

Maternal HIV and the Risk of Low Birth Weight and Preterm Birth in Western Kenya: Evidence from a Prospective Cohort Using Propensity Score Methods

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Abstract

Despite widespread use of antiretroviral therapy (ART), maternal HIV infection remains a major public health concern in sub-Saharan Africa, and its association with adverse birth outcomes such as low birth weight (LBW) and preterm birth (PTB) inconsistently reported. This study investigates the association between maternal HIV infection and the risk of LBW and PTB in Western Kenya, comparing advanced statistical methods to control for confounding.

We conducted a Kenya-specific sub-analysis of documented pregnancy outcomes ($n = 2,399$) from *PRISMA Maternal and Newborn Health Study*, a multi-country, prospective open-cohort study that enrolled pregnant participants before 20 weeks of gestation through community-hospital based surveillance. Weighted Propensity Score Matching (WPSM) and Inverse Probability Weighting (IPW) were employed to control for potential confounders—including job type, maternal age, parity, residence, wealth quantile, education level—and to compare effect estimate robustness. Log binomial generalized linear mixed effects models were used to assess the association.

The median age was 26 years, and overall HIV prevalence was 13.0% (311/2,399), showing a strong age gradient—from 5.6% among participants < 20 years to 30.6% among those ≥ 35 years. All women living with HIV (WLWH) reported being on antiretroviral therapy during pregnancy. Using WPSM, WLWH were more likely to have infants with LBW [Relative Risk (RR) = 1.68, 95% CI: 1.39–2.03] and PTB [RR = 1.68 95% CI: 1.41–2.01]. IPW yielded similar results in direction, with slightly differing risk estimates for LBW [RR = 1.66, 95% CI: 1.51–1.82] and PTB [RR = 1.32, 95% CI: 1.21–1.44].

Maternal HIV infection, despite antiretroviral therapy, is independently associated with an increased risk of LBW and PTB. Consistency across two propensity score methods strengthens confidence in these findings. Strengthening integrated maternal HIV and antenatal care services is critical for reducing the residual burden of adverse birth outcomes among HIV-exposed pregnancies.

Background

The intersection of maternal HIV infection and adverse birth outcomes remains a significant public health concern (1), particularly in sub-Saharan Africa where HIV affects approximately 1.3 million pregnant women annually (2–4). While antiretroviral therapy (ART) has dramatically reduced mother-to-child transmission of HIV from 25–30% to less than 5% in resource-limited settings (5), low birth weight (LBW), defined as birth weight < 2,500 g, and preterm birth (PTB), defined as delivery before 37 completed weeks of gestation, remain leading causes of neonatal morbidity and mortality (4). These adverse outcomes are consistently associated with both short-term complications and long-term health consequences, including developmental delays, chronic diseases, and reduced educational achievement (6).

In sub-Saharan Africa, Kenya included, the prevalence of LBW and PTB is estimated to be approximately 10–14% (7–9) and 12–3% (9–5–15–8) (10, 11) respectively, with LBW associated with threefold greater

risk of neonatal mortality (12). While most studies have shown an increased likelihood of LBW (13–15) and PTB (16) among pregnant women living with HIV (WLWH), other studies across African countries have reported no significant association (17–19). These differing findings may be attributed to heterogeneity across studies in terms of study design, population characteristics, the methods used to control for confounding variables, and ART uptake rates (13, 20). Additionally, socioeconomic factors, nutritional status, and access to healthcare services may confound these relationships (21, 22).

While randomized controlled trials (RCTs) are considered the gold standard for establishing causal relationships, they are neither ethical nor feasible in studying the effects of maternal HIV infection on birth outcomes. Advanced statistical methods such as propensity score matching (PSM) and inverse probability weighting (IPW) have emerged as powerful alternatives that can approximate key features and rigor of experimental designs in observational studies (23–27). These methods have gained prominence in epidemiological research due to their ability to reduce selection bias and control for confounding factors effectively. Methodological studies have demonstrated that PSM and IPW can produce estimates that closely approximate those obtained from RCTs when properly implemented. Comprehensive comparisons of treatment effects estimated using PSM and IPW versus RCTs across multiple healthcare domains have found concordance rates exceeding 85% when key assumptions were met (23, 27). In addition, these methods could potentially reduce bias by up to 90% compared to conventional regression analyses in observational studies of maternal health outcomes (24, 27). Conceptually, both methods are grounded in the counterfactual framework and the assumption of strong ignorability (25, 26). PSM creates matched sets of treated and untreated subjects who share similar observed characteristics, effectively simulating the random assignment process of an RCT. IPW, on the other hand, creates a pseudo-population where the distribution of confounders is balanced between exposure groups, similar to what would be achieved through randomization (28).

