses was that the cITS approach assessed the comparison between paired data elements at each time point across a 66-month period rather than at just two time points (immediately before the IHP intervention start date and at one postintervention time point, as in the PSM-DID analysis).

The cITS analysis was only conducted for selected indicators for which suitable data elements were available to serve as comparator values. For example, the data element for insecticide-treated bed nets (ITNs) distributed during ANC1 clinic visits was compared with the total number of ANC1 clinic visits. Contrast this against, for example, the data element for moderate acute malnutrition for which no suitable comparator in the RHIS could be determined. This approach also allowed for a plus or minus five percentage point swing when comparing target and comparator values. For example, the RHIS data element for total facility births was used as a comparator for live births. If the total number of facility births was equal to the number of live births, that facility was classified as a “success” in a binary classification of matching between the two. Furthermore, if the total number of live births was within ±5 percentage points of total reported births, the facility was also classified as a “success” (i.e., 96 live births compared with 100 total births at the same facility was considered a “success”). This approach allowed for small perturbations in reporting accuracy to be ignored.

For the cITS secondary analysis, ***uncomplicated***, rather than ***complicated***, was selected to increase the overall number of analyzed health facilities with non-missing data points. Many thousands of health facilities and health posts do not treat severe cases of malaria, diarrhea, or pneumonia—they refer them to reference facilities. By substituting treated cases of uncomplicated malaria, diarrhea, and pneumonia, we were able to keep otherwise dropped facilities in the analysis.

Another secondary analysis was conducted that compared intervention HZ facilities that received intensified support from the IHP against other intervention HZs that did not receive this intensified support. (Given the nature of this analysis, the latter group served as comparison facilities.) Apart from this change, the analysis mirrored that of the primary PSM-DID analysis; however, given that this analysis assumed implementation of interventions at the HZ level rather than at the province level, WCB-adjusted p-values were not calculated because the number of HZs with intensified support was 59 compared with 119 HZs without intensified support.

2021 Nurses' Strike

The 2021 nurses' strike in DRC may have disrupted the provision of health services and as a result, could potentially influence the results of the impact evaluation. Although the timeframe used for Year 3 outcome values was after the nurses' strike had started, a time series that encompassed the nurses' strike was used in the interpolation process to lend a more robust structure to the seasonal decomposition step.

Limitations

There were several limitations of the evaluation and threats to carrying it out as planned.

First, the impact evaluation component of the study investigated only the impact of the USAID IHP on proxy indicators related to service provision, including treatment of childhood illnesses, contraceptive use, vaccinations, and ANC. Because data on health outcomes, service quality, and health systems governance and leadership were not available from non-project areas, the impact on these aspects could not be rigorously assessed. However, to descriptively explore these aspects, a performance evaluation is being carried out using both quantitative and qualitative data collected in the nine USAID IHP provinces[2] to explore changes in proxy indicators for three USAID IHP objectives—health systems strengthening, quality integrated health services, and healthy behaviors—and the factors that enabled or limited the success of the project.

Second, the impact evaluation was based on routine data from the RHIS. Although it was expected that using a research design based on these data (i.e., numerous, repeated health facility observations over extended periods and the real-time indicators of service coverage) would provide power and cost advantages over a research design based on intermittent population-based surveys, poor data quality remained a threat due to inaccurate data on counts of services provided (numerators) and the populations that are served (denominators). These disadvantages could lead to two consequences. First, poor data quality could add spurious variability to the dependent variable. If it was a random measurement error, it would add to the variation of the random error in the model, with the consequence of larger standard errors in the estimated coefficients increasing the chances of not finding significant effects when there was impact. This is a common problem in research studies based on data from health management information systems, and there is little that the evaluator can do to address the issue. Second, measurement error could

[2] Qualitative data will be collected in three provinces and in Kinshasa.

potentially evolve over time as data quality improves concurrently with increasing rigorousness and completeness of data reporting. Because USAID IHP aims to improve RHIS data quality, these improvements could be different in intervention and comparison areas, which will create a type of endogeneity[3] in the program variable of the model that varies over time, so it is not controlled by the fixed effects. This heteroskedasticity[4] would be accounted for through the estimation of robust standard errors. In addition, the RHIS indicators used as outcomes for this evaluation were not sex-disaggregated, making an assessment of sex-related differences impossible to perform. However, despite the lack of data on sex, several indicators included in the analysis were focused on women's experiences as they related to women's and children's well-being, such as new modern contraceptive acceptors, ANC clinic visits, birth rate, low birth weight births, and exclusive breastfeeding.

Third, the DRC is an unstable environment and there was a possibility that both the implementation of USAID IHP, and D4I and USAID IHP survey activities, could be affected by political and social unrest during the project period. This was not likely to affect the impact evaluation component of the study, which relied on RHIS data, but it could affect future surveys by precluding travel to sampled provinces, HZs, and facilities.

Results

Data Processing

Table 1 on the next page shows the effects of the data cleaning process. Nearly 22,000 health facility records were obtained from the RHIS. After removing those provinces and HZs that previously received intensive health systems strengthening support or experienced policies meant to boost overall clinic volumes in the face of EVD epidemic, a loss of 3,045 health facility records was noted. An additional 586 health facility records were removed because they were completely blank across all selected data elements. Across the remaining records, the degree of data missingness varied, with an average missingness of 65.0 percent (i.e., on average, each data set for each individual data element had 65.0% of its data missing/blank). The data set for treatment of complicated diarrhea/dehydration was nearly 92 percent blank. The most well-reported data element among the 12 selected RHIS indicators as outcomes was live births, with only 35 percent of its data missing/blank. Few data points were identified (and removed) as outliers; they comprised, on average, only 0.20 percent of available, non-missing values. We arbitrarily set a decision rule to remove health facility records with seven or more consecutive missing values, which allowed for a liberal run of missing values. The final data sets ranged from 616 health facility records (treatment of complicated diarrhea/dehydration) to 10,837 records (live births). Data availability across these final data sets averaged 82 percent, with a high of 91.7 percent (live births) to a low of 68.9 percent (live births <2,500 grams). The final data sets were those across which interpolation was conducted.

[3] A model in which the explanatory variable is correlated with the error term.
[4] A case in which the standard errors of a variable are not constant over time.

Table 1. Data processing steps and loss of health facility records

	Data Cleaning Steps						Interpolation Step	
RHIS Data Element	Total health facility record count	Count after removal of ASSP and EVD-affected areas	Count after removal of records with no data	Percentage of missing data points	Percentage of non-missing data points removed as outliers	Percentage of records removed with ≥7 consecutive missing values	Available health facility records (final)	Percentage of non-missing data points (final)
New acceptors of modern contraceptive methods	21,767	18,722	18,136	64.2%	0.25%	73.9%	4,731	87.6%
Attendance at the fourth ANC visit	21,767	18,722	18,136	42.4%	0.22%	49.0%	9,244	91.2%
ITN distribution during ANC visits	21,767	18,722	18,136	56.7%	0.14%	68.3%	5,741	77.2%
Live births	21,767	18,722	18,136	34.4%	0.33%	40.2%	10,837	91.7%
Live births <2,500 grams	21,767	18,722	18,136	86.9%	0.07%	94.2%	1,060	68.9%
Exclusive breastfeeding	21,767	18,722	18,136	56.7%	0.22%	64.1%	6,510	86.3%
Measles vaccination	21,767	18,722	18,136	54.9%	0.38%	58.3%	7,586	88.4%
Pentavalent vaccination	21,767	18,722	18,136	53.9%	0.36%	57.8%	7,649	89.5%
Moderate acute malnutrition	21,767	18,722	18,136	74.1%	0.17%	82.4%	3,185	83.1%
Complicated malaria treatment	21,767	18,722	18,136	77.0%	0.07%	86.1%	2,525	85.5%
Complicated diarrhea/dehydration treatment	21,767	18,722	18,136	91.5%	0.02%	96.6%	616	75.2%
Complicated pneumonia treatment	21,767	18,722	18,136	86.5%	0.04%	93.3%	1,221	79.6%

EVD=Ebola virus disease; ANC=antenatal care

Covariate Balance

The gradient boosted model and PSM process were successful in balancing the distribution of all selected indicators across comparison and intervention sites. The comparison of absolute standardized mean difference values before and after the gradient boosted model and PSM process showed that matching significantly reduced the absolute standardized mean difference for each indicator to below the standard threshold of 10 percent. **Figure 4** in Appendix 1 shows that each of the propensity score weighted absolute standardized mean difference values were also below the five percent threshold. Restricting the propensity scores to a region of common support only led to the exclusion of 2.0 percent (96 of 4,794) of the intervention facilities and 1.3 percent (91 of 7,188) of the comparison facilities (**Figure 5** in Appendix 1).

Common Trends

The analysis carried out to investigate the common trends assumption suggested no significant differences between the comparison and intervention groups in the preintervention time series trends for all but three of the RHIS indicators (i.e., new acceptors of modern contraceptive methods, ITN distribution during first ANC clinic visits, and measles vaccinations). Note that attempts to satisfy the common trends assumption between the comparison and intervention groups in the preintervention period for new acceptors of modern contraceptive methods proved unsuccessful. To formally test the assumption of common trends, we separately regressed each of the 12 selected RHIS indicators transformed to rates on a linear measure for time trend in the preintervention period interacted with a dummy variable for the intervention group. Time-invariant covariates of urban/rural HZ status, hospital facility, prevalence of improved housing (HZ level), and educational attainment of WRA (HZ level) were included in each linear regression model. Inverse probability weights calculated from the propensity scores (ps/(1-ps)) for comparison facilities were also used in these models (intervention facilities were ascribed a weight of 1). The p-values reported in **Figures 6a** and **6b** in Appendix 1 are for the coefficients of the interaction term, which showed whether the comparison and intervention groups demonstrated a different time trend before the onset of IHP activities. For all but three of the RHIS indicators assessed, the differences in trends across the comparison and intervention groups were not statistically significant at an alpha level of 0.05. Taking into consideration the success in achieving covariate balance between the comparison and intervention groups, the results of the linear regression for preintervention time trends and a visual inspection of these trends, we could expect that the common trend assumption was plausible for each indicator, except for new acceptors of modern contraceptive methods, ITN distribution during first ANC clinic visits, and measles vaccinations.

An additional set of analyses was conducted to assess common trends under the scenario that compared IHP HZs receiving intensified support to IHP HZs receiving the standard intervention package (**Figures 7a** and **7b** in Appendix 1). Five RHIS indicators did not satisfy the common trends assumption (i.e., new acceptors of modern contraceptive methods, live births, live births <2,500 grams, moderate acute malnutrition, and complicated pneumonia treatment). Interpreting the regression results for these five indicators should be done with caution.

Regression Outcomes

This section presents the main analysis results with supplementary analyses results interleaved throughout for better triangulation of outcomes. **Table 2** includes a summary of the DID estimators from the main analysis for each of the 12 RHIS indicators assessed. **Figures 2a** and **2b** graphically show the DID regression results for the primary outcomes. A similar table (**Table 3** in Appendix 1) and figures (**Figures 8a** and **8b** in Appendix 1) were generated for the scenario that compared IHP HZs receiving intensified support with IHP HZs receiving the standard intervention package.

