USAID Integrated Health Program Evaluation Report

Impact Evaluation Results

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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 six years of the United States Agency for International Development (USAID) Integrated Health Program's (IHP) implementation in nine provinces of the Democratic Republic of the Congo (DRC). The IHP focuses, in part, on increasing utilization of health facility-based maternal and child healthcare and family planning services. The impact evaluation investigates the extent to which changes in healthy behaviors and health outcomes are 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 only led to the exclusion of 2.3 percent (104 of 4,504) of intervention facilities and 1.5 percent (101 of 6,937) 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, significant changes were observed in six of the 13 RHIS indicators. Five of the significant changes suggested impacts in the anticipated direction. Of these, the largest magnitude was observed for new acceptors of modern contraceptive methods, adding an additional 4.06 women per 1,000 women of reproductive age when compared to non-intervention areas. A significant change in the unanticipated direction was observed for complicated malaria treatment, which decreased by 3.18 cases per 1,000 children under 5 years of age. The remaining seven of the 13 indicators did not show significant changes.

For future projects, USAID may draw its attention to those indicators that show little to no movement in the anticipated direction, such as treatment of complicated malaria, and prevalence of malnutrition in children, and consider whether any adjustments are warranted in future programs. Findings from this portion of the evaluation will be triangulated with those from the health system surveys and the qualitative data collection, and D4I will make final recommendations in the endline evaluation report.

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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
IRBs	Institutional Review Boards
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 achievement of the following overall performance objectives:

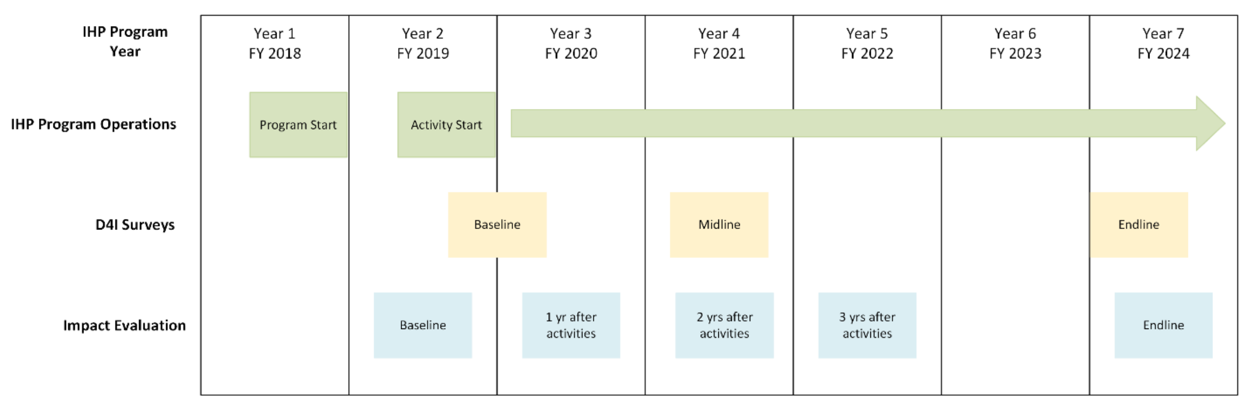
- **Objective 1**: Strengthen health systems, governance, and leadership at the provincial, health zone (HZ), and facility levels in target health zones.
- **Objective 2**: Increase access to quality, integrated health services in target health zones.
- **Objective 3**: Increase adoption of healthy behaviors,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

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/DRC Mission 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 FP and health care 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 below shows the timing of program rollout 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 provided more comprehensive support to a limited subset of 60 HZs across the nine provinces. These 60 HZs were considered to 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—could best leverage resources to improve health outcomes. This activity stratification in the USAID IHP target provinces was used as the basis for a secondary analysis, as described in the Methods section.

Methods and Limitations

Methods

D4I conducted two types of evaluation components for this study: a performance evaluation and 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 addressed in the evaluation were:

1. Did the expected changes in outcomes and impacts occur?
    a. Strengthen health systems, governance, and leadership at provincial, health zone (HZ), and facility levels in target HZs.
    b. Increase access to quality, integrated health services in target HZs.
    c. Increase 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 these attributable to USAID IHP?
3. Did the project contribute to gender equity in health services and within the health system?
4. What factors enabled or limited the success of USAID IHP?

The performance evaluation aspect of the study addressed Research Questions 1, 3, and 4. Data for this component of the study were collected from multiple sources, including: the DRC's routine health information system (RHIS); surveys of healthcare facilities, health zone 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—addressed Research Question 2. The impact evaluation used a quasi-experimental design based on a propensity score matched difference-in-differences model fit to RHIS data. Ethical approval for this work was provided by the Institutional Review Boards (IRBs) of Tulane University and the Kinshasa School of Public Health.

Analysis of Impact Using a Difference-in-Differences Model Five 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 may 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 an 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 which collects health facility data monthly. The unit of analysis is the facility and as the program was implemented at the province level, a random effect was included to account for this in regression modeling. Additionally, 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 267 and a high of 2,329), wild cluster bootstrapping 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 Benjamini-Hochberg procedure (1995).

The intervention arm included facilities from within health zones in USAID IHP provinces (including both hospitals and health centers) in the preintervention (June 2018–May 2019) and postintervention (June 2019–July 2024) periods. All facilities from within IHP-targeted provinces were exposed to IHP activities. The comparison arm included facilities within comparable and non-excluded health zones from provinces not receiving USAID IHP support. Excluded health zones were those that were supported by a previous and intensive health systems strengthening project (the Access to Primary Health Care program going by the French acronym *ASSP*) which was active in Kasaï, Nord Ubangi, and Sud Ubangi provinces. Additionally, health zones that experienced Ebola virus disease (EVD) outbreaks (N=33) were also removed from consideration as certain policies were enacted in these affected health zones that were designed to increase health service utilization. Only one of the 33 health zones affected by EVD is in an IHP target province. Nearly 85 percent of the EVD-affected health zones 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 encompass two of our outcomes of interest. A previous analysis

[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 (HSS) evaluation literature, “impact” is also often used to refer to the effects on service delivery or other aspects of health systems functioning (Adams, et al., 2012). For the purposes of this evaluation, we use “impact” in the latter sense unless otherwise noted.

showed similar findings following the enactment of a free care policy across EVD-affected health zones 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 et al, 2008; Hyndman et al, 2022) of R (R Core Team, 2021) was used to interpolate health facility time series. Note that each successive analysis takes advantage of a longer time series than predecessor analyses. This scenario may help to establish a more robust seasonal component to individual health facility time series trends, which is exploited during the interpolation process. Health facility time series with gaps of 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 pulled population statistics for health areas and health zones directly from the RHIS. As these were overall population counts, we calculated 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 within the United Nations. Hospital-based rates were calculated using their respective health zone 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 reflect three-month averages for March–May of 2019, which were compared to averages spanning the same three months in 2024. These three months were specifically chosen as they immediately precede the onset of IHP activity implementation (June 2019). Due to the variable nature of data availability within 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 are used to adjust for observed confounders to produce more valid causal effect estimates. This covariate balancing is the degree to which the distribution of covariates is similar across intervention assignment. Covariate balancing requires proper model specification to avoid biased estimates. Researchers may 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 which 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 which we used to build our gradient boosted model.

The objective of the PSM process was to match a pool of health facilities from the comparison provinces to those in the intervention provinces such that the distributions of selected RHIS indicators were similar between the two groups. This process helps to 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) Other new cases
4) Suspected malaria
5) Confirmed uncomplicated malaria
6) Uncomplicated diarrhea
7) Uncomplicated pneumonia
8) New pregnancies
9) Sulfadoxine/pyrimethamine dose 1
10) Antenatal care clinic visits 1, 2, and 3
11) Births
12) 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 infers that the comparison units provide 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). Additionally, a formal statistical test was used to assess equality of trends using a 12-month preintervention period.

Before the DID analyses were conducted, 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—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 2024 that corresponded to the timeframe for which average estimates were taken for the outcome indicators identified for use in the DID analyses. Missing vegetation index data for March 2024 was estimated using linear interpolation. Health zone-level estimates were obtained for 2015 prevalence of improved housing and for 2014 educational attainment of women of reproductive age, the last time such published measures were estimated. Health zone 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 health zone.

The DID linear regression model can be defined as follows:

$$Yit = \alpha + \beta Ti + \gamma At + \delta(Ti \times At) + COVSit + COVSi + \epsilon it$$

where *Yit* is the outcome of interest for facility *i* at time *t*, *Ti* indexes health facilities in the intervention health zones, *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 $\delta=0$ is tested to determine whether the IHP intervention had an effect as δ represents 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 9). 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 complicated 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

A nursing strike that took place in 2021 led to disruptions. Initially the strike was composed of non-medical nursing staff but soon expanded to include nurses and administrators. The provinces most affected by the strike were Tanganyika, Haut-Katanga, Sankuru, Lomami, and Sud-Kivu. Health facilities were temporarily closed due to a lack of available staff in some areas. However, in Lualaba, Haut-Katanga, and Kasai-Central, provincial authorities were able to work with providers to continue activities in collaboration with other partners. The strike 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 the outcome values was after the nurses' strike, 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 are several limitations of the impact evaluation.

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 are not available from non-project areas, impacts on these aspects cannot be rigorously assessed. However, to descriptively explore these aspects, a performance evaluation was 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 of the study was based on routine data from the RHIS. Although it is 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) provides power and cost advantages over a research design based on intermittent population-based surveys, poor data quality remains 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 is a random measurement error, it will 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 is 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 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] was accounted for through the estimation of robust standard errors. Additionally, the RHIS indicators used as

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

outcomes for this evaluation are not sex-disaggregated, making an assessment of gender-related differences impossible to perform. However, despite the lack of data on sex and gender, several indicators included in the analysis are focused on women's experiences as they relate to women's and children's wellbeing, such as new modern contraceptive acceptors, antenatal care clinic visits, birth rate, resuscitated births, low birth weight births, and exclusive breastfeeding.

Results

Data Processing

Table 1 shows the effects of the data cleaning process. Just over 23,000 health facility records were pulled from the RHIS—a complete take for the country. After removing those provinces and health zones that previously received intensive health systems strengthening support or experienced policies meant to boost overall clinic volumes in the face of EVD epidemics, a loss of 3,115 health facility records was noted. An additional 326 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 67.76% (i.e., on average, each data set for each individual data element had 67.76% of its data missing/blank). The data set for treatment of complicated diarrhea/dehydration was about 92% blank. The most well-reported data element among the 13 selected as outcomes was live births with only about 36.57% of its data missing/blank. Few data points were identified (and removed) as outliers comprising, on average, only about 0.11% of available, non-missing values. We arbitrarily set a decision rule to remove health facility records with seven or more consecutive missing values, which allows for a liberal run of missing values. Final data sets ranges from 453 health facility records (treatment of complicated diarrhea/dehydration) to 10,525 records (live births). Data availability across these final data sets averaged at about 85% with a high of 93.28% (live births) to a low of 74.37% (live births <2,500g). The final data sets were those across which interpolation was conducted.