Within a prospective cohort of pregnant women followed throughout gestation in Western Kenya—a resource-limited setting where birth outcomes are strongly influenced by demographic, socioeconomic, and healthcare access factors—we sought to determine the effect of maternal HIV status on pregnancy outcomes. By applying both weighted propensity score matching (WPSM) and inverse probability weighting (IPW), we aim to address an important methodological gap and provides a direct comparison of analytic approaches while evaluating the association between maternal HIV infection and the risks of LBW and PTB.

Methods

Study Design and Setting

This analysis utilized data from the Pregnancy Risk, Infant Surveillance, and Measurement Alliance (PRISMA) Maternal and Newborn Health (MNH) Study, a multi-country, prospective open-cohort study designed to identify pregnancy risk factors and adverse birth outcomes. The present sub-analysis focused on the western Kenya sites, including urban (Kisumu) and rural (Siaya) counties, which have

among the highest HIV prevalence rates in Kenya (11.1% and 9.8%, respectively) (29). The data analyzed were collected between September 2022 and February 2026.

Study Population and Sampling

The PRISMA study employed a community-based surveillance system to identify and enroll pregnant women before 20 weeks of gestation, confirmed by ultrasound. Community health volunteers worked within defined catchment areas to identify pregnant women through household visits and referrals from local health facilities. All identified pregnant women were screened for eligibility.

Inclusion criteria include: aged ≥ 18 years or meeting criteria for emancipated minors, residence within the study catchment area with no plans to relocate during the study period, intrauterine pregnancy < 20 weeks gestational age verified by ultrasound, and provide informed consent to participate. This analysis included only PRISMA participants in Kenya with documented pregnancy outcomes and HIV status data.

Data Collection

Data were collected at enrollment and during scheduled follow-up visits throughout pregnancy and the postpartum period. At enrollment, trained study staff administered a structured questionnaire to obtain information on sociodemographic characteristics, obstetric history, medical history, and household characteristics. Physical examinations and laboratory assessments—including malaria testing, hemoglobin measurement, and rapid HIV testing in accordance with national guidelines—were conducted.

Follow-up visits occurred at five antenatal time points (enrollment < 20 weeks, ANC-20 weeks, ANC-28 weeks, ANC-32 weeks, and ANC-36 weeks). At each visit, participants underwent clinical assessment, malaria testing using rapid diagnostic tests (RDTs) and microscopy, and hemoglobin measurement. Between scheduled visits, participants were encouraged to seek care at study health facilities for any illness, and all acute care visits were documented.

Outcome and Exposure Measurements

The primary outcomes were low birth weight (LBW), defined as birth weight $< 2,500$ g, and preterm birth (PTB), defined as delivery before 37 completed weeks of gestation (4).

The primary exposure was maternal HIV status. Covariates evaluated include sociodemographic characteristics (maternal age, education level, occupation, marital status, and household wealth index constructed using principal component analysis of household assets), obstetric factors (gravidity, parity, gestational age at enrollment, and pregnancy type [singleton vs multiple]), and clinical factors (malaria status, hemoglobin level, mid-upper arm circumference [MUAC], blood pressure, and relevant clinical

history). Both baseline and repeated measurements across 4–5 antenatal care visits through delivery were considered where appropriate.

Statistical Analysis

Descriptive statistics were generated prior to matching or weighting. Continuous variables were summarized using means with standard deviations or medians with interquartile ranges, depending on distribution. Group comparisons for continuous variables were performed using the Wilcoxon rank-sum test. Categorical variables were summarized as frequencies and percentages and compared using Pearson's chi-squared test or Fisher's exact test, as appropriate.

Confounders included in the propensity score and inverse probability weighting model were job type, maternal age, parity, residence, wealth quantile, and education level based on the criterion that they must be associated with both the exposure and the outcome, and must precede the exposure temporally. Job type, maternal age, parity, residence, wealth quintile, and education level satisfied these criteria based on prior literature and directed acyclic graph (DAG) reasoning. Malaria infection, MUAC/nutritional status, anemia, and syphilis were included as covariates in the outcome model rather than the PS model because, while they may influence the outcome, they are more plausibly intermediates or contemporaneous conditions rather than pre-exposure confounders. Including intermediates in a PS model can introduce bias by blocking causal pathways. These variables were therefore adjusted for in the outcome model as a conservative sensitivity measure.

Weighted Propensity Score Matching (WPSM): Propensity scores were estimated using logistic regression. Matching was performed using 1:3 nearest-neighbor matching with a caliper of 0.2 standard deviations of the logit of the propensity score to ensure close matches while minimizing bias from extreme propensity score differences and preserving statistical power. Covariate balance after matching was assessed using standardized mean differences and variance ratios.