Although nine of the 12 indicators showed significant differences between the comparison and intervention sites, the magnitude of the differences were quite small in several instances. For example, the rate of live births across intervention sites was 0.44 cases higher per 1,000 WRA relative to the rate of live births across comparison sites. This difference was significant (unadjusted p-value = 0.0041) and likely attributable, in part, to the very large sample size noted for live births (nearly 11,000 health facility records). It is important to note, however, that both the WCB adjusted p-value and the Bonferroni-adjusted p-value for live births were insignificant. In the analysis comparing IHP HZs receiving intensified support with IHP HZs receiving the standard intervention package, the DID estimator showed that the rate of live births in the intensified activity areas was 1.15 cases more per 1,000 WRA; however, this finding was not significant. The cITS analysis showed an immediate increase in live births (incidence rate ratio [IRR] [95% confidence interval [CI]: 1.15 [0.60, 2.22], p-value=0.6733) and a slight increase in the longer-term trend of live births (IRR [95% CI]: 1.04 [0.99, 1.09], p-value=0.1703) across intervention sites relative to comparison sites, although both findings were non-significant.

Based on the unadjusted p-value, the DID estimator for ITNs distributed during ANC1 visits demonstrated weak evidence, with 0.37 more ITNs distributed per 1,000 population of WRA across intervention sites relative to comparison sites. However, both the WCB adjusted p-value and the Bonferroni-adjusted p-value for this indicator were non-significant. Additionally, the common trends assumption was not satisfied for this indicator. In the analysis comparing IHP HZs receiving intensified support with IHP HZs receiving the standard intervention package, the DID estimator showed that the rate of ITN distribution during ANC1 in the intensified activity areas was 4.85 fewer per 1,000 WRA; however, this finding was not significant. The cITS analysis suggested a slight immediate increase in ITNs distributed during ANC1 clinic visits (IRR [95% CI]: 1.18 [0.96, 1.46], p-value=0.1199) and virtually no change in the longer-term trend (IRR [95% CI]: 1.01 [1.00, 1.02], p-value=0.0811) at intervention sites relative to comparison sites.

Based on the unadjusted p-value, the DID estimator for treatment of complicated malaria demonstrated evidence for 1.48 fewer treated cases per 1,000 population of children under five years across intervention sites relative to comparison sites. However, both the WCB adjusted p-value and the Bonferroni-adjusted p-value for this indicator were non-significant. In the analysis comparing IHP HZs receiving intensified support with IHP HZs receiving the standard intervention package, the DID estimator showed that the rate of complicated malaria treatment in the intensified activity areas was 3.23 more per 1,000 children under five years; however, this finding was not significant. The cITS analysis suggested an immediate but non-significant increase in treatment of uncomplicated malaria cases (IRR [95% CI]: 1.68 [0.80, 3.55], p-value=0.1728) and a slight positive and significant change in the longer-term trend (IRR [95% CI]: 1.04 [1.00, 1.09], p-value=0.0485) for children under five years among intervention sites relative to comparison sites.

Based on the unadjusted p-value, the DID estimator for treatment of complicated diarrhea/dehydration demonstrated evidence for 0.73 more treated cases per 1,000 population of children under five years across intervention sites relative to comparison sites. Unlike any of the other 11 RHIS indicators assessed in this analysis, both the WCB adjusted p-value and the Bonferroni-adjusted p-value for this indicator were significant. In the analysis comparing IHP HZs receiving intensified support with IHP HZs receiving the standard intervention package, the DID estimator showed that the rate of complicated diarrhea/dehydration treatment in the intensified activity areas was 2.79 more per 1,000 children under five years; however, this finding was not significant. The cITS analysis suggested an immediate and significant decrease in treatment of uncomplicated diarrhea cases (IRR [95% CI]: 0.62 [0.39, 1.00], p-value=0.0495) but a slight positive and significant change in the longer-term trend (IRR [95% CI]: 1.04 [1.01, 1.07], p-value=0.0028) for children under five years among intervention sites relative to comparison sites.

Based on the unadjusted p-value, the DID estimator for treatment of complicated pneumonia demonstrated evidence for 1.59 more treated cases per 1,000 population of children under five years across intervention sites relative to matched comparison sites. For this analysis, the WCB adjusted p-value was significant but the Bonferroni-adjusted p-value was not. In the analysis comparing IHP HZs receiving intensified support versus IHP HZs receiving the standard intervention package, the DID estimator showed that the rate of complicated pneumonia treatment in the intensified activity areas was only 0.13 more per 1,000 children under five years; however, this finding was not significant. The cITS analysis suggested an immediate and non-significant decrease in treatment of uncomplicated pneumonia cases (IRR [95% CI]: 0.93 [0.50, 1.74], p-value=0.8312) but a slight positive and significant change in the longer-term trend (IRR [95% CI]: 1.05 [1.02, 1.09], p-value=0.0043) for children under five years among intervention sites relative to comparison sites.

None of the other assessed RHIS indicators fit a data availability scenario wherein a cITS analysis could be conducted. However, for those that did, results are presented in **Table 16** in Appendix 1.

The primary outcomes for the remaining RHIS indicators showed minimal and non-significant differences when considering Bonferroni-adjusted p-values, except for exclusive breastfeeding and moderate acute malnutrition. Based on the unadjusted p-value, the DID estimator demonstrated evidence for 44.92 more instances of exclusive breastfeeding per 1,000 population of children under six months across intervention sites relative to comparison sites. For this indicator, the WCB adjusted p-value was significant but the Bonferroni-adjusted p-value was not. In addition, based on the unadjusted p-value for moderate acute malnutrition, the DID estimator demonstrated evidence for 3.75 more cases per 1,000 children under five years at intervention sites. Neither the WCB adjusted p-value nor the Bonferroni-adjusted p-value were significant for this indicator. A different scenario emerged for these two RHIS indicators when interpreting the results from the analysis that compared IHP HZs receiving intensified support against IHP HZs receiving the standard intervention package. In both instances, the rate of exclusive breastfeeding and moderate acute malnutrition dropped by a non-significant degree across intervention HZs receiving intensified support relative to their comparison sites.

Similar results were noted for both measles and pentavalent vaccinations among children under five years. Based on unadjusted p-values, the DID estimators for these two indicators demonstrated significant evidence for 0.80 and 0.78 more vaccinations per 1,000 population of children under five years. Only the WCB adjusted p-value for pentavalent vaccinations remained significant; otherwise, the adjusted p-values were non-significant. A similar, albeit non-significant, scenario was noted when interpreting the results from the analysis that compared IHP HZs receiving intensified support against IHP HZs receiving the standard intervention package. The DID estimators under this analysis showed 1.24 and 1.78 more vaccinations per 1,000 population of children under five years in zones receiving intensified support. The common trends assumption was not satisfied for the measles vaccination indicator.

Tables 4–15 in Appendix 1 show detailed results from the 12 DID regressions (primary outcomes).

