Multivariate Logistic Regression Analysis of Maternal Factors Associated with Stunting, Wasting and Underweight Among HIV-Exposed Infants at Jos University Teaching Hospital, Nigeria

[i]**Kefas Joy Dauda**
Department of Mathematical Sciences
Abubakar Tafawa Balewa University, Bauchi
kefasjoymutong@gmail.com

[ii]**Ahmed Abdulkadir**
Department of Mathematical Sciences
Abubakar Tafawa Balewa University, Bauchi

[iii]**Hamisu Idi**
Department of Mathematical Sciences
Abubakar Tafawa Balewa University, Bauchi

[iv]**Yakubu Paul Mandik**
Department of Mathematical Sciences
Abubakar Tafawa Balewa University, Bauchi
Corresponding author: Kefas Joy Dauda
(kefasjoymutong@gmail.com)

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Abstract
HIV-exposed infants remain nutritionally vulnerable even where prevention of mother-to-child transmission (PMTCT) services function well, yet few studies models stunting, wasting and underweight together or report the statistical assumptions behind their logistic regression models. This retrospective, cross-sectional study used secondary PMTCT and Early Infant Diagnosis records from Jos University Teaching Hospital (JUTH), Plateau State, Nigeria, to identify the maternal factors associated with the three outcomes. After a data quality assessment, 1,047 mother–infant records were analysed. Stunting, wasting and underweight were defined as WHO z-scores below −2 SD. Six maternal factors (age, employment status, antiretroviral therapy [ART] adherence, viral load suppression, ART regimen line and body mass index) were entered into three separate binary logistic regression models, after the independence of observations, multicollinearity, linearity of the logit and events per variable had been tested; all were satisfied. Stunting affected 31.6% of infants, underweight 20.2% and wasting 10.9%. Maternal underweight (adjusted odds ratio [AOR] 2.60), second-line ART (2.58), poor adherence (1.87) and unemployment or informal employment (1.66) independently predicted stunting; unsuppressed viral load (3.18), unemployment (2.24), poor adherence (1.77) and maternal underweight (1.77) predicted underweight; and maternal age alone predicted wasting

(AOR 0.95 per year). No factor was significant in all three models. All models were adequately calibrated (Hosmer–Lemeshow $p \geq 0.329$) with modest discrimination (area under the curve 0.631 to 0.711). Stunting, wasting and underweight therefore have distinct maternal determinants. Maternal nutritional status, treatment adherence and household economic circumstance are the main modifiable influences, which supports outcome-specific monitoring within PMTCT programmes rather than reliance on a single composite malnutrition indicator.

Keywords: *HIV-exposed infants, stunting, wasting, underweight, multivariate logistic regression, PMTCT, Nigeria.*

Introduction

1.1 Background to the Study

The scale-up of prevention of mother-to-child transmission (PMTCT) programmes has substantially reduced vertical transmission of HIV. It has also produced a growing population of infants who are HIV-exposed but uninfected (HEU) across Nigeria and the wider sub-Saharan African region. These infants continue to face a raised risk of poor growth. The cause is rarely a single factor; it is a combination of maternal circumstances, including socio-demographic conditions, antiretroviral therapy (ART) adherence, control of HIV disease and maternal nutritional status, which act together within the mother–infant pair. Even where a facility runs a well-established PMTCT and Early Infant Diagnosis (EID) programme, the nutritional trajectory of the infants it serves can remain an under-examined part of that programme.

Infant nutritional deficits are assessed with three World Health Organization (WHO) anthropometric indices, each capturing a different kind of growth failure: stunting, or chronic linear growth restriction (low length-for-age); wasting, or acute growth failure (low weight-for-length); and underweight (low weight-for-age), which may reflect either or both. All three remain common among Nigerian children. Using the 2018 Nigeria Demographic and Health Survey, Tesfaw and Fenta (2021) found that 36.2%, 21.4% and 6.7% of under-five children were stunted, underweight and wasted respectively, and Obasohan et al. (2024) found that 43.6% of children aged 6 to 59 months were poorly nourished by at least one anthropometric measure. HEU infants experience each of the three conditions at higher rates than HIV-unexposed infants (Neary et al., 2022; Fowler et al., 2022; Ekali et al., 2025; Modjadji et al., 2025).

Because the three conditions only partly overlap, and because the maternal factors that predict them are correlated with one another, each outcome is treated here as a separate function of the same set of maternal characteristics: $NS_j = f(X_1, \ldots, X_6) + \varepsilon$, for j = stunting, wasting, underweight. Isolating the independent contribution of each factor, for each outcome, requires a method that holds the others constant, and multivariate binary logistic regression does so. Applying it to secondary records already held in a hospital's PMTCT and EID programme is a low-cost and timely way to generate local evidence.