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

	Data Cleaning Steps						Interpolation Step	
Routine Health Information System Data Element	Total health facility record count	Count after removal of ASSP and EVD-affected areas	Count after removal of records with no data	Percent of missing data points	Percent of non-missing data points removed as outliers	Percent of records removed with ≥7 consecutive missing values	Available health facility records (final)	Percent of non-missing data points (final)
New acceptors of modern contraceptive methods	23,120	20,005	19,679	64.35%	0.17%	77.93%	4,344	90.28%
Attendance at the fourth ANC visit	23,120	20,005	19,679	44.47%	0.10%	54.51%	8,952	92.95%
Insecticide-treated bed net distribution during ANC visits	23,120	20,005	19,679	56.32%	0.09%	72.28%	5,455	81.26%
Live births	23,120	20,005	19,679	36.57%	0.12%	46.52%	10,525	93.30%
Live births <2,500g	23,120	20,005	19,679	87.75%	0.07%	95.67%	852	74.38%
Exclusive breastfeeding	23,120	20,005	19,679	57.52%	0.13%	68.08%	6,281	89.22%
Measles vaccination	23,120	20,005	19,679	56.49%	0.21%	62.30%	7,418	90.77%
Pentavalent vaccination	23,120	20,005	19,679	55.73%	0.20%	61.97%	7,484	91.45%
Moderate malnutrition	23,120	20,005	19,679	74.68%	0.14%	85.13%	2,926	86.61%
Complicated malaria treatment	23,120	20,005	19,679	78.53%	0.06%	88.95%	2,175	88.39%
Complicated diarrhea/dehydration treatment	23,120	20,005	19,679	92.18%	0.02%	97.70%	453	79.72%
Complicated pneumonia treatment	23,105	19,994	19,668	87.65%	0.04%	95.06%	973	82.98%
Newborns not breathing at birth who were resuscitated	23,120	20,005	19,679	88.64%	0.04%	95.73%	841	75.33%

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** of Appendix 1 shows that each of the propensity score weighted absolute standardized mean difference values was below the five percent threshold as well. Restricting the propensity scores to a region of common support only led to the exclusion of 2.3 percent (104 of 4,504) of intervention facilities and 1.5 percent (101 of 6,937) of comparison facilities (**Figure 5** of Appendix 1).

Common Trends

The common trends assumption suggests 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 group in the preintervention these indicators proved unsuccessful. To formally test the assumption of common trends, we separately regressed each of the 13 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 health zone status, hospital facility, prevalence of improved housing (health zone level), and educational attainment of women of reproductive age (health zone 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 (note that intervention facilities were ascribed a weight of 1). The p-values reported in **Figures 6a**, **6b** and **6c** of Appendix 1 are for the coefficients of the interaction term, which shows whether the comparison and intervention groups demonstrated a different time trend prior to 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 can expect that the common trend assumption is plausible for the indicators, apart from new acceptors of modern contraceptive methods, measles vaccinations of children under 5, and rate of ITN distribution at ANC visits. The interpretation of these latter indicators should be taken with caution.

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). Three RHIS indicators did not satisfy the common trends assumption (i.e., new acceptors of modern contraceptive methods, live births and moderate acute malnutrition). 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 13 RHIS indicators assessed. **Figures 2a**, **2b**, and **2c** graphically show the DID regression results for the primary outcomes. A similar table (**Table 3** in Appendix 1) and figures (Figures **8a**, **8b**, and **8c** in Appendix 1) were generated for the scenario that compared USAID IHP HZs receiving intensified support with USAID IHP HZs receiving the standard intervention package.

Although 10 of the 13 indicators showed significant differences between 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 0.71 cases higher per 1,000 WRA relative to the rate of live births across comparison sites. This difference was significant (unadjusted p-value < 0.001) 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 and the Benjamini-Hochberg adjusted p-values for live births were not statistically significant. Similarly, the rate of live births in USAID IHP HZs receiving intensive support was virtually identical to comparison IHP HZs (DID estimator = -0.04; p-value = 0.8792). The cITS analysis showed an immediate non-significant increase in live births (incidence rate ratio [IRR] [95% confidence interval]: 1.16 [0.90, 1.5], p-value=0.2456) and a significant, slight increase in the longer-term trend of live births (IRR [95% CI]: 1.02 [1, 1.03], p-value=0.0414) across intervention sites relative to comparison sites.

Based on both unadjusted and adjusted p-values, the DID estimator for ITNs distributed during ANC visits demonstrated weak evidence, with 0.76 more ITNs distributed per 1,000 population of WRA across intervention sites relative to comparison sites. However, the common trends assumption was not satisfied for this estimator. 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 ANC visits was 0.13 fewer ITNs distributed per 1,000 population of WRA; however, this finding was not significant. The cITS analysis suggested a slight immediate increase in ITNs distributed during ANC clinic visits (IRR [95% CI]: 1.22 [0.62, 2.43], p-value=0.5649) and virtually no change in the longer-term trend (IRR [95% CI]: 1.01 [0.97, 1.06], p-value=0.5930) at intervention sites relative to comparison sites.

Based on the unadjusted p-values, the DID estimator for treatment of complicated pneumonia treatment demonstrated evidence for 2.15 more treated cases per 1,000 population of children under five years across intervention sites relative to matched comparison sites. For this analysis, both the WCB adjusted p-value and the Benjamini-Hochberg adjusted p-value were significant. 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 0.55 more per 1,000 children under five years; however, this finding was not significant. The cITS analysis suggested an immediate and non-significant increase in treatment of uncomplicated pneumonia cases (IRR [95% CI]: 1.16 [0.66, 2.05], p-value=0.5974) but a slight positive and significant change in the longer-term trend (IRR [95% CI]: 1.05 [1.02, 1.09], p-value=0.0006) for children under five years among intervention sites relative to comparison sites.

Based on the unadjusted p-values, the DID estimator for treatment of complicated malaria treatment demonstrated evidence for 3.19 fewer treated cases per 1,000 population of children under five years across intervention sites relative to matched comparison sites. For this analysis, both the WCB adjusted p-value, and the Benjamini-Hochberg adjusted p-value were statistically significant. 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 malaria treatment in the intensified activity areas was only 0.19 more per 1,000 children under five years; however, this finding was not significant. The cITS analysis suggested an immediate and non-significant increase in treatment of uncomplicated malaria cases (IRR [95% CI]: 1.31 [0.76, 2.27], p-value=0.3290) but a slight positive change in the longer-term trend (IRR [95% CI]: 1.02 [0.99, 1.05], p-value=0.1445) for children under five years among intervention sites relative to comparison sites. The observed trend change was not significant.

Only two further indicators—the rate of SP1 dose distribution at ANC1 and the treatment rate of uncomplicated diarrhea—had sufficient data to conduct the cITS analysis. Neither indicator suggested a significant level change between the comparison and intervention groups. However, the p-value suggested a small, sustained increase in the treatment rate of uncomplicated diarrhea in IHP intervention areas. The results of the cITS analyses are presented in **Table 16** in Appendix 1.

The indicators for new acceptors of modern contraceptive methods and measles vaccination observed significant increases in both unadjusted and adjusted p-values. The DID estimator for new acceptors of modern methods indicated 4.06 additional women per 1,000 WRA in the intervention facilities compared to the comparison facilities (**Table 2**). In the analysis comparing IHP HZs receiving intensified support versus IHP HZs receiving the standard intervention package, the DID estimator showed that rate in the intensified activity areas was 0.93 fewer women per 1,000 WRA; however, this finding was not significant (**Table 3**). Similarly, in the IHP intervention facilities, the rate of measles vaccinations was 1.15 vaccinations higher per 1,000 children under five years than in comparison facilities (**Table 2**). When comparing IHP HZs receiving intensified support versus IHP HZs receiving the standard intervention package, the DID estimator showed that rate in the intensified activity areas was 0.29 fewer measles vaccinations per 1,000 children under 5 years of age; however, this value was also not significant (**Table 3).** It should be noted that neither indicator satisfied the common trends assumption required by DID analysis and the results should therefore be interpreted with caution (Figure 6a and 6b).

Based on the unadjusted p-values, the DID estimator for exclusive breastfeeding demonstrated evidence for 92.86 more cases per 1,000 population of children under six months across intervention sites relative to matched comparison sites (Table 2). However, neither the WCB or the Benjamini-Hochberg p-values were significant. In the analysis comparing IHP HZs receiving intensified support versus IHP HZs receiving the standard intervention package, the DID estimator showed a significant decrease of 71.61 cases per 1,000 children under six months in HZs receiving intensified support compared to those receiving the standard package (Table 3).

Tables 4–15 in Appendix 1 show detailed results from the 13 DID regressions (primary outcomes).

Figure 2a. Graphical depictions of the difference-in-differences analyses by RHIS indicator

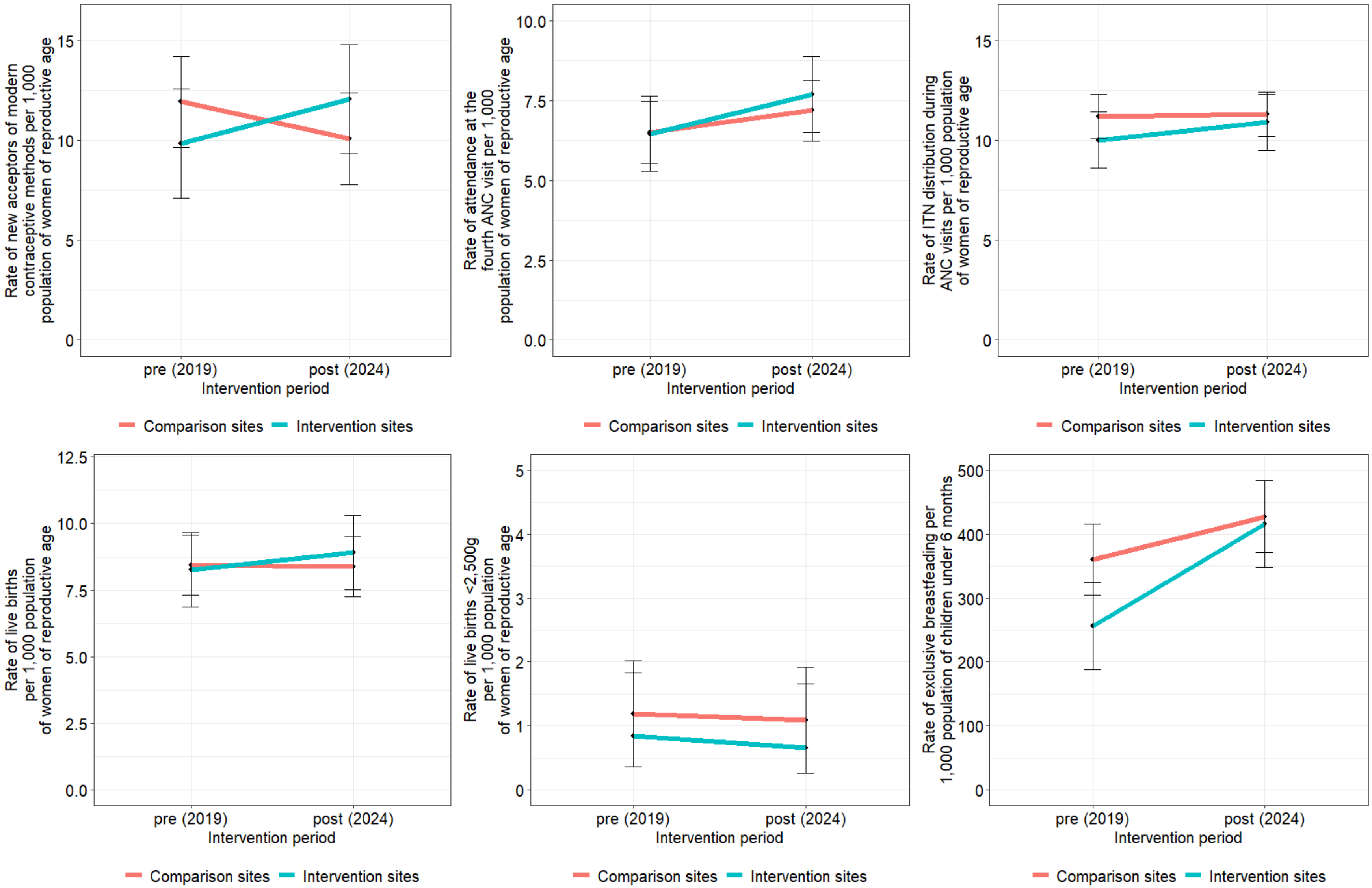


Figure 2b. Graphical depictions of the difference-in-differences analyses by RHIS indicator