Figure 2a. Graphical depictions of DID analyses by RHIS indicator

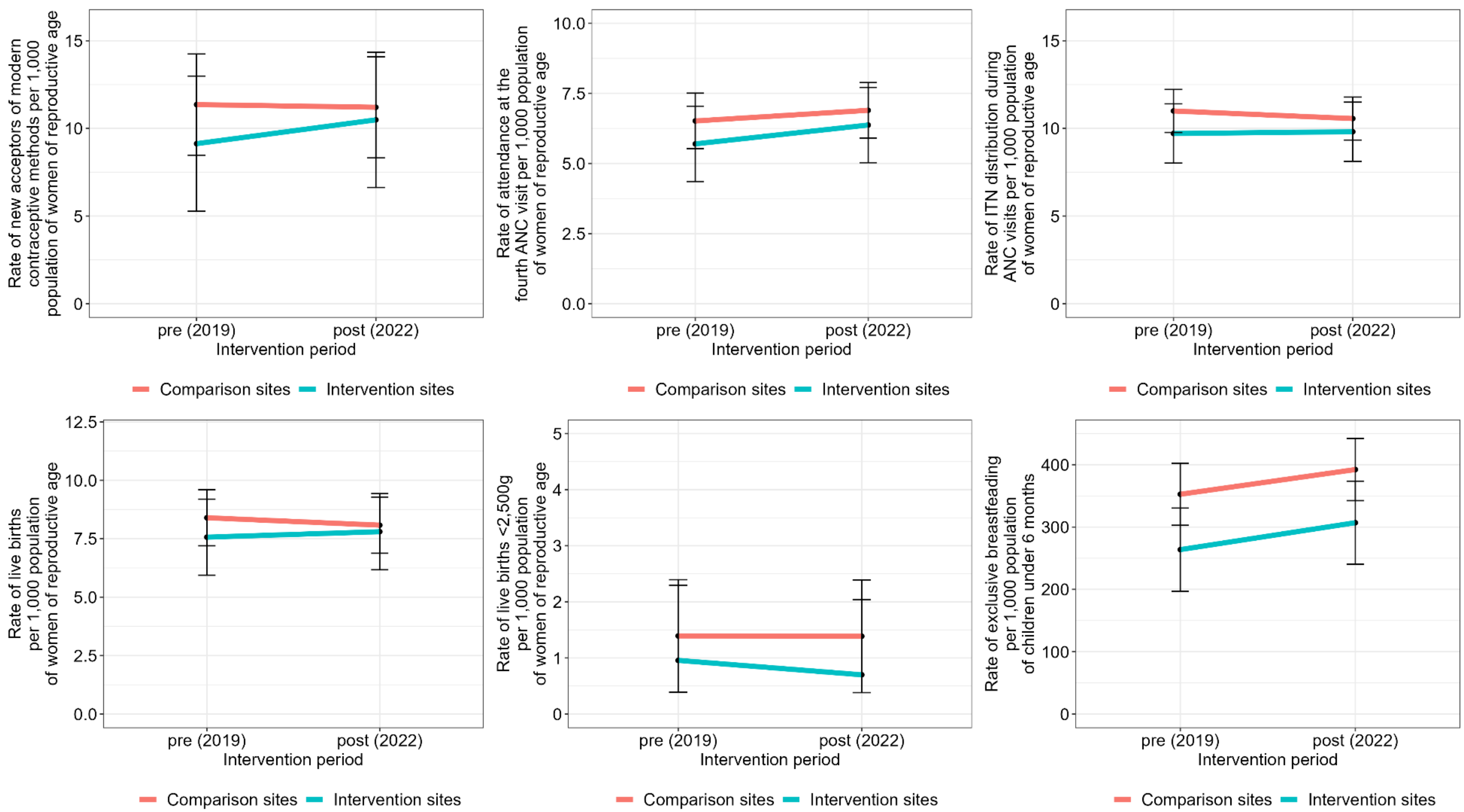


Figure 2b. Graphical depictions of DID analyses by RHIS indicator

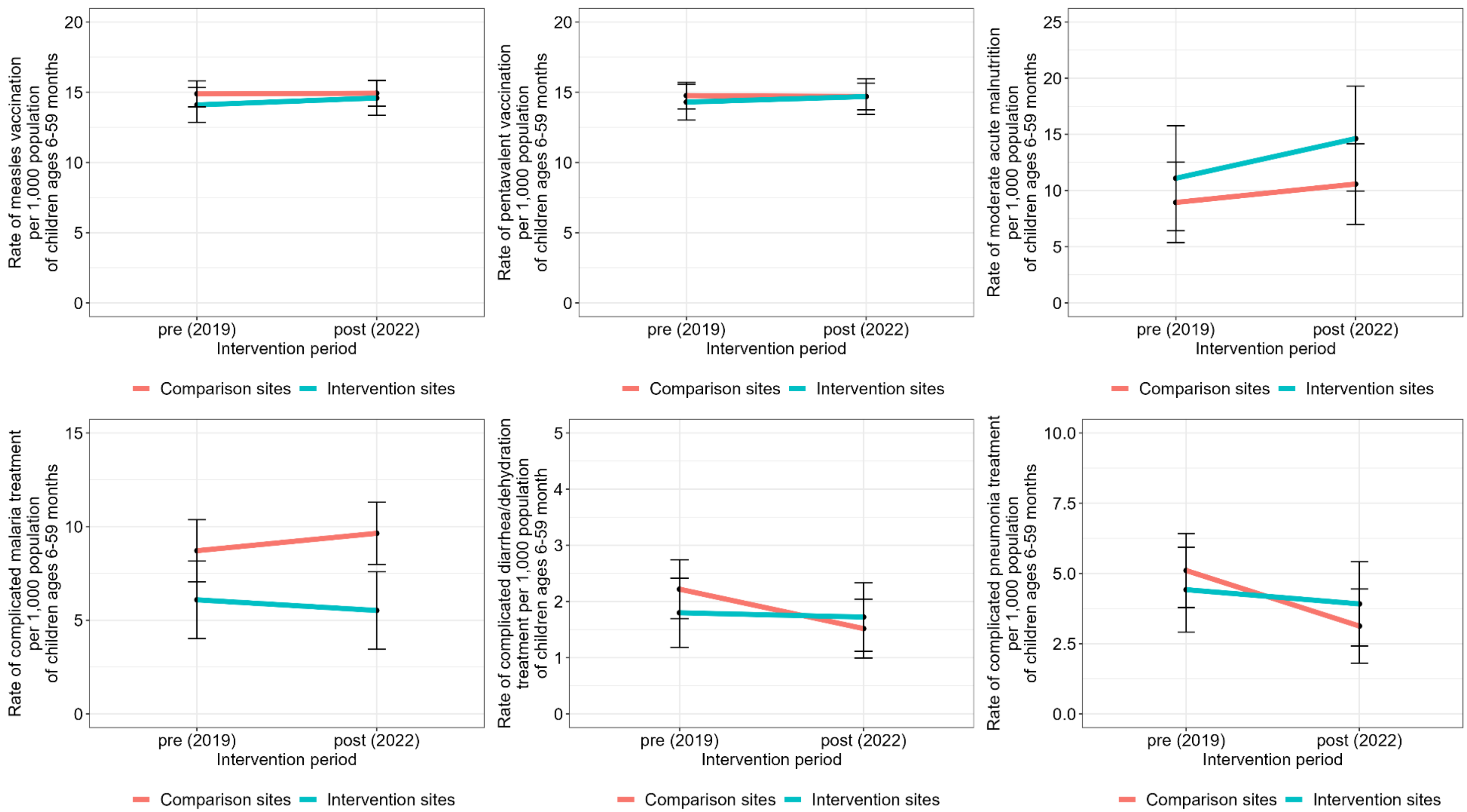


Table 2. Summary of DID estimators by RHIS indicator assessed

RHIS indicator	2019 vs 2022			
	DID estimator [WCB 95% CI]	Unadjusted p-value	WCB p-value	Bonferroni corrected p-value
New acceptors of modern contraceptive methods per 1,000 WRA*	1.59 [-0.50, 3.70]	***0.0003***	0.1758	1.0000
Attendance at the fourth ANC visit per 1,000 WRA	0.24 [-0.38, 0.87]	0.0791	0.4615	1.0000
ITN distribution during ANC visits per 1,000 WRA*	0.37 [-0.28, 1.02]	0.0719	0.2068	1.0000
Live births per 1,000 WRA	0.44 [-0.12, 1.01]	***0.0041***	0.1399	1.0000
Live births <2,500 grams per 1,000 WRA	-0.18 [-0.56, 0.20]	0.2471	0.4276	1.0000
Exclusive breastfeeding per 1,000 children under 6 months	44.92 [-7.49, 97.28]	***0.0002***	0.1179	1.0000
Measles vaccination per 1,000 children under 5 years*	0.80 [-0.09, 1.65]	***<0.0001***	0.0729	0.8748
Pentavalent vaccination per 1,000 children under 5 years	0.78 [0.00, 1.53]	***<0.0001***	***0.0450***	0.5400
Moderate acute malnutrition per 1,000 children under 5 years	3.75 [-1.34, 8.83]	***0.0002***	0.1648	1.0000
Complicated malaria treatment per 1,000 children under 5 years	-1.48 [-3.34, 0.42]	***0.0313***	0.1019	1.0000
Complicated diarrhea/dehydration treatment per 1,000 children under 5 years	0.73 [0.37, 1.10]	***0.0167***	***0.0010***	***0.0120***
Complicated pneumonia treatment per 1,000 children under 5 years	1.59 [0.32, 2.86]	***0.0485***	***0.0230***	0.2760

*Common trends assumption not satisfied in the preintervention period.
Baseline measures included in the DID analyses reflect three-month averages for March 2019 through May 2019, which were compared with averages spanning the same three months in 2022.
RHIS – routine health information system; DID – difference-in-differences; WCB – wild cluster bootstrap; *CI* – confidence interval; *WRA* –women of reproductive age; *ANC* – antenatal care

Summary and Implications

Overall, mostly small changes were observed in the RHIS indicators assessed three years into USAID IHP program implementation. Because this impact analysis is expected to occur on an annual basis, year-over-year results need to be interpreted in the proper context. For example, the time required for project start-up activities before the integrated health strategies began in earnest may have tempered the potential impact of the project during its first year. This notion was borne out in the results of the cITS analyses, which largely showed no significant immediate changes in the assessed indicators due to the onset of IHP activities. Nevertheless, the Year 3 impact evaluation results showed movement in the anticipated direction for many of the indicators assessed relative to comparison sites, although the changes were not found to be statistically significant when interpreted through the lens of Bonferroni-corrected p-values. The exception was complicated diarrhea/dehydration treatment per 1,000 children under five years of age as assessed in the primary DID analysis. This indicator was the only one to demonstrate significance (in an intended direction) for the unadjusted, WCB-adjusted, and Bonferroni-corrected p-values. Nevertheless, this significant change amounted to less than one additional and appropriately treated complicated diarrhea/dehydration case per 1,000 children under five years of age when comparing intervention with comparison sites.

Overall, the results highlighted areas that may warrant additional program focus, such as treatment of severe childhood illnesses, and prevention and treatment of moderate acute malnutrition in children. Although slight, there were two indicators whose DID estimators suggested movement in an unanticipated direction when comparing intervention sites with comparison sites, (i.e., more instances of moderate acute malnutrition and fewer instances of complicated malaria treatment), neither of which were significant based on adjusted p-values. Contrast this analysis with the cITS that represented a more targeted look at *uncomplicated malaria* treatment practices and a slight, but significant change in the intended direction was noted over the longer-term trend. At least in the case of moderate acute malnutrition, additional instances per 1,000 children under five years could have been due to heightened awareness around diagnosis as a direct result of IHP activities. With this indicator, the analysis of IHP HZs stratified by intensified and standard activities suggested that intervention HZs were recording fewer instances of moderate acute malnutrition.

Although no results from the analysis that compared IHP HZs receiving intensified support against IHP HZs receiving the standard intervention package were found to be significant, directional changes in the interpretation of the DID estimators were noted for seven of the 12 indicators. This means that when the primary analysis noted additional or fewer cases/instances for an indicator, the secondary analysis limited to only IHP provinces stratified by activity level noted the opposite. It is worth noting, however, that none of the results from the secondary analysis using only IHP HZs stratified by activity level were significant.

It is also important to remember that the impact evaluation used routinely reported health facility data for which poor data quality remained an issue. Inaccuracies in data reporting could add spurious variability to the dependent variables used in the DID regression analyses, which has the potential to mask the detection of significant effects where there may have been an impact. Note that our analyses for both the PSM and DID procedures made use of the most well-reported data elements in the RHIS.

Unfortunately, the RHIS indicators for new acceptors of modern contraceptive methods, ITN distribution during ANC visits, and measles vaccinations did not satisfy the common trends assumption in the preintervention period. This meant that the comparison group did not serve as an appropriate counterfactual to the intervention group and that the results should be interpreted with caution.

Recommendations

The USAID IHP should draw its attention to those indicators that showed little to no movement in the anticipated direction, such as treatment of complicated malaria and moderate acute malnutrition in children, and consider whether any mid-course adjustments to program strategies and their implementation are warranted.

References

Adam, T., Hsu, J., de Savigny, D., Lavis, J.N., Røttingen, J.A., Bennett, S. (2012). Evaluating health systems strengthening interventions in low-income and middle-income countries: are we asking the right questions? *Health Policy and Planning*, 27 Suppl 4, iv9–19. Retrieved from https://europepmc.org/article/MED/23014156

Hyndman, R.J. & Khandakar, Y. (2008). Automatic time series forecasting: the forecast package for R. *Journal of Statistical Software*, 27(3), 1–22. Retrieved from https://www.jstatsoft.org/article/view/v027i03

Hyndman, R., Athanasopoulos, G., Bergmeir, C., Caceres, G., Chhay, L., Kuroptev, K., ... Yasmeen, F. (2023). Forecasting functions for time series and linear models, version 8.20. Retrieved from https://cran.r-project.org/web/packages/forecast/forecast.pdf

Lopez Bernal, J., Cummins, S., & Gasparrini, A. (2018). The use of controls in interrupted time series studies of public health interventions. *International Journal of Epidemiology*, 47(6), 2082–2093. Retrieved from https://pubmed.ncbi.nlm.nih.gov/29982445/

McCaffrey, D.F., Ridgeway, G., & Morral, A.R. (2004). Propensity score estimation with boosted regression for evaluating causal effects in observational studies. *Psychological Methods*, 9(4), 403–25. Retrieved from https://pubmed.ncbi.nlm.nih.gov/15598095/

R Core Team. (2018). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.gbif.org/tool/81287/r-a-language-and-environment-for-statistical-computing

Appendix 1. Additional Figures and Tables

Figure 3. Receiver operating characteristic curve for gradient boosted model used to estimate propensity scores