Inverse Probability Weighting (IPW)

Inverse probability weighting was applied to create a weighted pseudo-population in which measured confounders were balanced between HIV-exposed and unexposed groups. Stabilized weights were calculated as the inverse probability of the observed exposure conditional on covariates. This approach increased the influence of individuals underrepresented in their exposure group and reduced confounding by measured variables. Stabilized inverse probability weights were calculated using the *WeightIt* package in R, targeting the Average Treatment Effect (ATE). Weights were estimated as $P(A = 1)/PS$ for the exposed group and $P(A = 0)/(1 - PS)$ for the unexposed group, where PS is the propensity score estimated via logistic regression and $P(A)$ is the marginal probability of exposure.

For each weighted and matched dataset, log-binomial generalized linear mixed-effects models with a log link were fitted to estimate the association between maternal HIV infection and the risks of LBW and PTB. Models adjusted for additional covariates associated with birth outcomes, including

anthropometric and clinical measures (blood pressure (BP) levels, hypertension, maternal anemia point of care, MUAC, malaria positivity, poor obstetric history *multiple pregnancies*, and number of ANC visits). Random effects were included to account for within-participant correlation across repeated antenatal measurements and trimester-related clustering. Multiple pregnancies (twins/higher-order) were included in the analysis. Clustering by pregnancy ID was applied in the mixed-effects models to account for the non-independence of outcomes from multiple gestations within the same pregnancy. The variable “multiple pregnancy” was also included as a covariate.

The final multivariable model was constructed using a stepwise approach guided by statistical significance ($p < 0.05$) and a priori clinical relevance. Model fit was evaluated using the Akaike Information Criterion (AIC). Results are presented as risk ratios (RRs) with 95% confidence intervals (CIs).

To assess the robustness of the analytical approaches, we compared covariate balance using absolute standardized mean differences (SMD), with values exceeding the 0.1 threshold indicating inadequate balance. Agreement between methods was evaluated based on consistency in the direction of association, similarity in effect size magnitude (defined as within a 10% difference), overlap of confidence intervals, and concordance in statistical significance ($p < 0.05$). Consistent findings across both approaches were interpreted as strengthening causal inference. All analyses were conducted using R version 4.5.2.

Results

A total of 2,399 pregnant women with documented pregnancy outcomes were included during the study period, comprising 2,088 (87%) HIV-negative and 311 (13%) HIV-positive women (Table 1). The median (IQR) age was 26.0 (7.8) years, and approximately 38.1% (913/2,399) resided in rural Karemo, Siaya County. HIV prevalence increased with maternal age. The lowest prevalence occurred among women aged < 20 years (5.6%, $n = 11$), whereas the highest was observed among those aged ≥ 35 years (30.6%, $n = 68$). Geographically, HIV prevalence was higher in rural Karemo (16.0%, $n = 146$) than in peri-urban Manyata (11.1%, $n = 165$). HIV prevalence decreased with increasing education level. Women with primary education had the highest prevalence (21.0%, $n = 139$), whereas those with tertiary education had the lowest (7.0%, $n = 43$). ART coverage (100% among WLWH).

Table 1

Baseline characteristics of pregnant women by maternal HIV status, Western Kenya PRISMA cohort, 2022–2026

Characteristic	HIV Status		Overall
	Negative, N (%)	Positive, N (%)	N (%)
Total	2088 (87.0%)	311 (13.0%)	2,399
Maternal age, Median (IQR)	26 (7.3)	30 (9.1)	26 (7.8)
Maternal age, n (%)			
<20 years	185 (94.4%)	11 (5.6%)	196 (8.2%)
20–34 years	1,749 (88.3%)	232 (11.7%)	1,981 (82.6%)
35 + years	154 (69.4%)	68 (30.6%)	222 (9.3%)
Residence, n (%)			
Peri-urban Manyata	1,321 (88.9%)	165 (11.1%)	1,486 (61.9%)
Rural-Karemo	767 (84.0%)	146 (16.0%)	913 (38.1%)
SES quintile, n (%)			
Lowest SES	430 (93.3%)	31 (6.7%)	461 (19.2%)
Low SES	410 (90.9%)	41 (9.1%)	451 (18.8%)
Middle SES	419 (84.3%)	78 (15.7%)	497 (20.7%)
High SES	407 (83.6%)	80 (16.4%)	487 (20.3%)
Highest SES	422 (83.9%)	81 (16.1%)	503 (21.0%)
Marital status, n (%)			
Married	1,708 (86.9%)	258 (13.1%)	1,966 (82.0%)
Single/divorced/widowed	380 (87.8%)	53 (12.2%)	433 (18.0%)
Education level, n (%)			
Tertiary	567 (93.0%)	43 (7.0%)	610 (25.4%)
Secondary	992 (88.9%)	124 (11.1%)	1,116 (46.5%)
Primary	524 (79.0%)	139 (21.0%)	663 (27.6%)
None	5 (50.0%)	5 (50.0%)	10 (0.4%)

Abbreviations: HIV: human immunodeficiency virus; SES: socioeconomic status quintile derived from a composite household wealth index. Quintiles were defined within the study sample, with Lowest representing the poorest 20% and Highest representing the wealthiest 20% of participants.; MUAC: mid-upper arm circumference; ANC: antenatal care; IQR, interquartile range; N (%), number (percentage).