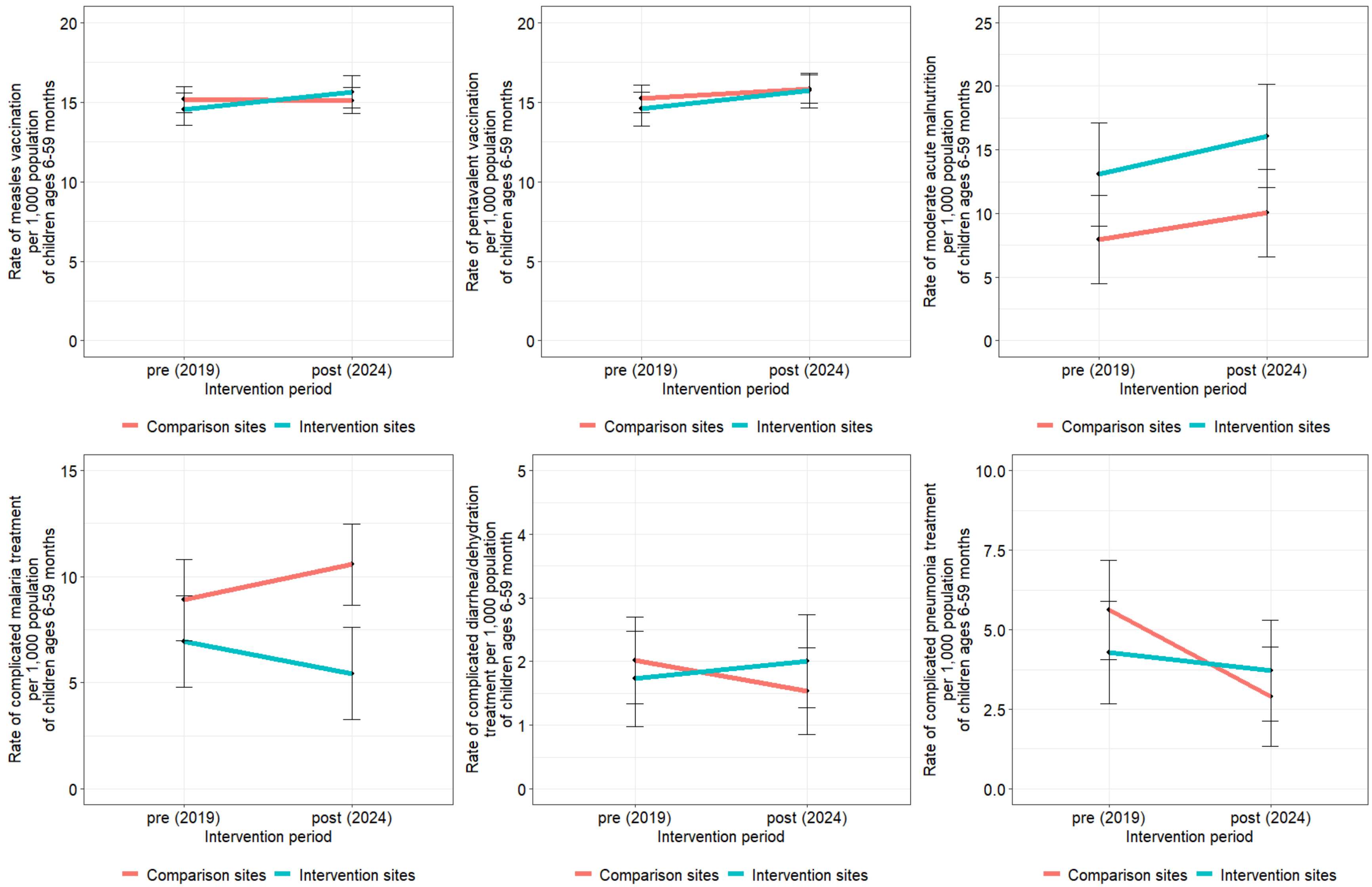


Figure 2c. Graphical depictions of the difference-in-differences analyses by RHIS indicator

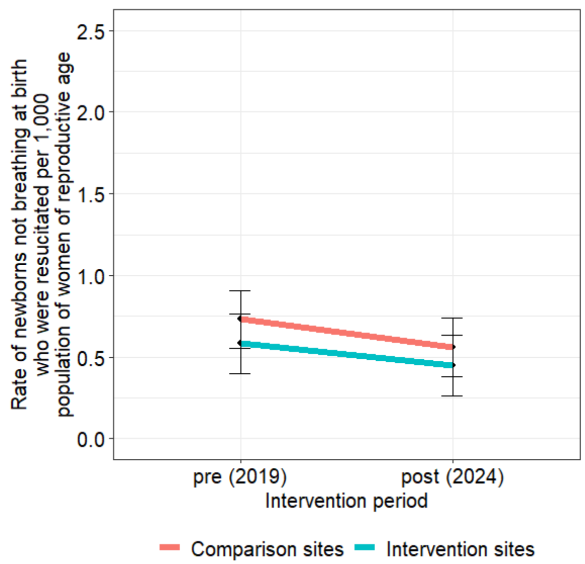


Table 2. Summary of difference-in-differences estimators by assessed RHIS indicator

RHIS indicator	2019 vs 2024			
	DID estimator [WCB 95% CI]	Unadjusted p-value	WCB p-value	Benjamini-Hochberg adjusted p-value
New acceptors of modern contraceptive methods per 1,000 WRA*	4.06 [1.18, 6.95]	***< 0.001***	***0.022***	***0.048***
Attendance at the fourth ANC visit per 1,000 WRA	0.55 [-0.32, 1.42]	***< 0.001***	0.230	0.332
Insecticide-treated bed net distribution during ANC visits per 1,000 WRA*	0.76 [0.19, 1.31]	***< 0.001***	***0.013***	***0.048***
Live births per 1,000 WRA	0.71 [-0.08, 1.49]	***< 0.001***	0.105	0.170
Live births <2,500g per 1,000 WRA	-0.08 [-0.4, 0.24]	0.643	0.668	0.668
Exclusive breastfeeding per 1,000 children under-6 months	92.86 [-0.65, 184.79]	***< 0.001***	0.061	0.113
Measles vaccination per 1,000 children under-5 years*	1.15 [0.29, 2.01]	***< 0.001***	***0.019***	***0.048***
Pentavalent vaccination per 1,000 children under-5 years	0.53 [-0.44, 1.49]	***0.008***	0.310	0.403
Moderate malnutrition per 1,000 children under-5 years	0.92 [-1.74, 3.56]	***0.018***	0.550	0.649
Complicated malaria treatment per 1,000 children under-5 years	-3.19 [-6.03, -0.51]	***< 0.001***	***0.007***	***0.046***
Complicated diarrhea/dehydration treatment per 1,000 children under-5 years	0.76 [0.4, 1.11]	0.053	***0.001***	***0.013***
Complicated pneumonia treatment per 1,000 children under-5 years	2.15 [0.77, 3.53]	***0.044***	***0.020***	***0.048***
Newborns born not breathing who were resuscitated per 1,000 WRA	0.04 [-0.13, 0.19]	0.731	0.632	0.668

*Common trends assumption not satisfied in the preintervention period.
Bold text indicates p-values less than 0.05.
Baseline measures included in the DID analyses reflect three-month averages for March 2019 through May 2019, which were compared to averages spanning the same three months in 2024.
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 seven years into USAID IHP program implementation. The impact evaluation results showed 11 of 13 indicators had moved in the desired direction, with 5 of those 11 indicators exhibiting significant differences between IHP intervention facilities and comparison facilities when adjusting for multiple hypothesis testing, suggesting that USAID IHP significantly impacted those indicators. Of the significant indicators, the largest magnitude of impact was observed for new acceptors of modern methods of contraception. Small impacts were observed in the provision of ITNs at ANC visits, treatment of complicated diarrhea/dehydration, and measles vaccinations.

Overall, the results highlight areas that may require additional focus in future programs, such as the treatment of complicated malaria and the prevention of malnutrition in children. The DID estimates of both indicators suggested movement in an undesired direction when comparing intervention sites with comparison sites (i.e., more instances of moderate acute malnutrition and fewer instances of complicated malaria treatment). Notably, the treatment of complicated malaria was significant based on both unadjusted and adjusted p-values. Evidence from the cITS analysis indicates an increase in treatment of *uncomplicated* malaria in IHP intervention facilities, though these results were not significant. Further investigation may be warranted to contextualize whether the decrease is due to better treatment preventing the incidence of complicated malaria cases or a lack of treatment of severe cases in IHP supported HZs.

It is also important to note 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. However, our analyses for both the PSM and DID procedures were based on the most well-reported data elements in the RHIS.

Unfortunately, the RHIS indicators for new acceptors of modern contraceptive methods, measles vaccinations of children under five, and rate of ITN distribution at ANC4 did not exhibit similar trends between the comparison and intervention facilities in the preintervention period and as such should be interpreted through the lens of not satisfying a basic assumption of the DID analysis. This means the comparison group does not serve as an appropriate counterfactual to the intervention group and results should be interpreted with caution.

Recommendations

When planning future programs, USAID should draw its attention to those indicators that showed little to no movement in the anticipated direction, such as treatment of complicated diarrhea/dehydration and moderate acute malnutrition in children and explore the factors behind the unanticipated decrease in treatment of complicated malaria in children under five years. Further, USAID should consider continuing the elements of USAID IHP that contributed to positive impacts, namely, new acceptors of FP, provision of ITNs at ANC visits, treatment of complicated diarrhea/dehydration, and measles vaccinations.