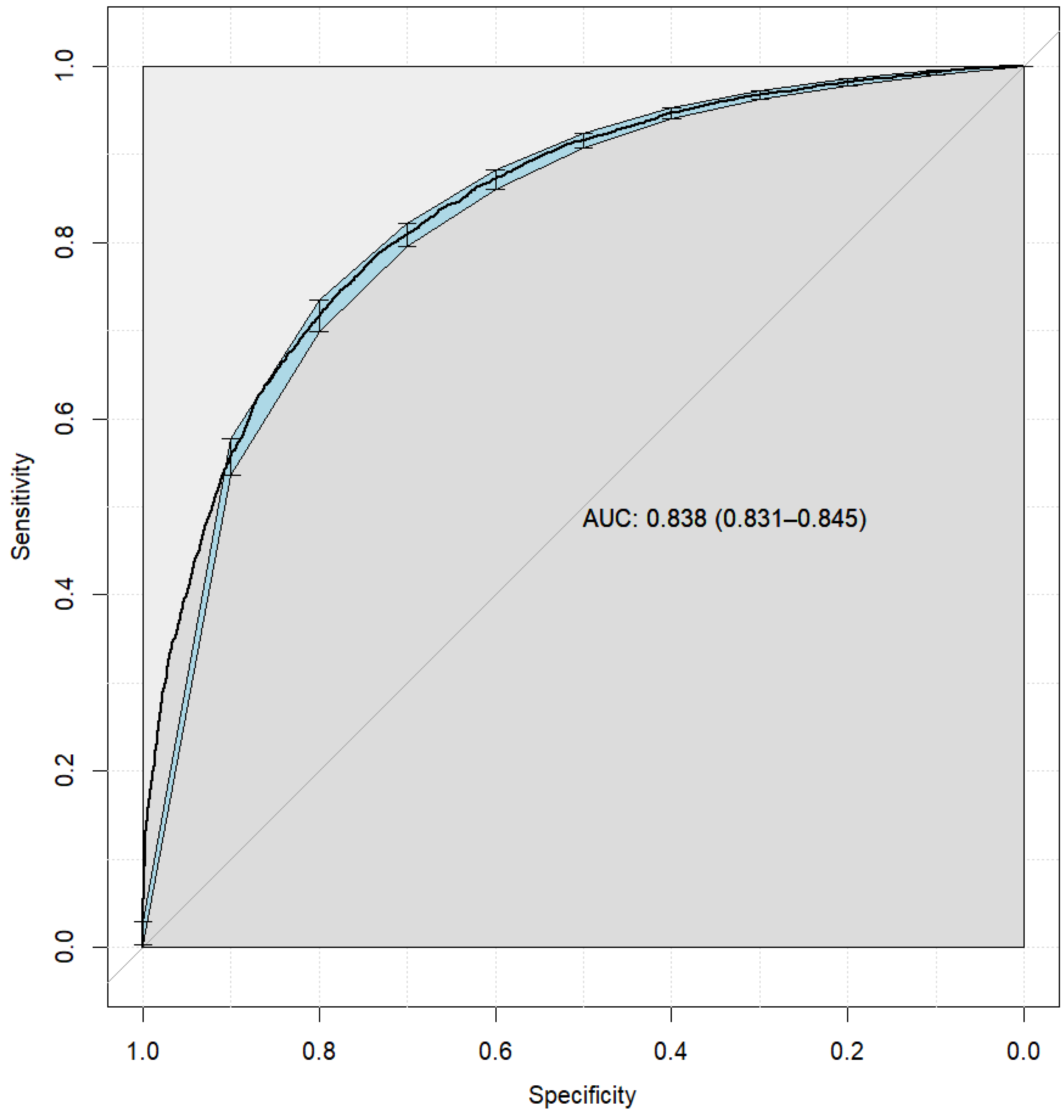
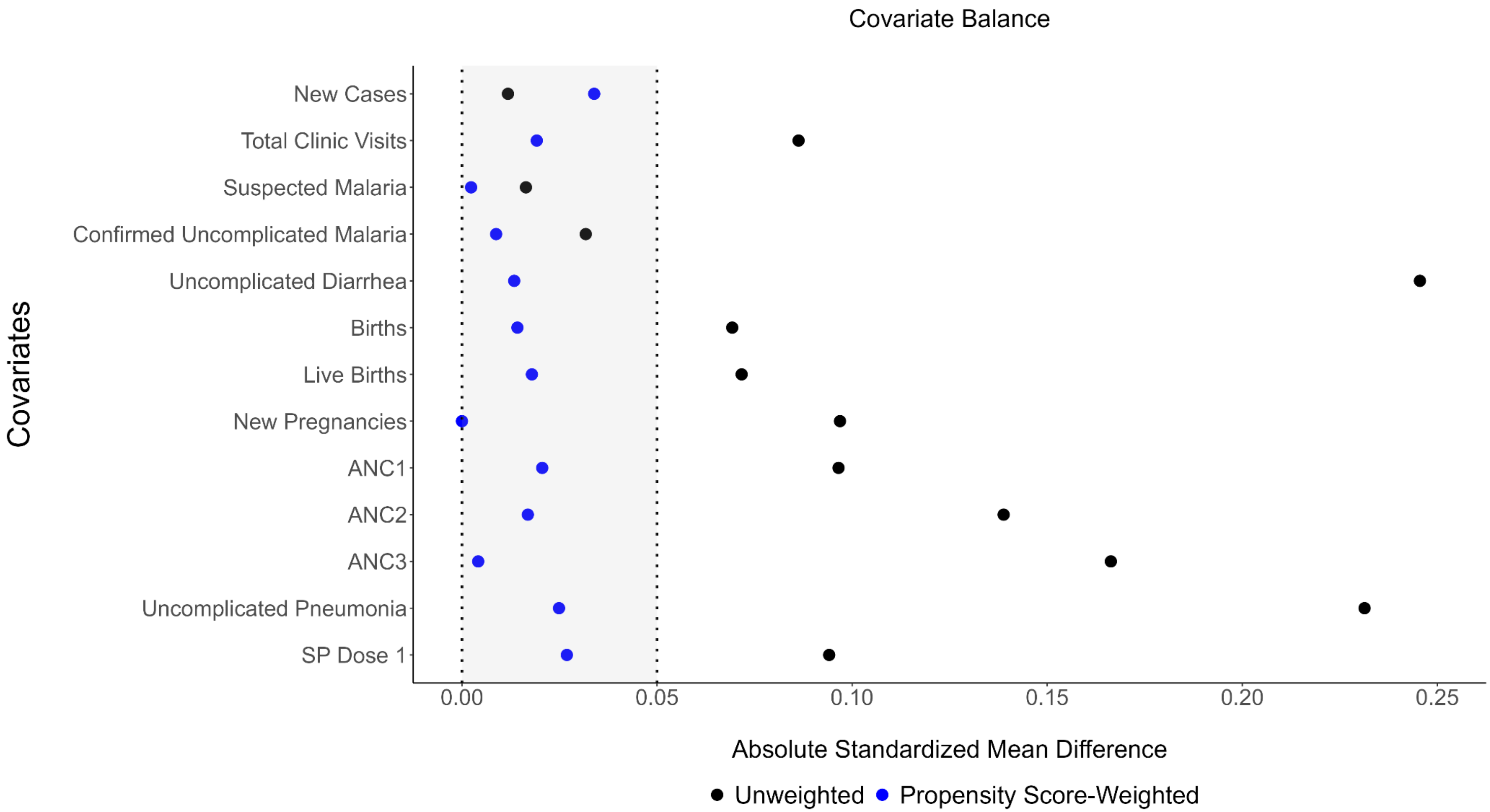


Figure 4. Love plot of covariate balance (primary analysis)



Black points represent the unadjusted absolute standardized mean difference (ASMD) between intervention and comparison values. Green points represent the adjusted ASMD between intervention and propensity score-weighted comparison values. An ASMD value less than 0.1 indicates good balance whereas values less than 0.05 indicate much better balance.

Figure 5. Propensity score region of common support before and after matching (primary analysis)

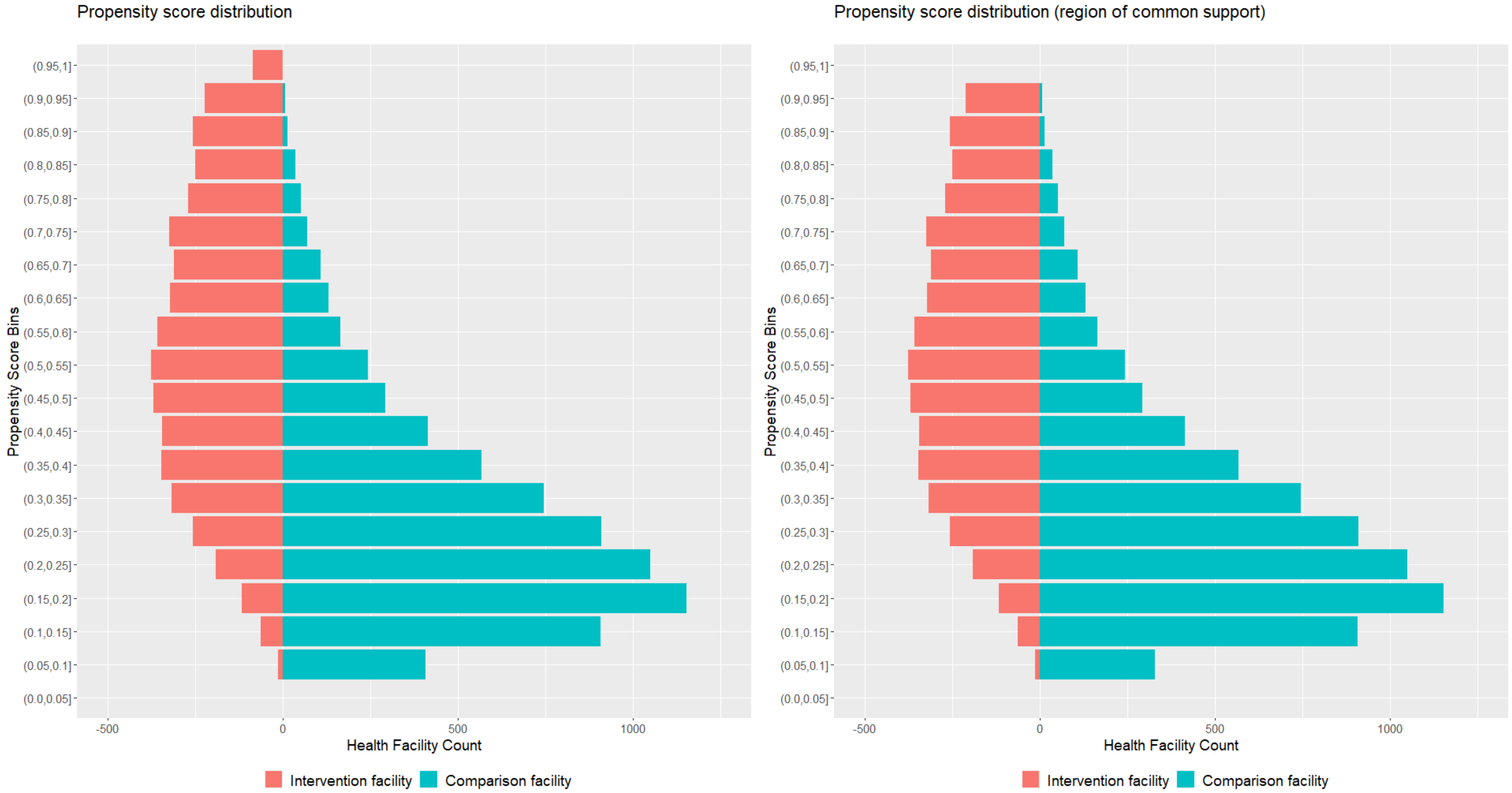


Figure 6a. Assessment of common trends assumption, by RHIS indicator (primary analysis)