Characteristic	HIV Status		Overall
	Negative, N (%)	Positive, N (%)	N (%)
Job type, n (%)			
Formal Employment	212 (91.0%)	21 (9.0%)	233 (9.7%)
Informal Employment	764 (83.3%)	153 (16.7%)	917 (38.2%)
House wife	488 (87.6%)	69 (12.4%)	557 (23.2%)
Not working	624 (90.2%)	68 (9.8%)	692 (28.8%)
Gravida, n (%)			
Primigravida	532 (94.8%)	29 (5.2%)	561 (23.4%)
Multiparous	1,292 (86.4%)	203 (13.6%)	1,495 (62.3%)
Grand multiparous	264 (77.0%)	79 (23.0%)	343 (14.3%)
MUAC at enrolment, n (%)			
Low: <23cm	123 (91.1%)	12 (8.9%)	135 (5.6%)
Normal: 23-32cm	1,693 (87.0%)	252 (13.0%)	1,945 (81.1%)
High: ≥33cm	272 (85.3%)	47 (14.7%)	319 (13.3%)
'Syphilis serostatus at enrollment, n (%)			
Negative	2,073 (87.1%)	306 (12.9%)	2,379 (99.2%)
Positive	15 (75.0%)	5 (25.0%)	20 (0.8%)
Malaria infection at enrollment, n (%)			
Negative	1,870 (87.1%)	278 (12.9%)	2,148 (89.5%)
Positive	218 (86.9%)	33 (13.1%)	251 (10.5%)
Number on ART		311 (100%)	
Overall proportion is calculated column-wise, to describe the population. All these characteristics are at enrollment			
Abbreviations: HIV: human immunodeficiency virus; SES: socioeconomic status quintile derived from a composite household wealth index. Quintiles were defined within the study sample, with Lowest representing the poorest 20% and Highest representing the wealthiest 20% of participants.; MUAC: mid-upper arm circumference; ANC: antenatal care; IQR, interquartile range; N (%), number (percentage).			

Table 2 presents the crude association between birth outcomes (PTB and LBW) and maternal HIV status. The prevalence of low birth weight was 15.5% among infants born to HIV-positive mothers compared with 11.2% among those born to HIV-negative mothers; this difference was statistically

significant ($p = 0.03$). Similarly, the rate of preterm birth was higher in the HIV-positive group (13.4%) than in the HIV-negative group (9.1%); this difference was statistically significant ($p = 0.015$). Based on the analysis of 2,432 infants, these crude estimates indicate an increased risk of adverse birth outcomes among HIV-exposed infants.

Table 2
Crude association between maternal HIV status and adverse birth outcomes (LBW and PTB),
Western Kenya PRISMA cohort

Characteristic	Overall	HIV status		p-value ¹
	N = 2,432	Negative	Positive	
Low birth weight, n (%)				0.03
No	2,078 (88.2%)	1,822 (88.8%)	256 (84.5%)	
Yes	277 (11.8%)	230 (11.2%)	47 (15.5%)	
Preterm birth < 37weeks, n (%)				0.015
No	2,197 (90.3%)	1,919 (90.9%)	278 (86.6%)	
Yes	235 (9.7%)	192 (9.1%)	43 (13.4%)	
¹ Pearson's Chi-squared test				
Note: Pregnant women were 2399; infants 2,432, due to multiple pregnancies				

Figure 1 shows covariate balance before and after propensity score adjustment using inverse probability weighting (IPW) and weighted propensity score matching (WPSM). Before adjustment (red dots), substantial imbalance existed between HIV-positive and HIV-negative pregnant women across multiple covariates, with absolute standardized mean differences (SMD) exceeding the 0.1 threshold for acceptable balance. Notable imbalances were observed for propensity score ($SMD > 0.6$), maternal age categories (particularly advanced maternal age ≥ 35 years), gravidity (primigravida and grand multiparous women), and socioeconomic indicators including education level and SES quintiles. After applying both propensity score methods (green dots), balance improved substantially for nearly all covariates, with the majority achieving $SMD < 0.1$, indicating adequate balance. Both IPW and WPSM demonstrated similar effectiveness in reducing covariate imbalance, with adjusted SMDs clustering near zero and falling well within acceptable thresholds.