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Appendix 1. Additional Figures and Tables

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

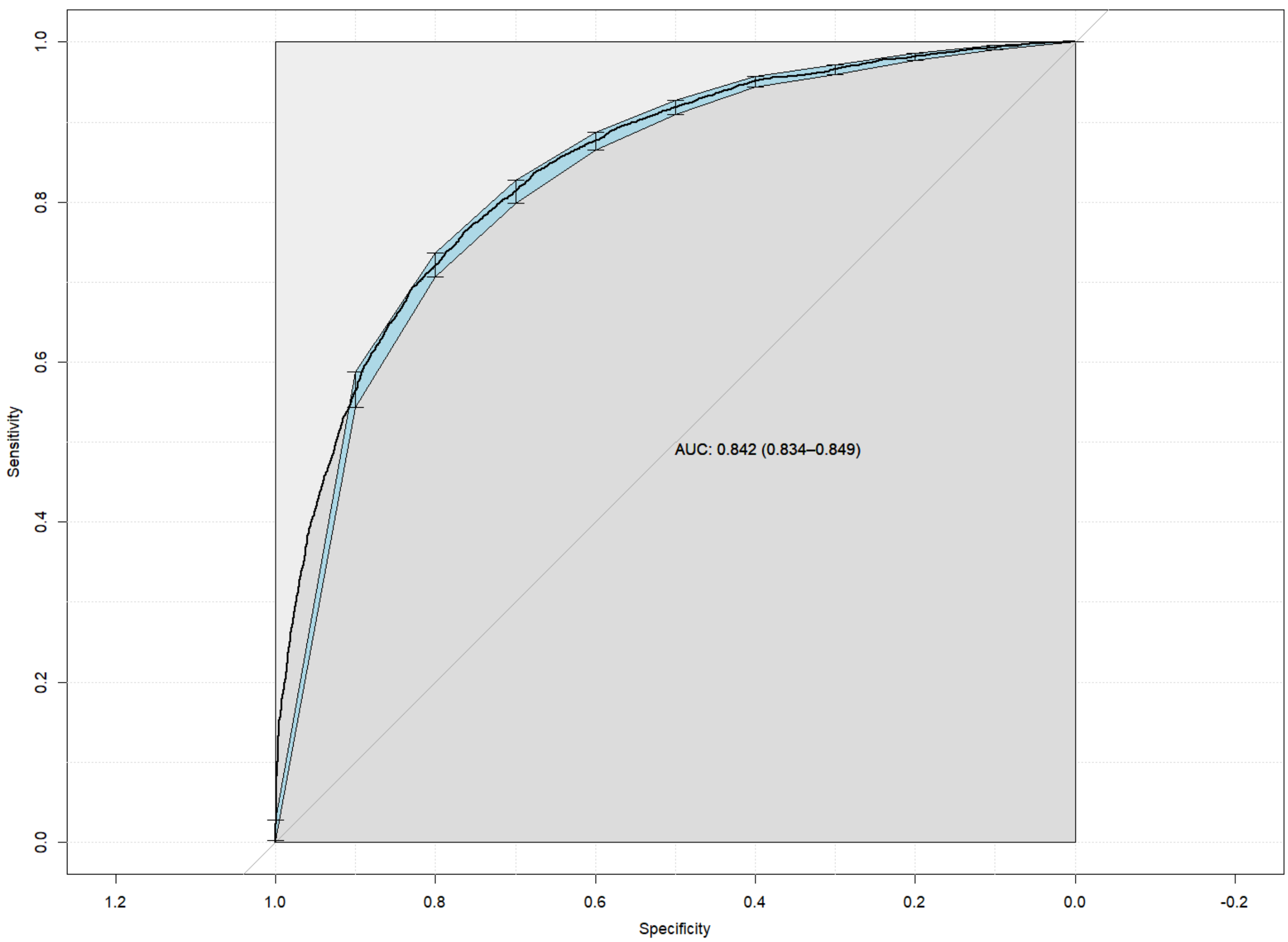
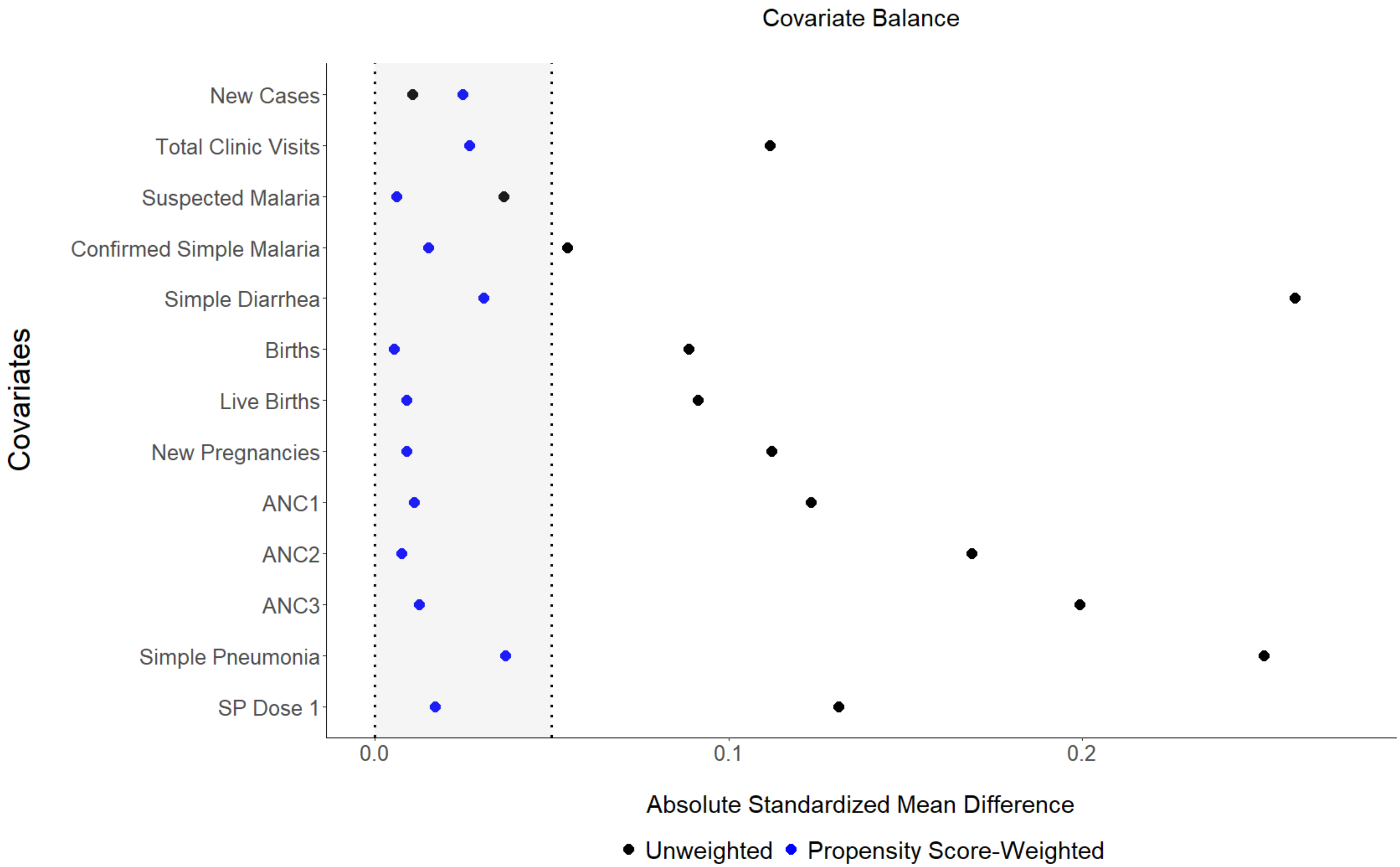


Figure 4. Love plot of covariate balance



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

Figure 5. Propensity score region of common support before and after matching

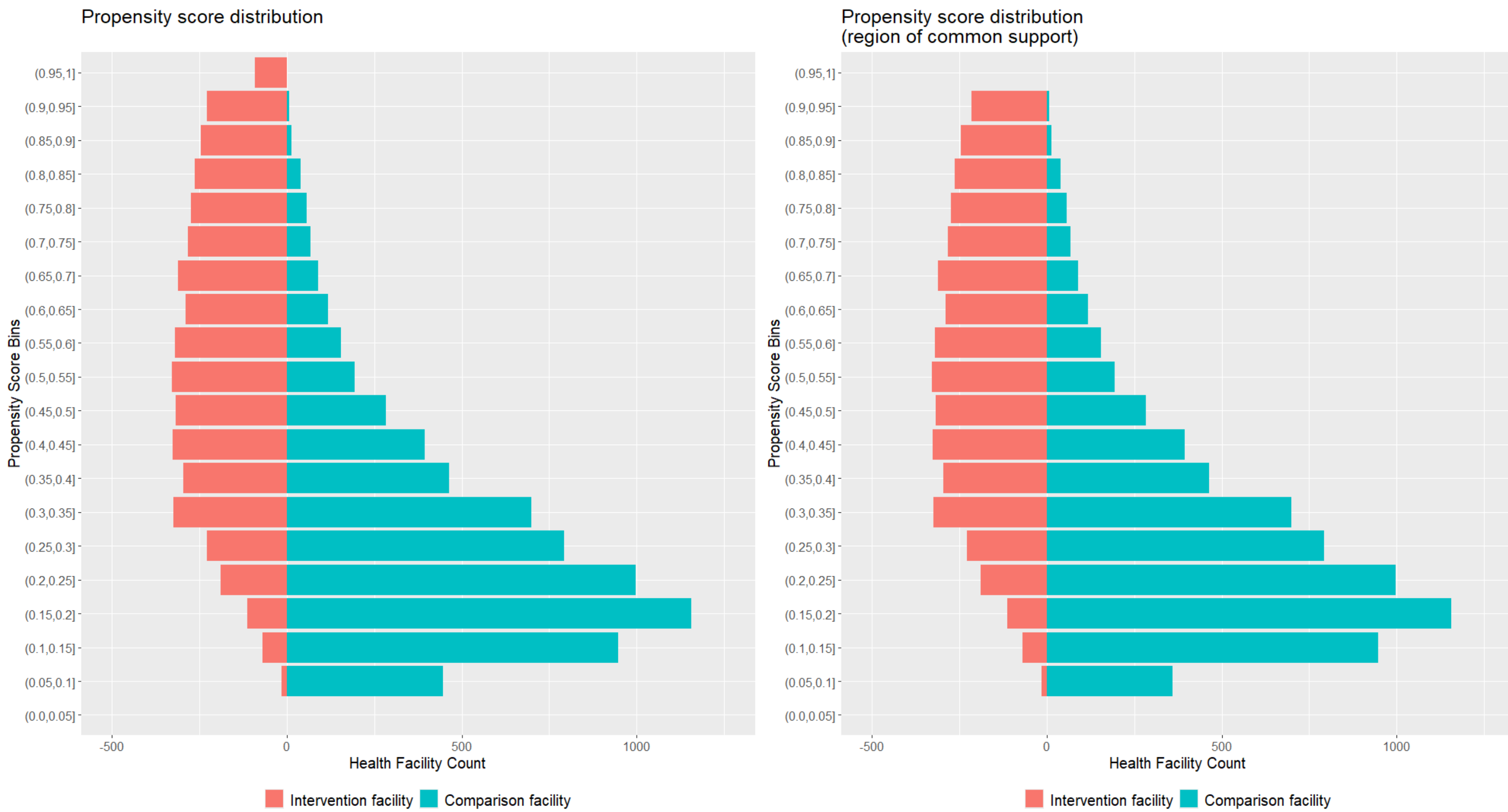


Figure 6a. Assessment of common trends assumption by RHIS indicator (primary analysis)