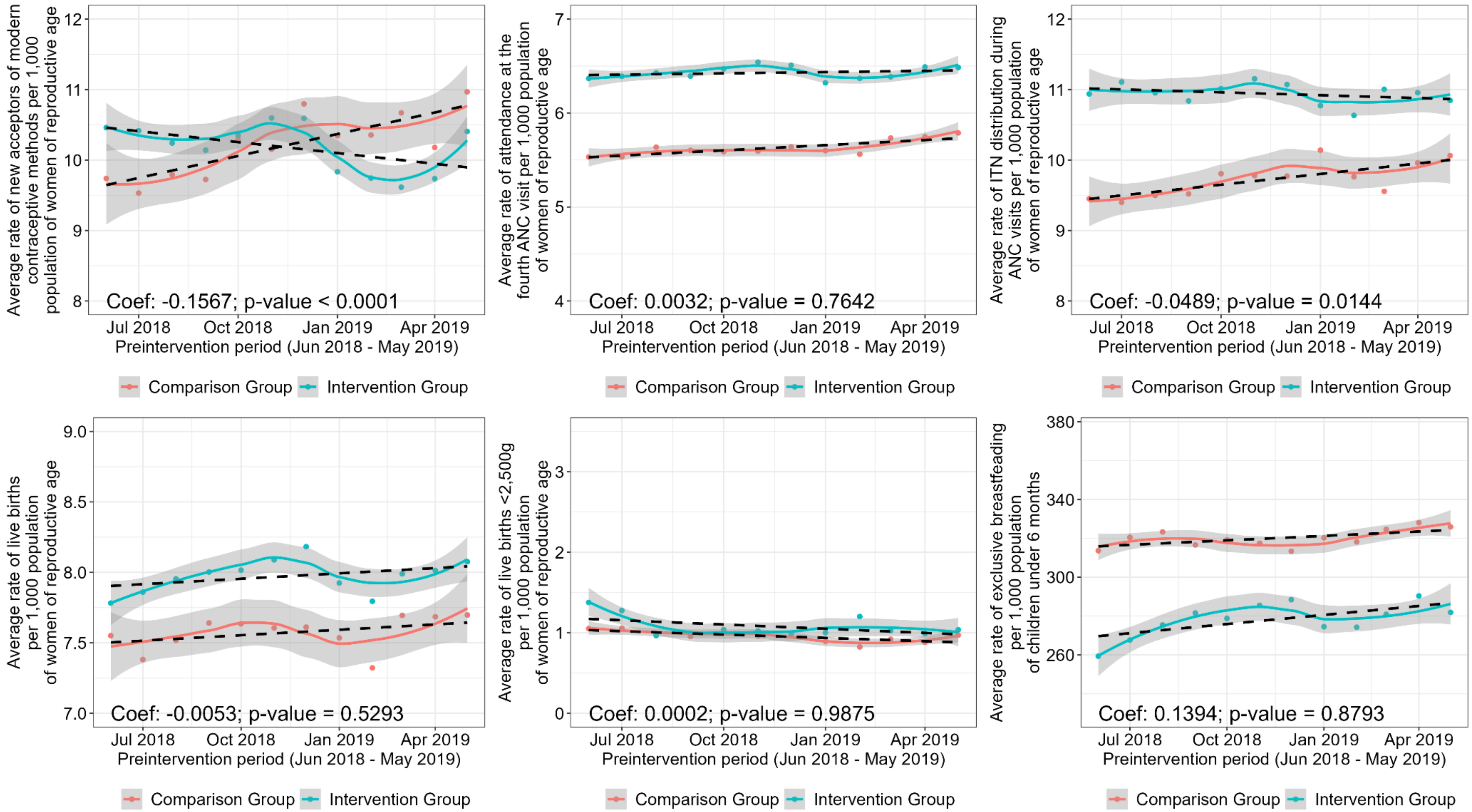


Figure 6b. Assessment of common trends assumption, by RHIS indicator (primary analysis)

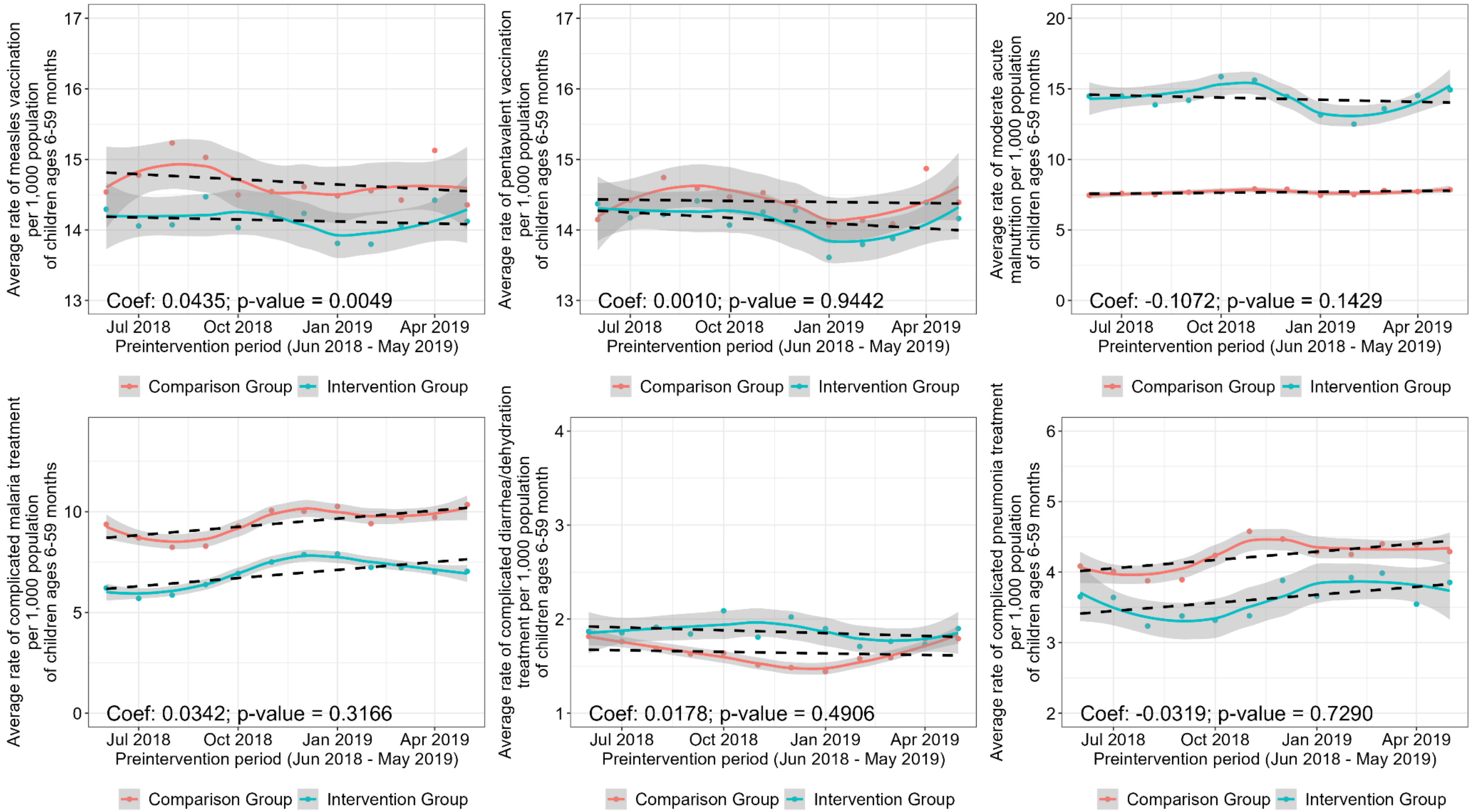


Figure 7a. Assessment of common trends assumption, by RHIS indicator (IHP HZs with intensified activities vs. IHP HZs with standard activities)

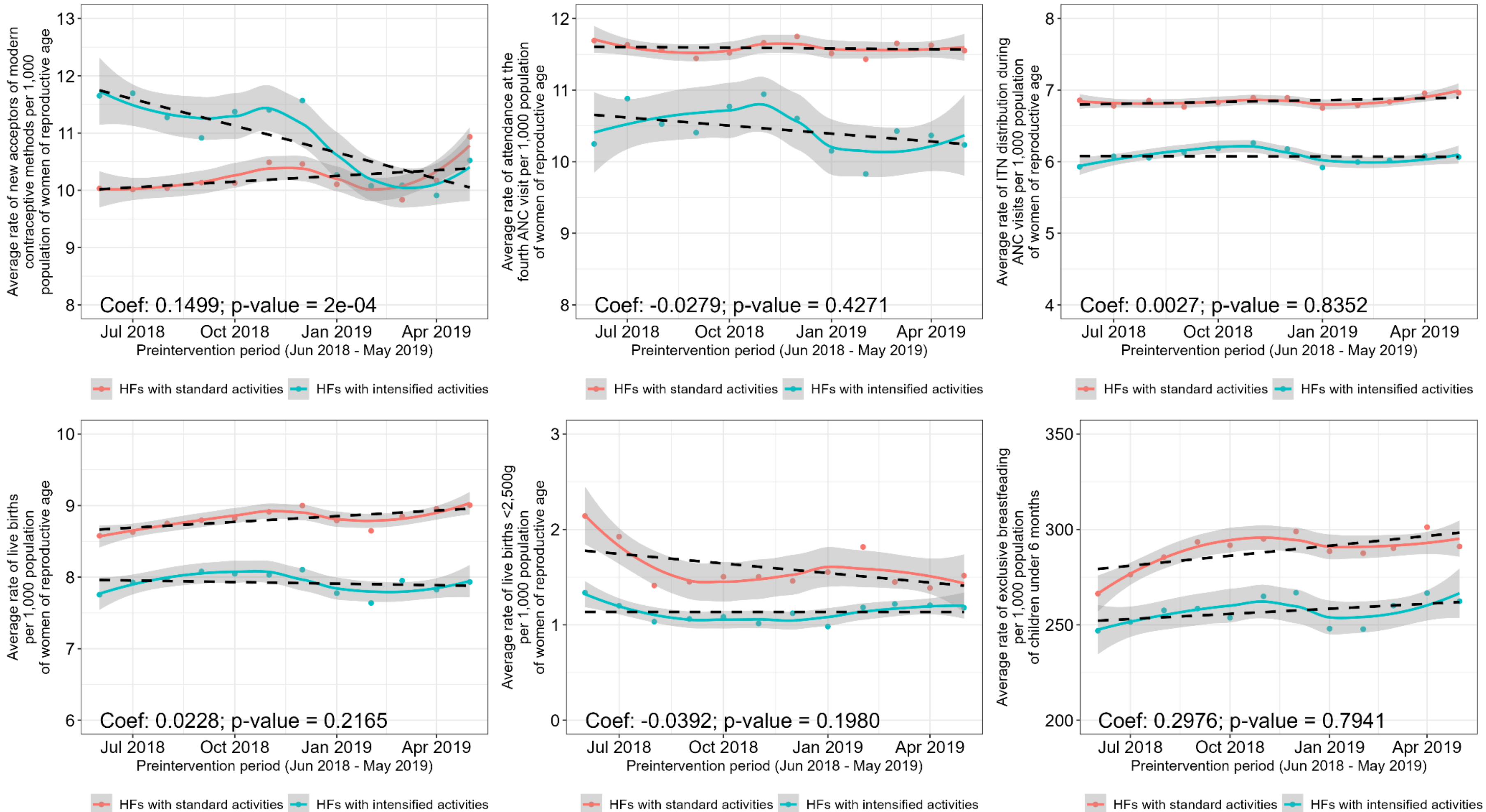


Figure 7b. Assessment of common trends assumption, by RHIS indicator (IHP HZs with intensified activities vs. IHP HZs with standard activities)