The WPSM and IPW models revealed consistent and statistically significant associations between maternal HIV status and adverse birth outcomes (Fig. 2).

For low-birth-weight outcomes shown in the upper panel of Fig. 2, both analytical approaches demonstrate that HIV-positive status is associated with an increased risk compared to HIV-negative women, though with somewhat different effect magnitudes. The IPW method yields an RR of 1.66 (95% CI: 1.51–1.82), indicating that HIV-positive women have approximately 66% higher risk of delivering low

birth weight infants compared to their HIV-negative counterparts after accounting for confounding through inverse probability weighting and model covariate adjustments. The WPSM approach produces a slightly higher point estimate of RR = 1.68 (95% CI: 1.39–2.03), suggesting a 68% increased risk of low birth weight among HIV-positive women in the matched sample. Both estimates exclude the null value of 1.0, with confidence intervals that do not cross the reference line, indicating statistically significant associations at conventional alpha levels. The slightly wider confidence interval for WPSM (spanning 0.64 units compared to 0.31 units for IPW) suggests that the IPW approach is more statistically efficient, retaining the full sample while reweighting observations rather than discarding unmatched units.

The lower panel of Fig. 2 presents analogous results for preterm birth, revealing a similar pattern of associations but with some notable differences in effect magnitudes. The IPW approach estimates an RR of 1.32 (95% CI: 1.21–1.44), indicating that HIV-positive women face a 32% higher risk of preterm delivery compared to HIV-negative women after weighting for propensity score differences. The WPSM method yields a higher point estimate of RR = 1.68 (95% CI: 1.41–2.01), suggesting a 68% increased risk of preterm birth among HIV-positive women in the matched cohort. As with low birth weight, both confidence intervals exclude unity and do not overlap with the null line, confirming statistically significant associations. The WPSM confidence interval is again notably wider (spanning 0.60 units) compared to IPW (spanning 0.23 units), consistent with the expected reduction in precision associated with matching procedures that discard unmatched observations.

All associations remained statistically significant after adjustment for blood pressure (BP) levels, hypertension, maternal anemia point of care, MUAC, malaria positivity, poor obstetric history *multiple pregnancies*, and number of ANC visits, suggesting robust relationships independent of the measured confounders variables. The much narrower confidence intervals in the IPW model suggest greater precision in these estimates (Fig. 2).

Discussion

This prospective study in Western Kenya provides demonstrates that maternal HIV infection is associated with increased risk of low birth weight (LBW) and preterm birth (PTB), even in the context of universal antiretroviral therapy (ART) use. Using two complementary causal inference approaches—weighted propensity score matching (WPSM) and inverse probability weighting (IPW)—methods designed to reduce confounding compared with conventional regression—the findings were consistent across approaches, supporting their validity. The concordance in direction, magnitude, and statistical significance strengthens confidence that the observed associations are unlikely to be explained solely by measured confounding. Methodological studies have demonstrated that these causal inference methods have been shown in some settings to reduce bias by up to 90% relative to traditional adjustment (27).

Women living with HIV (WLWH) had substantially elevated risks of LBW under both analytic frameworks. The slightly larger estimates from WPSM (68% higher risk) compared with 66% higher risk of LBW in

IPW, likely reflect differences in target estimands, with WPSM estimating the average treatment effect among the treated (ATT) and IPW estimating the population-average treatment effect (ATE) (26, 30). The close agreement between these approaches suggests broadly similar confounding structures across the treated and overall populations. Our findings align with prior studies from diverse settings that have reported increased risks 60–88% of adverse birth outcomes among HIV-exposed pregnancies, reinforcing the persistence of vulnerability despite widespread ART coverage (31–35). Prior work from China (36) and Florida (37) using propensity score methods reported similarly elevated risks for both outcomes, closely matching our findings. The stronger associations in our study may reflect regional differences in HIV care quality and management.

For preterm birth, the magnitude of association was higher under WPSM –68%– than 32% increase risk in IPW, a pattern consistent with methodological expectations. Matching restricts inference to a more comparable subset of women and may emphasize higher-risk profiles, whereas IPW retains the full cohort and typically yields more conservative population-level estimates when weights are stable (23). Nevertheless, both approaches demonstrated statistically significant elevations in PTB risk, consistent with pooled estimates reported in meta-analyses and regional studies which typically report pooled effect sizes of 1.50–1.70 (31, 32, 38). Regional studies, such as Malaba et al. in South Africa, have shown even stronger associations, further supporting the plausibility of our results (39). Differences in PTB risk across studies likely stem from variations in ART regimens, timing of initiation, adherence, viral suppression, and underlying population characteristics. Evidence from Zambia shows higher PTB risk among women initiating ART during pregnancy compared to those starting pre-conception (38). In our cohort, all women were already on ART, which may explain the comparatively lower risk estimates. Thus, differences in ART exposure and population profiles—not inconsistencies in the literature—account for the variation between our results and those from Zambia.