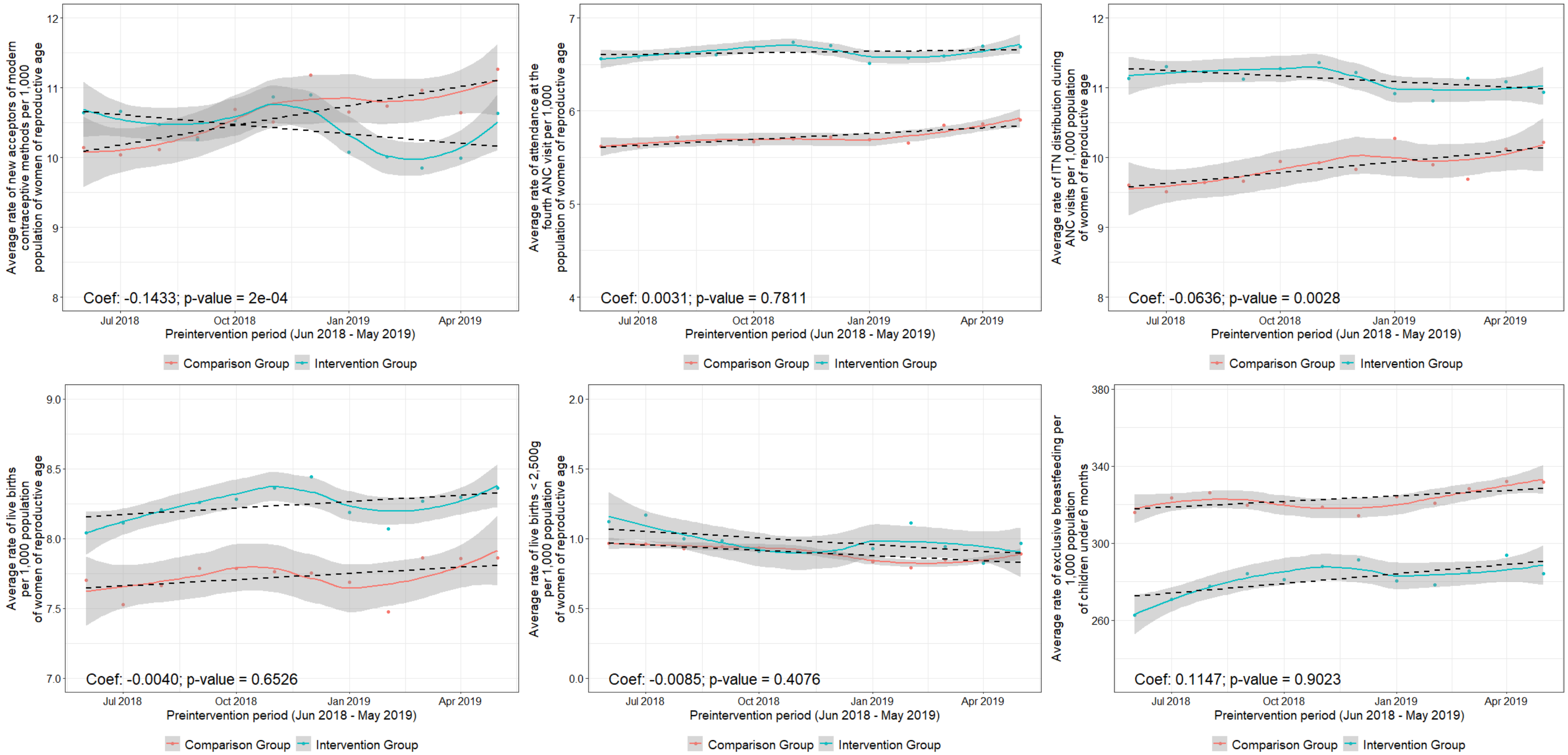


Figure 6b. Assessment of common trends assumption by RHIS indicator (primary analysis)

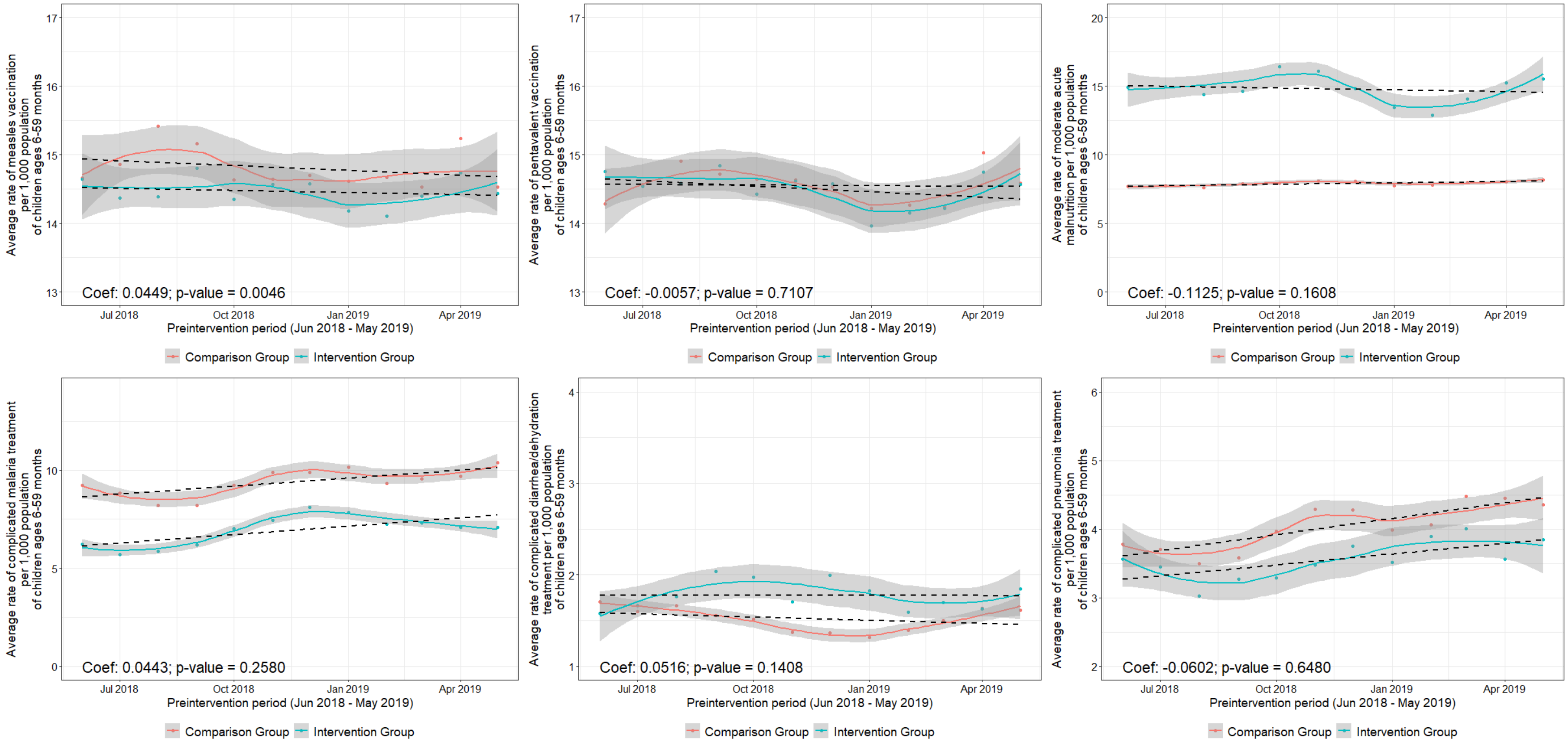


Figure 6c. Assessment of common trends assumption by RHIS indicator (primary analysis)

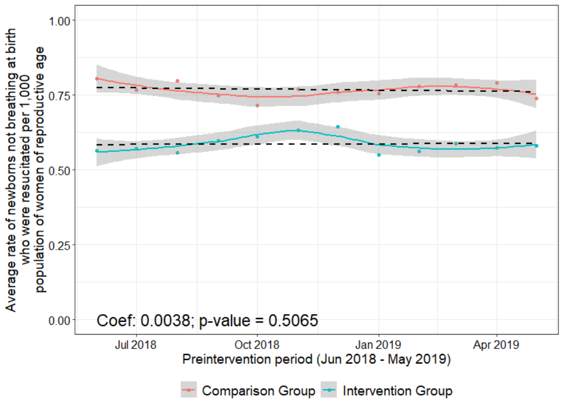


Figure 7a. Assessment of common trends assumption, by RHIS indicator (IHP HZs with intensified activities vs. IHP HZs with standard activities)