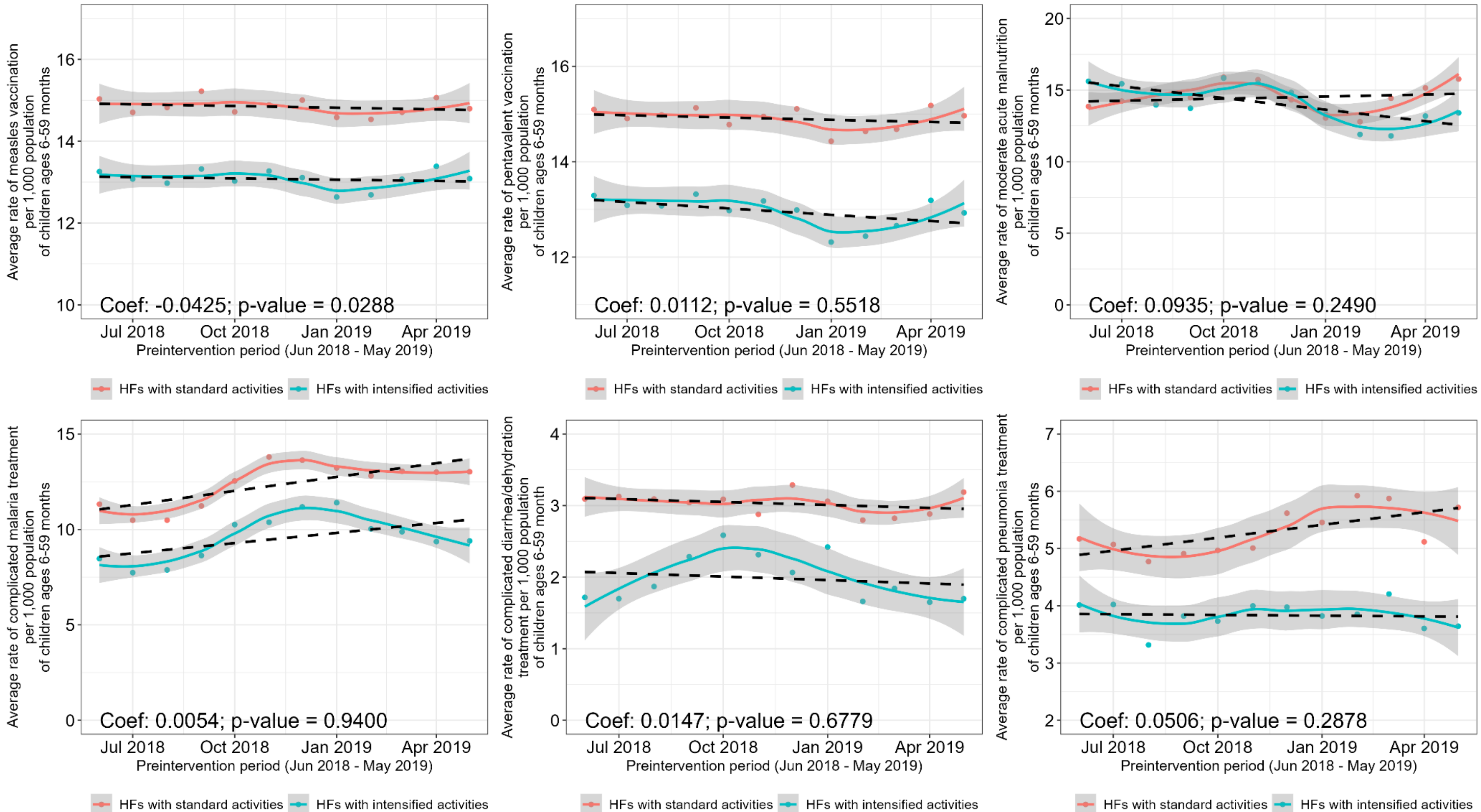


Figure 8a. Graphical depictions of the DID analyses, by RHIS indicator (IHP HZs with intensified activities vs. IHP HZs with standard activities)

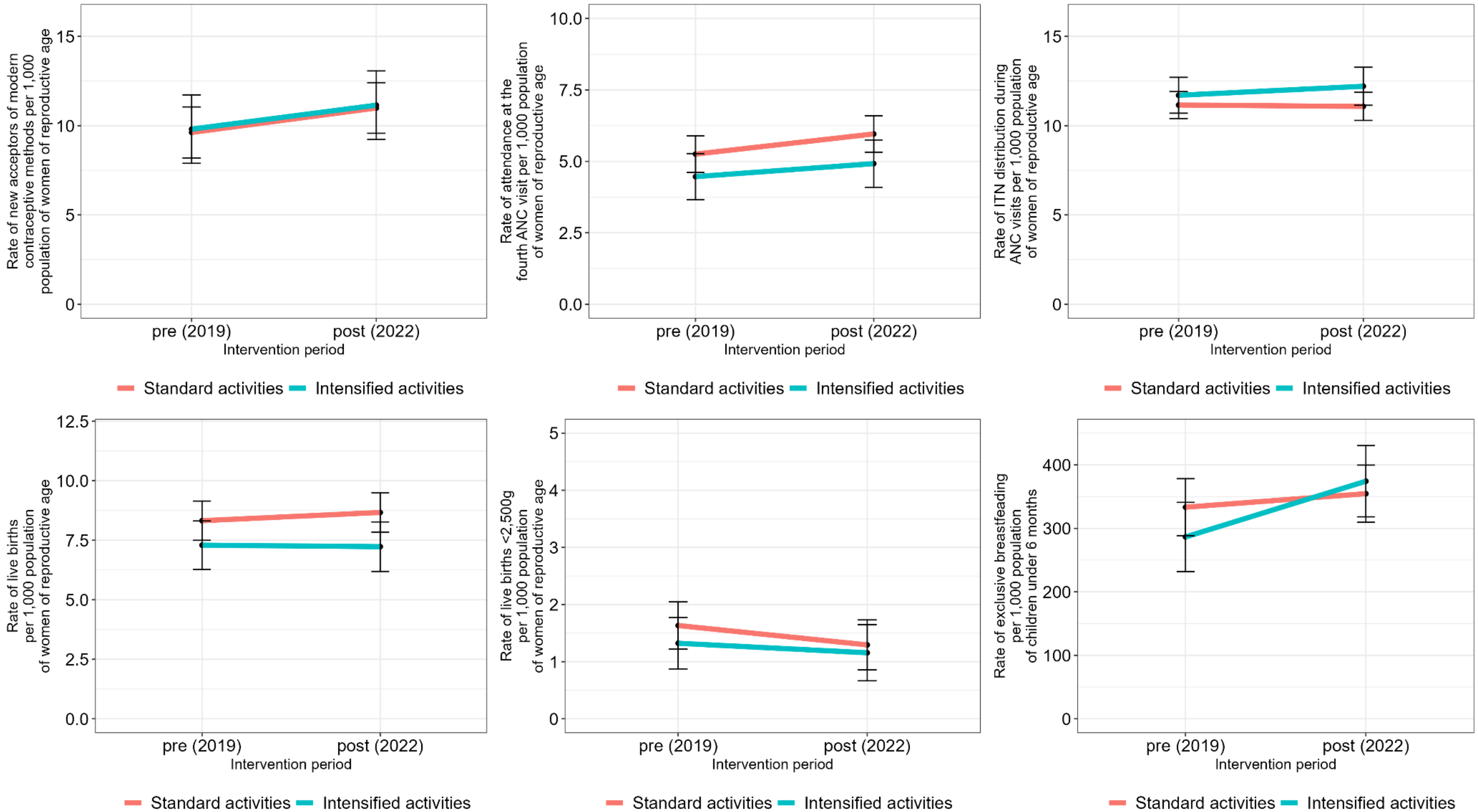


Figure 8b. Graphical depictions of the DID analyses, by RHIS indicator (IHP HZs with intensified activities vs. IHP HZs with standard activities)

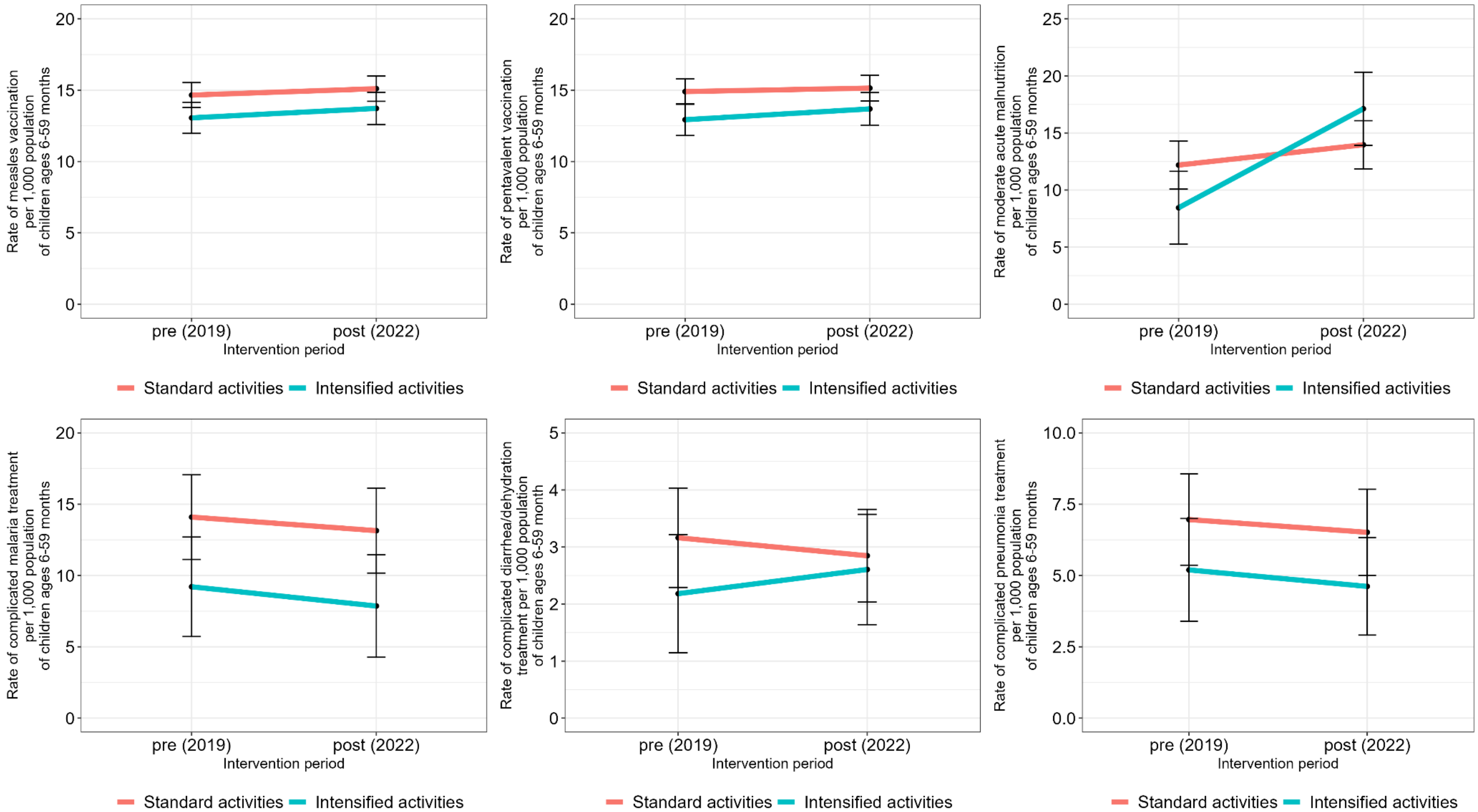


Table 3. Summary of DID estimators, by assessed RHIS indicator (IHP HZs with intensified activities vs. IHP HZs with standard activities)