Biological mechanisms and pathways may underlie these associations, as HIV-related systemic inflammation and altered immune responses can impair placental function and fetal development and increase susceptibility to preterm delivery and low birth weight (40–43). Although all WLWH in our cohort reported ART use during pregnancy, residual risks may persist due to factors such as timing of ART initiation, regimen composition, adherence patterns, and maternal comorbidities. These pathways warrant further investigation. Our findings reinforce WHO recommendations for increased monitoring of HIV-positive pregnancies, particularly with regard to fetal growth (44).

We also observed that HIV prevalence increased with maternal age and decreased with higher educational attainment, patterns consistent with the broader epidemiology of HIV in sub-Saharan Africa (45, 46). These gradients underscore the continuing influence of social—such as health information, economic opportunities, and partner selection, structural determinants (reflecting cumulative sexual exposure over the life course) on HIV risk and, by extension, on downstream maternal and infant health outcomes (47–49).

Importantly, both propensity score approaches achieved adequate covariate balance across key baseline characteristics, with standardized mean differences below conventional thresholds after adjustment. The strong agreement between IPW and WPSM across multiple criteria—including direction of association, overlapping confidence intervals, statistical significance, and effect size similarity within the predefined equivalence margin—provides methodological triangulation that supports the robustness of the findings. WPSM produces well-balanced matched samples that often yield more stable estimates, though at the cost of reduced power and generalizability reflected by relatively wider confidence intervals (23, 27, 30, 50). IPW, meanwhile, preserves all observations and can model variation across the entire population, contributing to higher explained variance and, consequently, narrower confidence intervals (26, 51). While each method has inherent trade-offs, the convergence of results across conceptually distinct approaches reduces the likelihood that the observed associations are artifacts of model specification.

Study Strengths and Limitations

Key strengths of this study include its prospective design, community-based enrollment of pregnant women before 20 weeks' gestation, relatively large sample size, and rigorous application of two complementary causal inference methods. The ability to directly compare WPSM and IPW within the same cohort provides important methodological insight and strengthens confidence in the observed associations. Additionally, the high ART coverage among WLWH reflects real-world programmatic conditions in western Kenya, enhancing the policy relevance of the findings.

Several limitations should be considered. First, although extensive covariate adjustment was performed, residual confounding from unmeasured factors—such as specific ART regimen, timing of ART initiation (pre-conception versus during pregnancy), adherence patterns, viral load suppression, and other chronic diseases—may have influenced the observed associations. Second, the study population consisted of women engaged in antenatal care and community surveillance, which may limit generalizability to women outside formal healthcare systems or in substantially different epidemiologic settings. Third, as with all propensity score approaches, causal interpretation depends on the assumption of no unmeasured confounding and correct model specification. Although weight diagnostics and balance metrics were satisfactory, some degree of model dependence cannot be fully excluded.

Conclusions

In this prospective cohort from western Kenya, maternal HIV infection was independently associated with significantly increased risks of both low birth weight (LBW: RR = 1.66–1.68) and preterm birth (PTB: RR = 1.32–1.68) even among women with universal antiretroviral therapy coverage — all women living with HIV in this cohort reported ART use during pregnancy. This finding suggests that ART alone does not fully eliminate the residual risk of adverse birth outcomes in HIV-positive pregnancies.

A central objective of this study was to compare two causal inference methods – weighted propensity score matching (WPSM) and inverse probability weighting (IPW) – for estimating the effect of maternal HIV on birth outcomes. Both methods produced consistent findings in direction and statistical significance, supporting the validity of the observed associations and demonstrating that the results are robust to the choice of analytical approach. However, the two methods showed meaningful differences in precision: IPW yielded narrower confidence intervals and greater statistical efficiency by retaining the full analytic sample through reweighting, while WPSM produced wider confidence intervals, reflecting the reduced effective sample size inherent to matching. Where the primary goal is estimating a population-average treatment effect with maximum precision in a well-measured observational cohort, IPW is the preferred approach. WPSM remains valuable when the inference target is the treated subgroup or when balance on observed covariates needs to be explicitly verified in a matched sample.

These findings underscore the need for enhanced fetal growth and preterm birth surveillance among women living with HIV within routine antenatal care in Kenya and similar high HIV-burden settings, even where ART coverage is high. Strengthening integrated maternal HIV and antenatal care services remains critical for reducing the residual burden of adverse birth outcomes among HIV-exposed pregnancies.

Future research should further explore the mechanisms driving residual risk despite ART coverage, including the role of ART regimen type, timing of initiation, and comorbidities, and should continue to evaluate the bias–variance trade-offs of propensity score methods across diverse epidemiological settings.