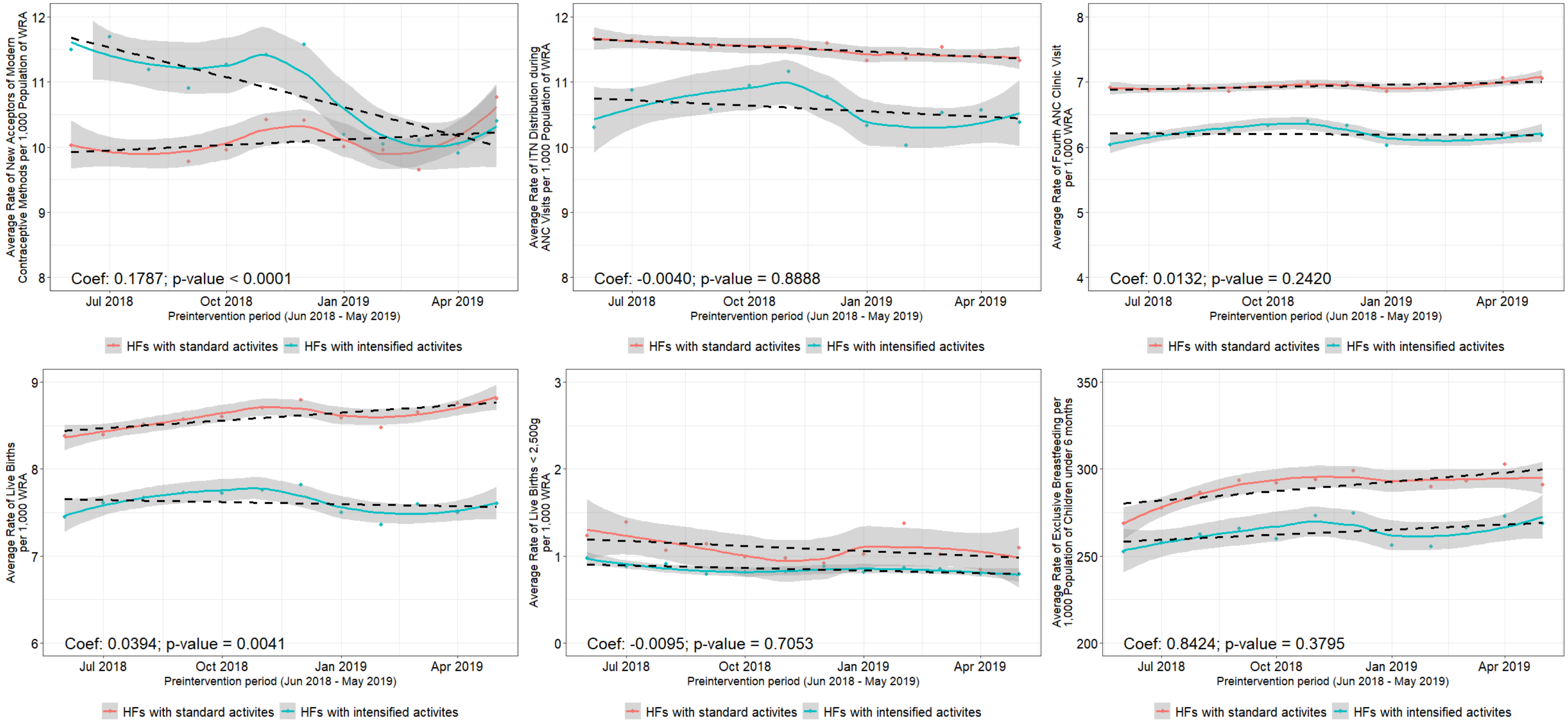


Figure 7b. Assessment of common trends assumption, by RHIS indicator (IHP HZs with intensified activities vs. IHP HZs with standard activities)

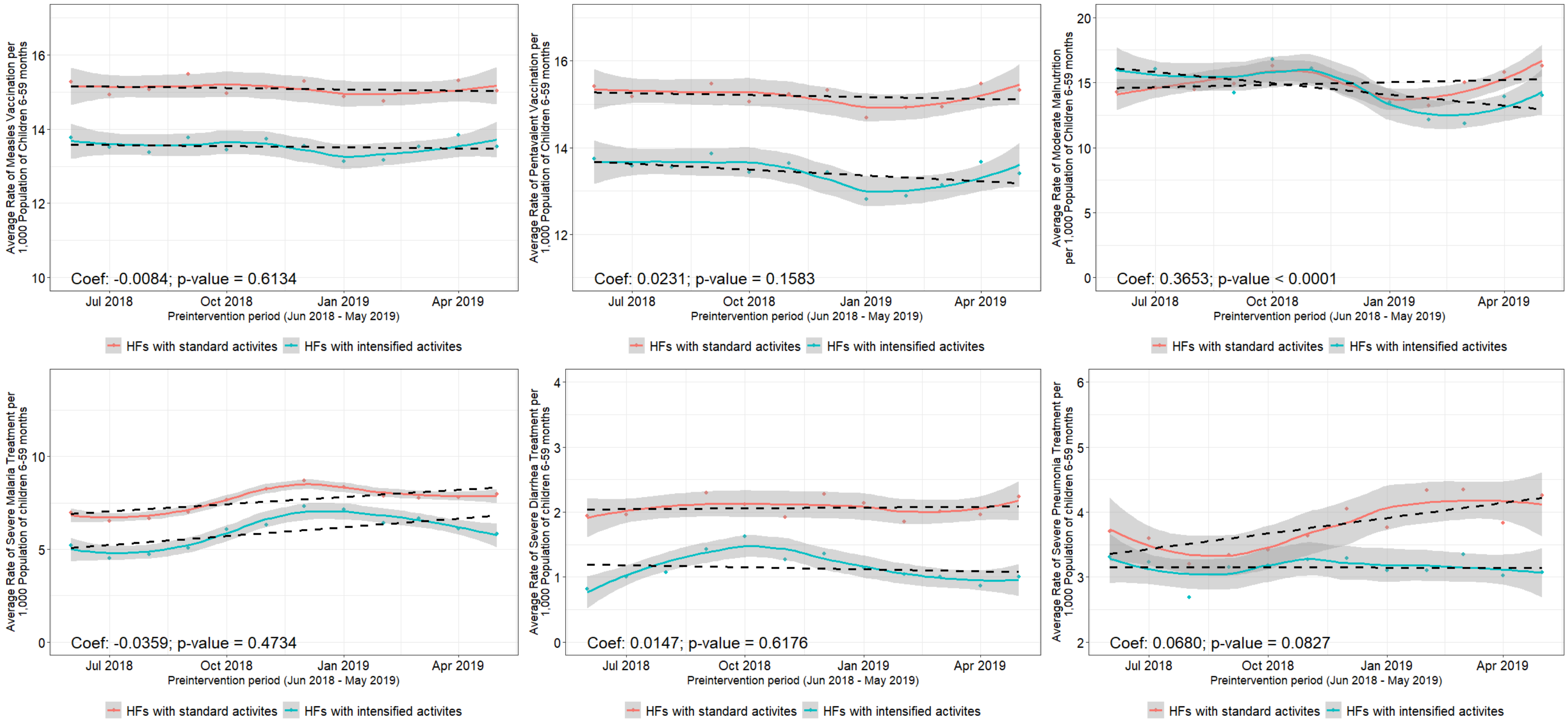


Figure 7c. Assessment of common trends assumption, by RHIS indicator (IHP HZs with intensified activities vs. IHP HZs with standard activities)

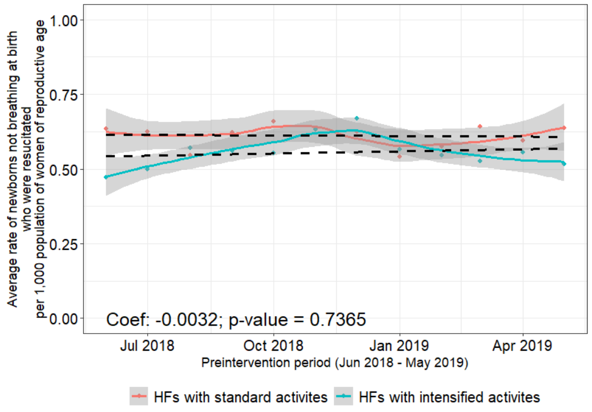


Figure 8a. Graphical depictions of the DID analyses, by RHIS indicator (IHP HZs with intensified activities vs. IHP HZs with standard activities)

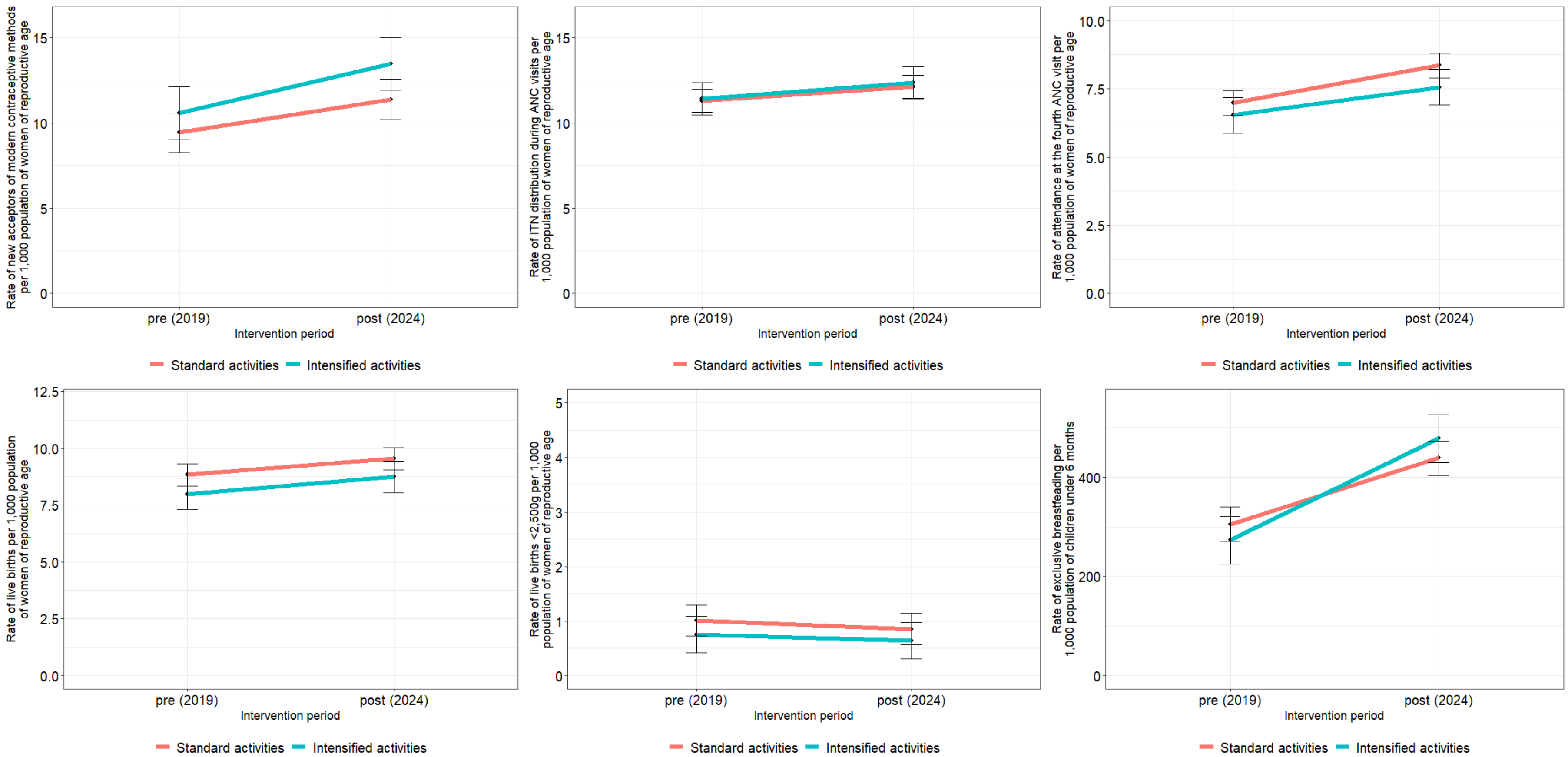


Figure 8b. Graphical depictions of the DID analyses, by RHIS indicator (IHP HZs with intensified activities vs. IHP HZs with standard activities)