RHIS indicator	2019 vs 2022		
	DID estimator [95% CI]	Unadjusted p-value	Bonferroni-adjusted p-value
New acceptors of modern contraceptive methods per 1,000 WRA*	-5.73 [-19.66, 7.90]	0.4170	1.0000
Attendance at the fourth ANC visit per 1,000 WRA	4.20 [-3.56, 12.03]	0.2984	1.0000
ITN distribution during ANC visits per 1,000 WRA	-4.85 [-10.13, 0.31]	0.0692	0.8301
Live births per 1,000 WRA	1.15 [-4.76, 7.00]	0.7030	0.5697
Live births <2,500 grams per 1,000 WRA	0.58 [-2.32, 3.49]	0.7023	1.0000
Exclusive breastfeeding per 1,000 children under 6 months	-127.08 [-488.81, 231.13]	0.4934	1.0000
Measles vaccination per 1,000 children under 5 years	1.24 [-5.08, 7.43]	0.6980	1.0000
Pentavalent vaccination per 1,000 children under 5 years	1.78 [-4.60, 8.05]	0.5812	1.0000
Moderate acute malnutrition per 1,000 children under 5 years	-7.27 [-35.42, 20.65]	0.6152	1.0000
Complicated malaria treatment per 1,000 children under 5 years	3.23 [-8.69, 15.10]	0.5996	1.0000
Complicated diarrhea/dehydration treatment per 1,000 children under 5 years	2.79 [-1.57, 7.17]	0.2197	1.0000
Complicated pneumonia treatment per 1,000 children under 5 years	0.13 [-6.22, 6.52]	0.9694	1.0000

*Common trends assumption not satisfied in the preintervention period.

Baseline measures included in the DID analyses reflect three-month averages for March 2019 through May 2019, which were compared with averages spanning the same three months in 2022.

RHIS – routine health information system; DID – difference-in-differences; *CI* – confidence interval; *WRA* –women of reproductive age; *ANC* – antenatal care

Figure 9. RHIS reporting rate of basic services, by province (July 2021–November 2021)

	Basic Services Reporting Rate				
Province	Jul 2021	Aug 2021	Sep 2021	Oct 2021	Nov 2021
Bas Uele	100.0	100.0	99.4	100.0	100.0
Equateur	99.8	98.7	98.9	95.7	87.1
Haut Katanga	89.6	95.0	88.9	89.7	83.8
Haut Lomami	91.0	95.9	91.5	91.5	86.7
Haut Uele	90.6	88.8	87.6	86.0	76.4
Ituri	99.2	95.5	95.4	88.8	80.0
Kongo Central	93.7	93.7	93.7	93.7	97.6
Kasai Oriental	99.8	100.0	99.5	97.6	94.9
Kwango	100.0	100.0	99.5	99.7	98.4
Kwilu	100.0	99.8	100.0	92.8	87.1
Kinshasa	96.6	98.1	98.5	98.1	98.5
Kasai Central	97.3	98.0	98.7	99.6	99.5
Kasai	97.3	99.8	99.5	99.7	98.9
Lualaba	87.6	91.6	93.3	93.8	95.5
Lomami	99.9	97.0	98.2	98.9	95.5
Maindombe	97.8	95.2	94.7	85.5	77.8
Mongala	100.0	99.6	100.0	98.8	87.3
Maniema	100.0	95.6	96.3	95.8	100.0
Nord Kivu	97.1	96.4	96.3	81.3	67.4
Nord Ubangi	98.7	99.6	98.7	95.1	93.7
Sud Kivu	83.5	78.7	77.4	76.8	71.7
Sankuru	99.1	73.4	71.3	84.7	87.3
Sud Ubangi	100.0	100.0	99.7	91.9	84.1
Tanganyika	73.3	29.5	25.8	38.2	14.9
Tshopo	99.9	99.6	100.0	87.4	72.0
Tshuapa	100.0	100.0	99.8	99.3	99.3

Extracted from the DRC RHIS January 7, 2022. The DRC RHIS is only available in French.

Table 4. Rate of new acceptors of modern contraceptive methods per 1,000 WRA (primary analysis)

	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Bonferroni-corrected p-value
Intervention facility*Post intervention period (DID est.)	1.59 [-0.5, 3.7]	0.0003	0.1758	1
Intervention facility	-0.25 [-1.65, 1.1]	0.4821	0.7752	
Post intervention period	-1.63 [-5.49, 2.05]	0.4438	0.3766	
Educational attainment - WRA	-1.84 [-2.58, -1.1]	<0.0001	0.001	
Prevalence of improved housing	-4.48 [-12.52, 3.11]	0.0535	0.4406	
Rainfall: 3-month average (Mar/Apr/May)	0.56 [-0.29, 1.37]	0.0008	0.1988	
NDVI: 3-month average (Mar/Apr/May)	-4 [-12.97, 4.48]	0.067	0.4895	
Urban health zone	0.38 [-1.22, 1.93]	0.2812	0.6643	

*WCB – wild cluster bootstrap; DID est. – difference-in-differences estimate; NDVI – normalized difference vegetation index. * denotes an interaction term.*

Table 5. Rate of attendance at the fourth ANC visit per 1,000 WRA (primary analysis)

	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Bonferroni-corrected p-value
Intervention facility*Post intervention period (DID est.)	0.24 [-0.38, 0.87]	0.0791	0.4615	1
Intervention facility	0.34 [-0.07, 0.74]	0.0006	0.2128	
Post intervention period	-0.09 [-1.45, 1.25]	0.9078	0.9021	
Educational attainment - WRA	-0.58 [-0.88, -0.29]	<0.0001	0.001	
Prevalence of improved housing	-4.56 [-9.98, 0.57]	<0.0001	0.2098	
Rainfall: 3-month average (Mar/Apr/May)	0.17 [-0.17, 0.52]	0.0018	0.4006	
NDVI: 3-month average (Mar/Apr/May)	-3.58 [-6.62, -0.65]	<0.0001	0.0579	
Urban health zone	-0.85 [-1.71, 0.02]	<0.0001	0.0759	

*WCB – wild cluster bootstrap; DID est. – difference-in-differences estimate; NDVI – normalized difference vegetation index. * denotes an interaction term.*

Table 6. Rate of ITN distribution during ANC visits per 1,000 WRA (primary analysis)

	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Bonferroni-corrected p-value
Intervention facility*Post intervention period (DID est.)	0.37 [-0.28, 1.02]	0.0719	0.2068	1
Intervention facility	-0.44 [-1.01, 0.14]	0.0004	0.2587	
Post intervention period	-1.13 [-2.86, 0.66]	0.211	0.1868	
Educational attainment - WRA	-0.94 [-1.53, -0.35]	<0.0001	0.001	
Prevalence of improved housing	-2.05 [-9.5, 5.48]	0.1495	0.6973	
Rainfall: 3-month average (Mar/Apr/May)	0.15 [-0.25, 0.55]	0.0545	0.6074	
NDVI: 3-month average (Mar/Apr/May)	1.44 [-3.49, 6.37]	0.1782	0.6014	
Urban health zone	-0.65 [-1.7, 0.4]	0.0004	0.1439	

*WCB – wild cluster bootstrap; DID est. – difference-in-differences estimate; NDVI – normalized difference vegetation index. * denotes an interaction term.*

Table 7. Rate of live births per 1,000 WRA (primary analysis)

	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Bonferroni-corrected p-value
Intervention facility*Post intervention period (DID est.)	0.44 [-0.12, 1.01]	0.0041	0.1399	1
Intervention facility	-0.33 [-0.61, -0.05]	0.0032	0.1518	
Post intervention period	-0.2 [-1.68, 1.32]	0.8223	0.7862	
Educational attainment - WRA	-0.89 [-1.38, -0.44]	<0.0001	0.001	
Prevalence of improved housing	-0.99 [-8.16, 6.63]	0.2139	0.8392	
Rainfall: 3-month average (Mar/Apr/May)	0.43 [0.08, 0.79]	<0.0001	0.012	
NDVI: 3-month average (Mar/Apr/May)	0.5 [-3, 4.12]	0.513	0.8042	
Urban health zone	-0.72 [-1.61, 0.2]	<0.0001	0.1239	

*WCB – wild cluster bootstrap; DID est. – difference-in-differences estimate; NDVI – normalized difference vegetation index. * denotes an interaction term.*

Table 8. Rate of live births <2,500 grams per 1,000 WRA (primary analysis)

	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Bonferroni-corrected p-value
Intervention facility*Post intervention period (DID est.)	-0.18 [-0.56, 0.2]	0.2471	0.4276	1
Intervention facility	0 [-0.21, 0.21]	0.9712	0.975	
Post intervention period	-0.34 [-1.12, 0.43]	0.6438	0.6723	
Educational attainment - WRA	0 [-0.12, 0.11]	0.9327	0.9361	
Prevalence of improved housing	-0.79 [-2.24, 0.65]	0.2533	0.2697	
Rainfall: 3-month average (Mar/Apr/May)	-0.05 [-0.18, 0.08]	0.3921	0.4645	
NDVI: 3-month average (Mar/Apr/May)	-0.13 [-1.1, 0.83]	0.8396	0.7732	
Urban health zone	-0.1 [-0.41, 0.21]	0.4249	0.5455	

*WCB – wild cluster bootstrap; DID est. – difference-in-differences estimate; NDVI – normalized difference vegetation index. * denotes an interaction term.*

Table 9. Rate of exclusive breastfeeding per 1,000 children under 6 months (primary analysis)

	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Bonferroni-corrected p-value
Intervention facility*Post intervention period (DID est.)	44.92 [-7.49, 97.28]	0.0002	0.1179	1
Intervention facility	33.63 [8.7, 58.66]	0.0001	0.0589	
Post intervention period	-85.14 [-164.22, -6.92]	0.0544	0.0539	
Educational attainment - WRA	-25.68 [-49.67, -1.11]	<0.0001	0.1079	
Prevalence of improved housing	62.47 [-262.64, 387.76]	0.2855	0.7003	
Rainfall: 3-month average (Mar/Apr/May)	-2.83 [-28.63, 23.24]	0.5513	0.8771	
NDVI: 3-month average (Mar/Apr/May)	-22.75 [-362.95, 325]	0.6961	0.9041	
Urban health zone	7.1 [-61.98, 77.87]	0.446	0.8511	