Declarations

Ethical Considerations and declaration

This study was conducted in accordance with the Declaration of Helsinki. The PRISMA study received ethical approval from the Kenya Medical Research Institute Scientific and Ethics Review Unit (KEMRI SERU) (#4166), the Liverpool School of Tropical Medicine (LSTM 23-020), and the Jaramogi Oginga Odinga Teaching and Referral Hospital (JOOTRH) Ethics Review Committee (549/21). All participants provided written informed consent to participate in the study. Data were anonymized, and strict data security procedures were implemented to protect participant confidentiality.

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Conflicts of interest

The authors declare no conflict of interests.

Authors contribution

FO contributed to the manuscript write up, VA, VM, RO, HO, DO, CS, HM, FA: contributed to manuscript critical review. FO, EK, JW, FO, BA, DG: contributed to data retrieval, data analysis and interpretation. KO contributed to Lab result generation.

Author disclaimer

The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Data availability

The dataset collected and analyzed in the context of this research are not publicly accessible owing to the confidentiality, ethical obligations and governing institutional regulations, but can be obtained from the corresponding author upon request.

Consent to Participate declaration: All participants provided written informed consent to participate in the study

Consent to Publish declaration: Not applicable.

Clinical trial number: not applicable

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52. Supplementary Table 1. *Baseline characteristics of pregnant women by maternal HIV status, Western Kenya PRISMA cohort, 2022–2026 after Propensity Score Matching.*