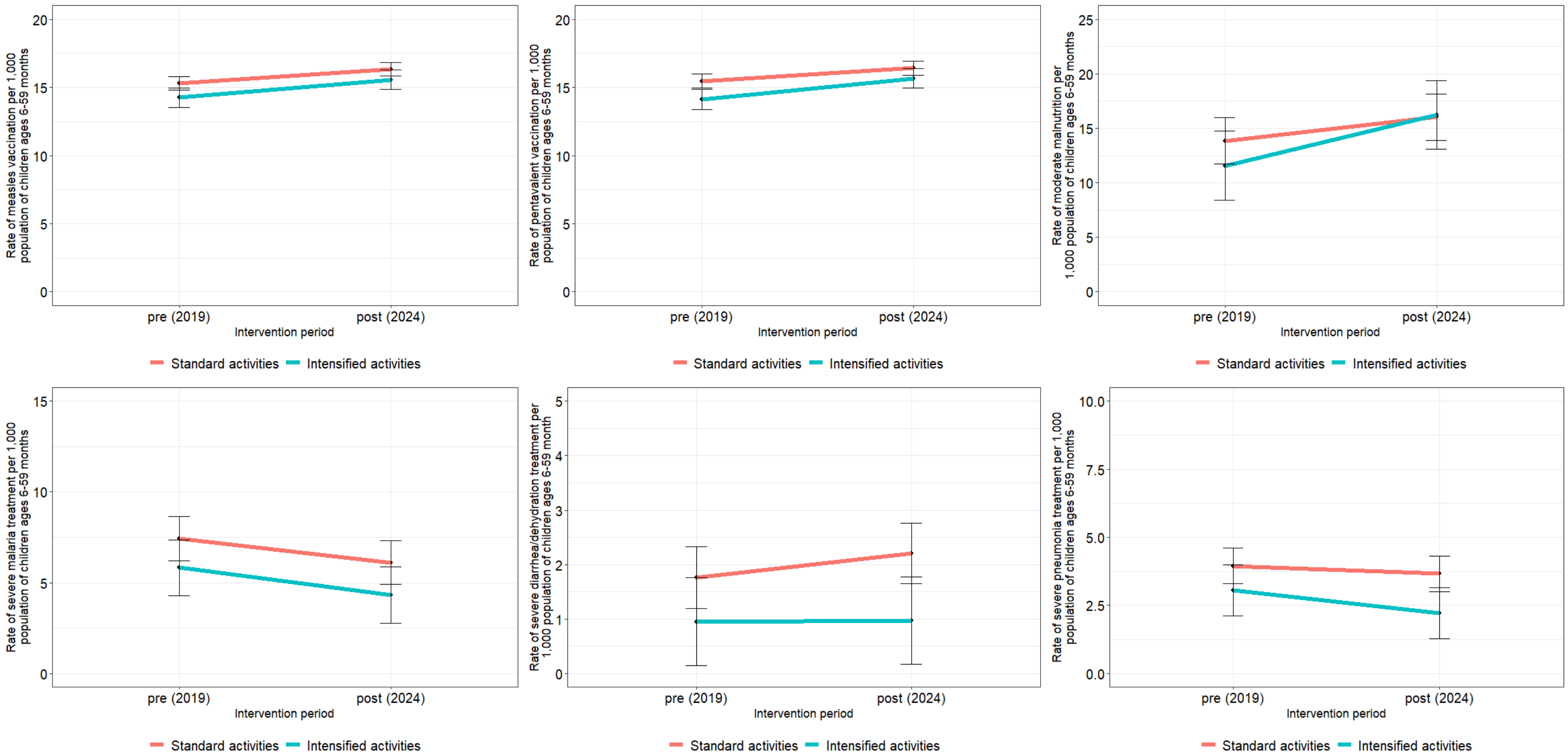


Figure 8c. Graphical depictions of the DID analyses, by RHIS indicator (IHP HZs with intensified activities vs. IHP HZs with standard activities)

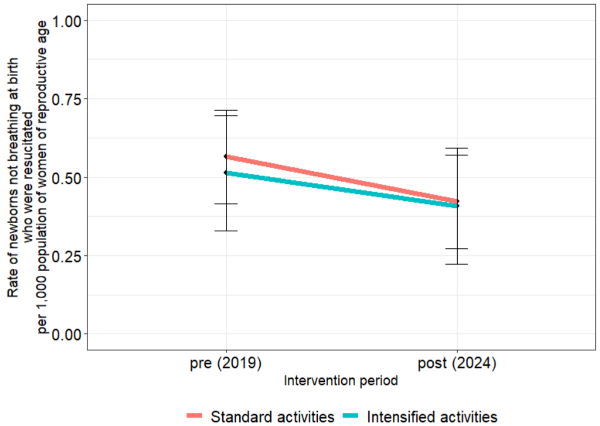


Table 3. Summary of DID estimators, by assessed RHIS indicator (IHP HZs with intensified activities vs. IHP HZs with standard activities)

RHIS Indicator	2019 vs 2024		
	DID estimator [95% CI]	Unadjusted p-value	Benjamini-Hochberg adjusted p-value
New acceptors of modern contraceptive methods per 1,000 WRA*	-0.93 [-1.96, 0.11]	0.0801	0.2083
Attendance at the fourth ANC visit per 1,000 WRA	0.36 [-0.04, 0.76]	0.0758	0.2083
ITN distribution during ANC visits per 1,000 WRA	-0.13 [-0.94, 0.68]	0.7527	0.8792
Live births per 1,000 WRA*	-0.04 [-0.54, 0.46]	0.8792	0.8792
Live births <2,500 grams per 1,000 WRA	-0.05 [-0.61, 0.51]	0.8649	0.8792
Exclusive breastfeeding per 1,000 children under 6 months	-71.61 [-107.98, -35.08]	***0.0001***	***0.0013***
Measles vaccination per 1,000 children under 5 years	-0.29 [-0.83, 0.25]	0.2933	0.6355
Pentavalent vaccination per 1,000 children under 5 years	-0.58 [-1.14, -0.03]	***0.0396***	0.1716
Moderate acute malnutrition per 1,000 children under 5 years*	-2.5 [-4.84, -0.14]	***0.0374***	0.1716
Complicated malaria treatment per 1,000 children under 5 years	0.19 [-1.5, 1.87]	0.8284	0.8792
Complicated diarrhea/dehydration treatment per 1,000 children under 5 years	0.42 [-0.77, 1.61]	0.4924	0.8002
Complicated pneumonia treatment per 1,000 children under 5 years	0.55 [-0.93, 2.02]	0.4677	0.8002
Newborns not breathing at birth who were resuscitated per 1,000 WRA	-0.04 [-0.31, 0.23]	0.7868	0.8792

*Common trends assumption not satisfied in the preintervention period.
Bold text indicates p-values less than 0.05.
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 2024.
RHIS – routine health information system; *DID* – difference-in-differences; *CI* – confidence interval; *WRA* –women of reproductive age; *ANC* – antenatal care

Table 4. Rate of complicated malaria treatment per 1,000 children ages 6–59 months (primary analysis)

Label	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Benjamini-Hochberg adjusted p-value
Intervention facility*Post intervention period (DID est.)	-3.19 [-6.03, -0.51]	0.0001	0.007	0.046
Intervention facility	1.67 [-0.93, 4.41]	0.0093	0.2537	
Post intervention period	-1.96 [-5.28, 1.69]	0.1998	0.3506	
Educational attainment - WRA	-0.25 [-0.93, 0.44]	0.3368	0.4835	
Prevalence of improved housing	-7.2 [-23.32, 10.13]	0.0789	0.3766	
Rainfall: 3-month average (Mar/Apr/May)	-0.23 [-1.55, 1.18]	0.4035	0.7962	
NDVI: 3-month average (Mar/Apr/May)	-1.52 [-17.2, 15.53]	0.7037	0.978	
Urban health zone	-2.27 [-3.92, -0.64]	0.0003	0.0689	

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

Table 5. Rate of complicated diarrhea/dehydration treatment per 1,000 children ages 6–59 months (primary analysis)

Label	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Benjamini-Hochberg adjusted p-value
Intervention facility*Post intervention period (DID est.)	0.76 [0.4, 1.11]	0.0527	0.001	0.013
Intervention facility	-0.49 [-0.74, -0.21]	0.1081	0.001	
Post intervention period	-0.29 [-0.75, 0.21]	0.5755	0.5005	
Educational attainment - WRA	-0.07 [-0.21, 0.09]	0.5584	0.6354	
Prevalence of improved housing	-0.21 [-2.53, 2.09]	0.9106	0.8961	
Rainfall: 3-month average (Mar/Apr/May)	0.2 [0.02, 0.38]	0.0852	0.3976	
NDVI: 3-month average (Mar/Apr/May)	1.96 [-1.1, 4.98]	0.2966	0.2158	
Urban health zone	-0.8 [-1.43, -0.19]	0.0246	0.027	

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

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

Label	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Benjamini-Hochberg adjusted p-value
Intervention facility*Post intervention period (DID est.)	2.15 [0.77, 3.53]	0.0441	0.02	0.048
Intervention facility	-2.72 [-4.14, -1.31]	0.0009	0.001	
Post intervention period	-1.34 [-3.04, 0.26]	0.2554	0.2797	
Educational attainment - WRA	-0.27 [-0.66, 0.11]	0.3841	0.2937	
Prevalence of improved housing	4.63 [-2.21, 11.69]	0.4278	0.2278	
Rainfall: 3-month average (Mar/Apr/May)	0.78 [-0.15, 1.71]	0.0124	0.2178	
NDVI: 3-month average (Mar/Apr/May)	7.06 [1.22, 13.06]	0.1757	0.03	
Urban health zone	-1.79 [-2.64, -1.01]	0.0742	0.022	

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

Table 7. Rate of newborns not breathing at birth who were resuscitated per 1,000 WRA (primary analysis)

Label	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Benjamini-Hochberg adjusted p-value
Intervention facility*Post intervention period (DID est.)	0.04 [-0.13, 0.19]	0.731	0.6324	0.668
Intervention facility	-0.17 [-0.27, -0.07]	0.0346	0.0559	
Post intervention period	-0.15 [-0.45, 0.16]	0.2703	0.3187	
Educational attainment - WRA	0 [-0.04, 0.04]	0.9219	0.8811	
Prevalence of improved housing	-0.23 [-1.29, 0.78]	0.5849	0.6024	
Rainfall: 3-month average (Mar/Apr/May)	0 [-0.12, 0.12]	0.9235	0.965	
NDVI: 3-month average (Mar/Apr/May)	-0.02 [-1.1, 1.01]	0.9577	0.97	
Urban health zone	-0.1 [-0.24, 0.04]	0.2087	0.1818	

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

Table 8. Rate of moderate acute malnutrition per 1,000 children ages 6–59 months (primary analysis)

Label	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Benjamini-Hochberg adjusted p-value
Intervention facility*Post intervention period (DID est.)	0.92 [-1.74, 3.56]	0.3259	0.5495	0.649
Intervention facility	2.07 [0.14, 3.99]	0.0069	0.2547	
Post intervention period	5.11 [0.49, 9.61]	0.0747	0.0589	
Educational attainment - WRA	-2.21 [-4.07, -0.44]	< 0.0001	0.0539	
Prevalence of improved housing	-12.36 [-27.6, 3.16]	0.0080	0.033	
Rainfall: 3-month average (Mar/Apr/May)	0.02 [-1.23, 1.32]	0.9535	0.981	
NDVI: 3-month average (Mar/Apr/May)	6.29 [-7.77, 20.11]	0.2164	0.4016	
Urban health zone	-2.38 [-6.15, 1.6]	0.0025	0.3207	