*WCB – wild cluster bootstrap; DID est. – difference-in-differences estimate; NDVI – normalized difference vegetation index. * denotes an interaction term.*

Table 10. Rate of measles vaccination per 1,000 children ages 6–59 months (primary analysis)

	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Bonferroni-corrected p-value
Intervention facility*Post intervention period (DID est.)	0.8 [-0.09, 1.65]	<0.0001	0.0729	0.8748
Intervention facility	-0.03 [-0.64, 0.64]	0.8028	0.9311	
Post intervention period	-0.72 [-2.05, 0.55]	0.3535	0.2877	
Educational attainment - WRA	-1.09 [-1.51, -0.66]	<0.0001	0.001	
Prevalence of improved housing	4.78 [-0.08, 9.52]	<0.0001	0.043	
Rainfall: 3-month average (Mar/Apr/May)	0.11 [-0.44, 0.7]	0.1344	0.6833	
NDVI: 3-month average (Mar/Apr/May)	3.15 [-2.3, 8.3]	0.0006	0.3127	
Urban health zone	-0.87 [-2.28, 0.49]	<0.0001	0.2368	

*WCB – wild cluster bootstrap; DID est. – difference-in-differences estimate; NDVI – normalized difference vegetation index. * denotes an interaction term.*

Table 11. Rate of pentavalent vaccination per 1,000 children ages 6–59 months (primary analysis)

	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Bonferroni-corrected p-value
Intervention facility*Post intervention period (DID est.)	0.78 [0, 1.53]	<0.0001	0.045	0.54
Intervention facility	-0.11 [-0.59, 0.4]	0.4374	0.7063	
Post intervention period	-0.54 [-1.89, 0.75]	0.4822	0.4346	
Educational attainment - WRA	-0.97 [-1.4, -0.54]	<0.0001	0.001	
Prevalence of improved housing	4.45 [-1.34, 10.49]	<0.0001	0.0799	
Rainfall: 3-month average (Mar/Apr/May)	0.16 [-0.42, 0.74]	0.0336	0.5884	
NDVI: 3-month average (Mar/Apr/May)	3.36 [-2.98, 9.59]	0.0003	0.3616	
Urban health zone	-1.09 [-2.93, 0.68]	<0.0001	0.2767	

*WCB – wild cluster bootstrap; DID est. – difference-in-differences estimate; NDVI – normalized difference vegetation index. * denotes an interaction term.*

Table 12. Rate of moderate acute malnutrition per 1,000 children ages 6–59 months (primary analysis)

	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Bonferroni-corrected p-value
Intervention facility*Post intervention period (DID est.)	3.75 [-1.34, 8.83]	0.0002	0.1648	1
Intervention facility	1.97 [-0.46, 4.43]	0.0157	0.3726	
Post intervention period	4.83 [-0.79, 10.39]	0.1506	0.1528	
Educational attainment - WRA	-2.2 [-4.28, -0.23]	<0.0001	0.0769	
Prevalence of improved housing	-1.17 [-16.25, 14.62]	0.8119	0.8771	
Rainfall: 3-month average (Mar/Apr/May)	-0.83 [-2.73, 1.12]	0.0314	0.4366	
NDVI: 3-month average (Mar/Apr/May)	16.28 [1.34, 31.62]	0.0025	0.0889	
Urban health zone	-3.91 [-8.05, 0.37]	<0.0001	0.1159	

*WCB – wild cluster bootstrap; DID est. – difference-in-differences estimate; NDVI – normalized difference vegetation index. * denotes an interaction term.*

Table 13. Rate of complicated malaria treatment per 1,000 children ages 6–59 months (primary analysis)

	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Bonferroni-corrected p-value
Intervention facility*Post intervention period (DID est.)	-1.48 [-3.34, 0.42]	0.0313	0.1019	1
Intervention facility	0.83 [-1.05, 2.66]	0.1222	0.5105	
Post intervention period	-2.01 [-5.43, 1.46]	0.1035	0.1678	
Educational attainment - WRA	-0.51 [-1.18, 0.15]	0.0181	0.1149	
Prevalence of improved housing	-9.5 [-26.31, 8.24]	0.0049	0.1499	
Rainfall: 3-month average (Mar/Apr/May)	0.59 [-0.63, 1.87]	0.0135	0.3626	
NDVI: 3-month average (Mar/Apr/May)	-7.1 [-25.28, 12.08]	0.0252	0.4026	
Urban health zone	-2.04 [-3.32, -0.72]	<0.0001	0.019	

*WCB – wild cluster bootstrap; DID est. – difference-in-differences estimate; NDVI – normalized difference vegetation index. * denotes an interaction term.*

Table 14. Rate of complicated diarrhea/dehydration treatment per 1,000 children ages 6–59 months (primary analysis)

	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Bonferroni-corrected p-value
Intervention facility*Post intervention period (DID est.)	0.73 [0.37, 1.1]	0.0167	0.001	0.012
Intervention facility	-0.69 [-1.01, -0.39]	0.0037	0.001	
Post intervention period	-0.48 [-1.04, 0.06]	0.1868	0.1718	
Educational attainment - WRA	-0.09 [-0.21, 0.04]	0.3067	0.3197	
Prevalence of improved housing	-0.74 [-2.69, 1.19]	0.5828	0.5534	
Rainfall: 3-month average (Mar/Apr/May)	0.28 [0.05, 0.52]	0.0062	0.2298	
NDVI: 3-month average (Mar/Apr/May)	1.41 [-0.64, 3.41]	0.3283	0.2597	
Urban health zone	-0.65 [-1.14, -0.17]	0.0133	0.02	

*WCB – wild cluster bootstrap; DID est. – difference-in-differences estimate; NDVI – normalized difference vegetation index. * denotes an interaction term.*

Table 15. Rate of complicated pneumonia treatment per 1,000 children ages 6–59 months (primary analysis)

	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Bonferroni-corrected p-value
Intervention facility*Post intervention period (DID est.)	1.59 [0.32, 2.86]	0.0485	0.023	0.276
Intervention facility	-1.95 [-3.1, -0.8]	0.0017	0.001	
Post intervention period	-0.61 [-1.99, 0.77]	0.5024	0.5065	
Educational attainment - WRA	-0.43 [-0.95, 0.1]	0.08	0.1738	
Prevalence of improved housing	4.06 [-2.5, 10.64]	0.3446	0.2308	
Rainfall: 3-month average (Mar/Apr/May)	1.15 [0.01, 2.27]	<0.0001	0.1229	
NDVI: 3-month average (Mar/Apr/May)	6.19 [1.95, 10.49]	0.1265	0.007	
Urban health zone	-1.59 [-2.35, -0.83]	0.0324	0.011	

*WCB – wild cluster bootstrap; DID est. – difference-in-differences estimate; NDVI – normalized difference vegetation index. * denotes an interaction term.*

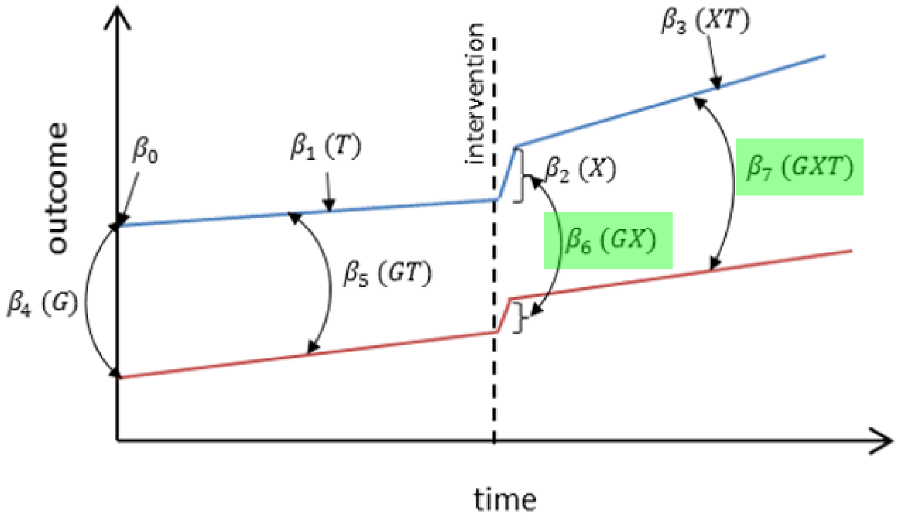
Table 16. Controlled interrupted time series regression results for level and slope terms

	Live Births	ITNs at ANC1	Tx Uncomplicated Malaria	Tx Uncomplicated Diarrhea	Tx Uncomplicated Pneumonia
	Total Births	ANC1	Uncomplicated Malaria	Uncomplicated Diarrhea	Uncomplicated Pneumonia
	3,555 matched pairs	913 matched pairs	3,424 matched pairs	2,482 matched pairs	2,303 matched pairs
	IRR [95% CI]	**IRR [95% CI]**	**IRR [95% CI]**	**IRR [95% CI]**	**IRR [95% CI]**
Difference between the change in level in the comparison and intervention groups associated with the intervention	1.15 [0.60, 2.22]	1.18 [0.96, 1.46]	1.68 [0.80, 3.55]	*0.62 [0.39, 1.00]	0.93 [0.50, 1.74]
Difference between the change in slope in the comparison and intervention groups associated with the intervention	1.04 [0.99, 1.09]	1.01 [1.00, 1.02]	*1.04 [1.00, 1.09]	**1.04 [1.01, 1.07]	**1.05 [1.02, 1.09]

ITN= insecticide-treated bed net; *ANC1*= first antenatal care clinic visit; *Tx*= treatment; *IRR*= incidence rate ratio; *CI*= confidence interval

*p<0.05; **p<0.01; ***p<0.001

Figure 10. Visual representation of a controlled interrupted time series with a single event



$$Y_t = \beta_0 + \beta_1 T + \beta_2 X_t + \beta_3 T X_t + \beta_4 G + \beta_5 G T + \beta_6 G X_t + \beta_7 G X_t T$$

T is a continuous count of time since the beginning of the time series, X is a marker of when the intervention starts (0 for preintervention and 1 for postintervention), and G is a binary variable for group (0 for comparison sites and 1 for intervention sites). B6 provides an estimate of the intervention effect immediately following implementation. B7 provides an estimate of postintervention slope differences between the control and intervention groups and gives an indication of the longer-term effect of the intervention. Source: Lopez Bernal, Cummins, & Gasparrini, 2018.

Data for Impact
University of North Carolina at Chapel Hill
123 West Franklin Street, Suite 330
Chapel Hill, NC 27516 USA
Phone: 919-445-9350 | Fax: 919-445-9353
D4I@unc.edu
http://www.data4impactproject.org

This publication was produced with the support of the United States Agency for International Development (USAID) under the terms of the Data for Impact (D4I) associate award 7200AA18LA00008, which is implemented by the Carolina Population Center at the University of North Carolina at Chapel Hill, in partnership with Palladium International, LLC; ICF Macro, Inc.; John Snow, Inc.; and Tulane University. The views expressed in this publication do not necessarily reflect the views of USAID or the United States government. TR-23-36 D4I