Figures

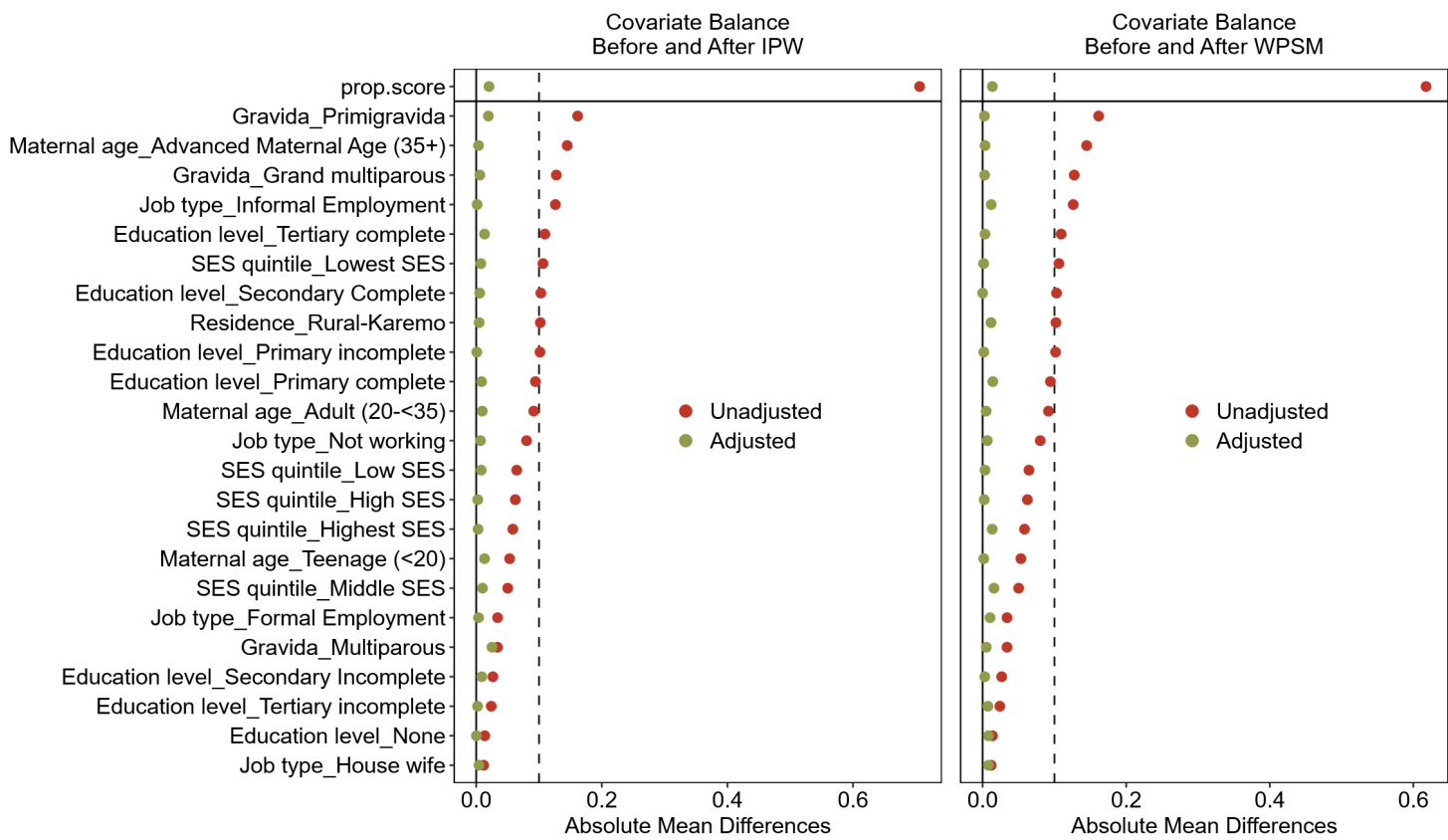


Figure 1

Comparison of covariates balance with absolute standardized mean differences (SMD): Weighted Propensity Score Matching (WPSM) and Inverse Probability Weighting (IPW) sets.

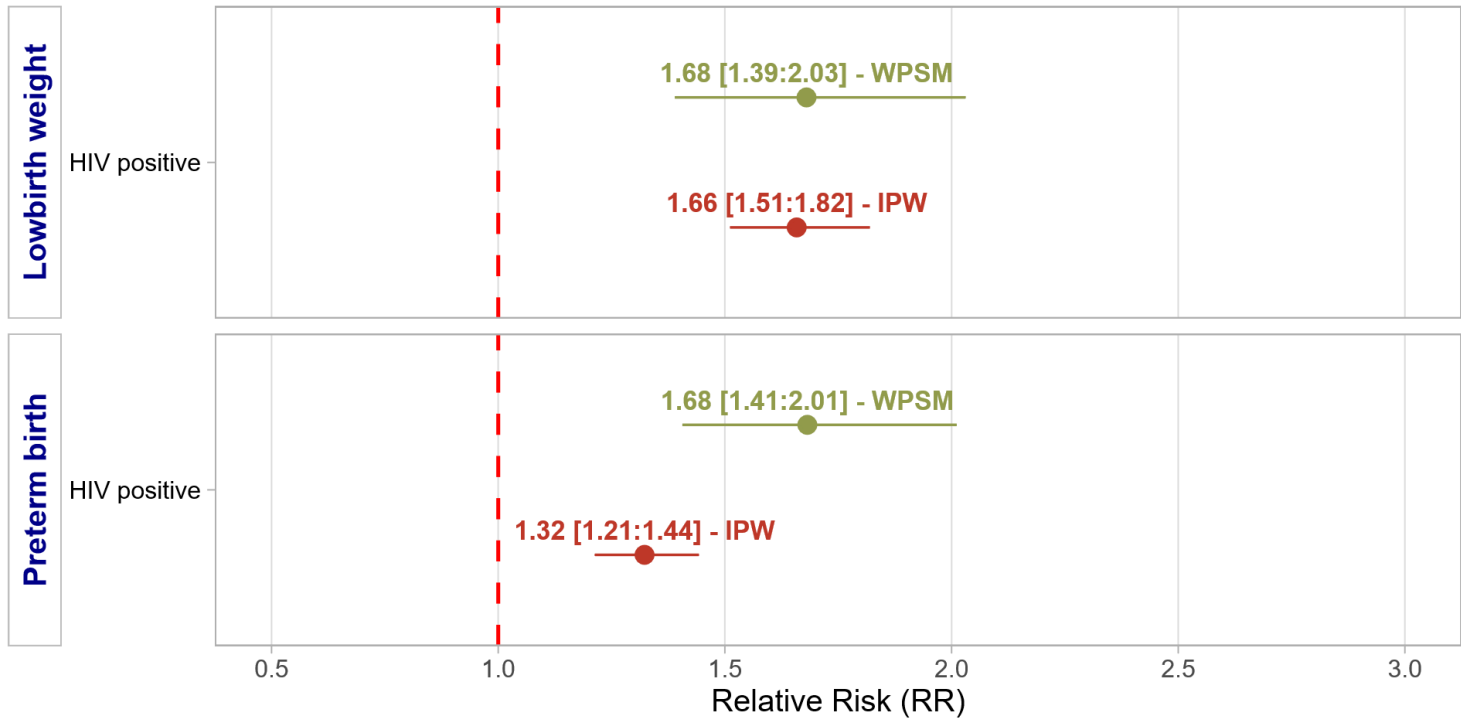


Figure 2

Adjusted analysis of low birth weight and preterm birth: using HIV weighted propensity score matching (WPSM) and inverse probability weighting (IPW) sets (blood pressure (BP) levels, hypertension, maternal anemia points of care, MUAC, malaria positivity, poor obstetric history, multiple pregnancies, and number of ANC visits).

Supplementary Files

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- [SupplementaryTable1.docx](#)