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

Table 9. Rate of pentavalent vaccination per 1,000 children ages 6–59 months (primary analysis)

Label	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Benjamini-Hochberg adjusted p-value
Intervention facility*Post intervention period (DID est.)	0.53 [-0.44, 1.49]	0.0076	0.3097	0.403
Intervention facility	0.61 [-0.19, 1.4]	< 0.0001	0.1489	
Post intervention period	-0.62 [-1.69, 0.48]	0.3852	0.2527	
Educational attainment - WRA	-1.17 [-1.56, -0.78]	< 0.0001	0.001	
Prevalence of improved housing	5.24 [-0.72, 11.44]	< 0.0001	0.044	
Rainfall: 3-month average (Mar/Apr/May)	0.36 [-0.15, 0.85]	< 0.0001	0.0839	
NDVI: 3-month average (Mar/Apr/May)	4.3 [-0.48, 9.48]	< 0.0001	0.1858	
Urban health zone	-1.02 [-2.53, 0.5]	< 0.0001	0.2018	

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

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

Label	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Benjamini-Hochberg adjusted p-value
Intervention facility*Post intervention period (DID est.)	1.15 [0.29, 2.01]	< 0.0001	0.019	0.048
Intervention facility	-0.06 [-0.78, 0.64]	0.6623	0.8661	
Post intervention period	-0.6 [-1.77, 0.59]	0.3808	0.3177	
Educational attainment - WRA	-1.12 [-1.47, -0.78]	< 0.0001	0.001	
Prevalence of improved housing	5.69 [0.67, 10.8]	< 0.0001	0.015	
Rainfall: 3-month average (Mar/Apr/May)	0.21 [-0.27, 0.67]	0.0022	0.3596	
NDVI: 3-month average (Mar/Apr/May)	5.45 [1.08, 10.02]	< 0.0001	0.033	
Urban health zone	-0.89 [-2.1, 0.36]	< 0.0001	0.1528	

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

Table 12. Rate of exclusive breastfeeding per 1,000 children under 6 months (primary analysis)

Label	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Benjamini-Hochberg adjusted p-value
Intervention facility*Post intervention period (DID est.)	92.86 [-0.65, 184.79]	< 0.0001	0.0609	0.113
Intervention facility	66.99 [38.73, 95.36]	< 0.0001	0.005	
Post intervention period	-104.68 [-177.99, -26.84]	0.0304	0.03	
Educational attainment - WRA	-37.37 [-64.53, -7.52]	< 0.0001	0.048	
Prevalence of improved housing	117.66 [-255.1, 462.52]	0.0783	0.4995	
Rainfall: 3-month average (Mar/Apr/May)	5.09 [-12.2, 23.24]	0.2981	0.5764	
NDVI: 3-month average (Mar/Apr/May)	12.54 [-310, 333.9]	0.8499	0.9481	
Urban health zone	13.88 [-48.48, 78.06]	0.1977	0.7183	

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

Table 13. Rate of live births <2,500 grams per 1,000 WRA (primary analysis)

Label	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Benjamini-Hochberg adjusted p-value
Intervention facility*Post intervention period (DID est.)	-0.08 [-0.4, 0.24]	0.6429	0.6683	0.668
Intervention facility	-0.1 [-0.29, 0.08]	0.4380	0.4555	
Post intervention period	-0.35 [-1.09, 0.36]	0.5994	0.6474	
Educational attainment - WRA	-0.03 [-0.1, 0.05]	0.5945	0.4066	
Prevalence of improved housing	-0.65 [-2.01, 0.76]	0.3725	0.3596	
Rainfall: 3-month average (Mar/Apr/May)	0.05 [-0.03, 0.12]	0.4251	0.3137	
NDVI: 3-month average (Mar/Apr/May)	0.18 [-1.07, 1.47]	0.7956	0.8092	
Urban health zone	0.16 [-0.1, 0.41]	0.2641	0.2847	

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

Table 14. Rate of live births per 1,000 WRA (primary analysis)

Label	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Benjamini-Hochberg adjusted p-value
Intervention facility*Post intervention period (DID est.)	0.71 [-0.08, 1.49]	< 0.0001	0.1049	0.170
Intervention facility	-0.05 [-0.55, 0.46]	0.6771	0.8941	
Post intervention period	-0.18 [-1.69, 1.31]	0.8499	0.8122	
Educational attainment - WRA	-0.86 [-1.22, -0.49]	< 0.0001	0.001	
Prevalence of improved housing	-0.77 [-7.35, 5.51]	0.3571	0.8412	
Rainfall: 3-month average (Mar/Apr/May)	0.54 [0.13, 0.94]	< 0.0001	0.002	
NDVI: 3-month average (Mar/Apr/May)	2.14 [-1.24, 5.47]	0.0080	0.1828	
Urban health zone	-0.61 [-1.43, 0.23]	< 0.0001	0.1499	

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

Table 15. Rate of attendance at the fourth ANC visit per 1,000 WRA (primary analysis)

Label	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Benjamini-Hochberg adjusted p-value
Intervention facility*Post intervention period (DID est.)	0.55 [-0.32, 1.42]	< 0.0001	0.2298	0.332
Intervention facility	0.68 [0.09, 1.28]	< 0.0001	0.1099	
Post intervention period	-0.04 [-1.27, 1.22]	0.9575	0.9381	
Educational attainment - WRA	-0.62 [-0.88, -0.38]	< 0.0001	0.001	
Prevalence of improved housing	-3.8 [-8.65, 1.15]	< 0.0001	0.3007	
Rainfall: 3-month average (Mar/Apr/May)	0.4 [0.03, 0.77]	< 0.0001	0.043	
NDVI: 3-month average (Mar/Apr/May)	-3.63 [-7.23, -0.02]	< 0.0001	0.1249	
Urban health zone	-0.8 [-1.59, -0.03]	< 0.0001	0.0529	

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

Table 16. Rate of ITN distribution during ANC visits per 1,000 WRA (primary analysis)

Label	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Benjamini-Hochberg adjusted p-value
Intervention facility*Post intervention period (DID est.)	0.76 [0.19, 1.31]	0.0005	0.013	0.048
Intervention facility	0.12 [-0.33, 0.58]	0.3486	0.6264	
Post intervention period	-1.18 [-2.72, 0.38]	0.2088	0.1508	
Educational attainment - WRA	-1.09 [-1.76, -0.41]	< 0.0001	0.003	
Prevalence of improved housing	2.84 [-9.62, 14.9]	0.0635	0.7213	
Rainfall: 3-month average (Mar/Apr/May)	0.21 [-0.16, 0.59]	0.0064	0.4126	
NDVI: 3-month average (Mar/Apr/May)	4.28 [-3.24, 11.51]	0.0002	0.1888	
Urban health zone	-0.19 [-1.18, 0.75]	0.3299	0.7003	

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

Table 17. Rate of new acceptors of modern contraceptive methods per 1,000 WRA (primary analysis)

Label	estimate [WCB 95% CI]	unadjusted p-value	WCB adjusted p-value	Benjamini-Hochberg adjusted p-value
Intervention facility*Post intervention period (DID est.)	4.06 [1.18, 6.95]	< 0.0001	0.022	0.048
Intervention facility	-1.85 [-4.2, 0.5]	< 0.0001	0.1928	
Post intervention period	-2.09 [-5.6, 1.28]	0.2634	0.2627	
Educational attainment - WRA	-1.46 [-2.18, -0.73]	< 0.0001	0.001	
Prevalence of improved housing	-6.26 [-14.92, 2.39]	0.0102	0.3806	
Rainfall: 3-month average (Mar/Apr/May)	0.74 [-0.14, 1.59]	< 0.0001	0.2018	
NDVI: 3-month average (Mar/Apr/May)	-7.37 [-16.69, 2.07]	0.0013	0.3247	
Urban health zone	0.2 [-1.45, 1.78]	0.5915	0.8352	

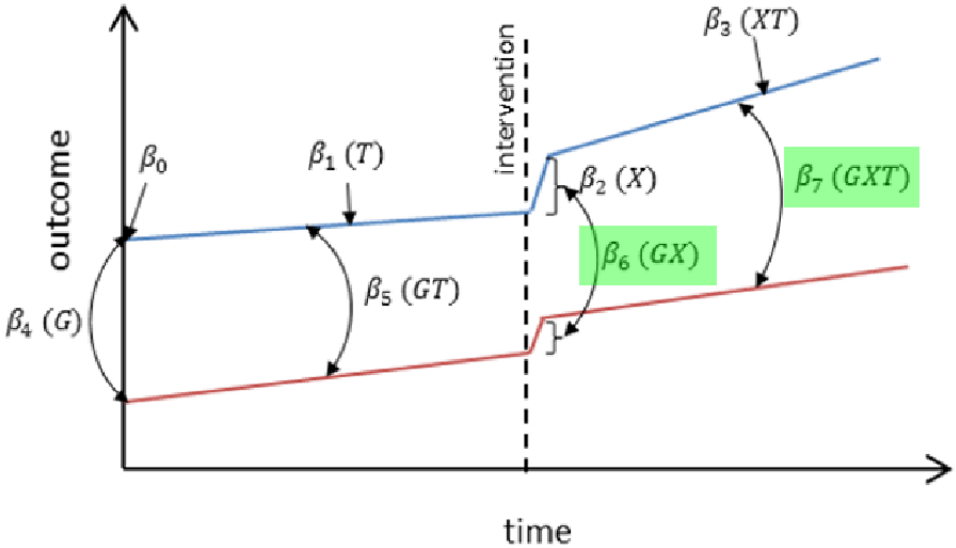
WCB – wild cluster bootstrap; DID est. – difference-in-differences estimate; NDVI – normalized difference vegetation index. * denotes an interaction term.

Table 18. Controlled interrupted time series regression results for level and slope term

	Live Births	ITNs at ANC1	SP1 Dose at ANC1	Tx Uncomplicated Malaria	Tx Uncomplicated Diarrhea	Tx Uncomplicated Pneumonia
	Total Births	ANC1	ANC1	Uncomplicated Malaria	Uncomplicated Diarrhea	Uncomplicated Pneumonia
	3,397 matched pairs	814 matched pairs	2,720 matched pairs	3,265 matched pairs	2,287 matched pairs	2,106 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	1.16 [0.9, 1.5]	1.22 [0.62, 2.43]	0.79 [0.3, 2.07]	1.31 [0.76, 2.27]	0.86 [0.56, 1.32]	1.16 [0.66, 2.05]
Difference between the change in slope in the comparison and intervention groups associated with the intervention	1.02* [1, 1.03]	1.01 [0.97, 1.06]	1.03 [0.96, 1.11]	1.02 [0.99, 1.05]	1.03* [1.01, 1.05]	1.05*** [1.02, 1.08]

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



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

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.

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