1.2 Statement of the Problem

Recent evidence confirms that HIV-exposed infants remain nutritionally vulnerable even where PMTCT services function well. In a survey of mother–infant pairs at 140 clinics in Kenya, Neary et al. (2022) found a higher prevalence of stunting and underweight among HEU infants than among HIV-unexposed infants. In Malawi and Uganda, Fowler et al. (2022) found that antiretroviral- and HIV-exposed uninfected children had persistently lower length-for-age and weight-for-age z-scores up to five years of age. In a 12-month cohort of 166 mother–infant pairs

in the Mathare and Kibera settlements of Nairobi, Kiilu et al. (2025) reported that the proportion of malnourished HIV-exposed infants rose from 22.0% at six weeks to 34.8% at six months. Younger maternal age, poor ART adherence, elevated viral load, second-line ART and maternal unemployment were independently associated with wasting, stunting or underweight in that cohort. Nigeria's own evidence has not caught up with this HIV-specific literature. Tesfaw and Fenta (2021), Amusa et al. (2023) and Obasohan et al. (2024) applied multivariate or multilevel models to national survey data and identified household wealth, maternal body mass index, maternal education and geopolitical zone as predictors of undernutrition in Nigerian children generally, but none isolated HIV-exposed infants or examined maternal treatment factors. In Plateau State, Damar et al. (2025) reported a 28.9% prevalence of stunting among primary school children in Qua'an-Pan Local Government Area, but in the general school-age population. Where maternal HIV status has been examined directly, the findings differ. Musuka et al. (2021) found maternal HIV-positive status associated with higher odds of stunting and underweight in Zimbabwe, whereas Magerko et al. (2024) found that maternal viral suppression was not significantly associated with any of the three outcomes among 674 Kenyan HEU infants. Such divergence suggests that the maternal factors predicting each outcome cannot safely be generalised from one setting to another. It is also uncommon for a single study to model all three outcomes together, test the assumptions of its logistic models and report adjusted odds ratios with full diagnostics. Of the studies reviewed here, only Kiilu et al. (2025) modelled all three outcomes, and it did not report multicollinearity or goodness-of-fit diagnostics. This study addresses these gaps by fitting separate multivariate logistic regression models for stunting, wasting and underweight among HIV-exposed infants in the PMTCT and EID records of Jos University Teaching Hospital (JUTH), Plateau State, Nigeria.

1.3 Objectives of the Study

The main objective of this study was to conduct a multivariate logistic regression analysis of the maternal factors associated with stunting, wasting and underweight among HIV-exposed infants, using secondary data from the PMTCT and EID programme records of JUTH. The specific objectives were to:

i. test the statistical assumptions underlying the logistic regression models for the three outcomes, namely independence of observations, absence of serious multicollinearity, linearity of the logit for the continuous predictor and adequacy of sample size relative to the number of predictors;
ii. determine the maternal factors that independently and significantly predict stunting, wasting and underweight after adjusting for the other covariates; and
iii. estimate the adjusted odds ratios and 95% confidence intervals for each maternal predictor, in order to quantify the strength and direction of its association with each outcome.

1.4 Scope of the Study

The study is limited to secondary data on HIV-exposed infants aged 0 to 24 months and their mothers, extracted from the PMTCT and EID records of JUTH, Jos. It covers six maternal factors (maternal age, employment status, ART adherence, viral load suppression, ART regimen line and maternal nutritional status) and three outcomes (stunting, wasting and underweight), each modelled separately. Other determinants, such as infant feeding practice and household food security, are not examined. The cross-sectional design supports statistical association, not causal inference, and infants who left care before an anthropometric assessment was recorded are

not represented.

Review of Related Literature

2.1 Conceptual and Theoretical Framework

The conceptual framework positions six maternal factors, namely age, employment or socio-economic status, ART adherence, viral load suppression, ART regimen line and body mass index, as independent variables that jointly and separately predict three infant outcomes: stunting, wasting and underweight. The three outcomes are treated as related but analytically distinct, in line with the WHO convention of reporting them separately and with the finding of Obasohan et al. (2024) that their predictors overlap but are not identical. A factor that is significant for one outcome therefore carries no automatic implication for the others.

The study draws on UNICEF's (1990) framework of the determinants of child malnutrition, which separates immediate causes (inadequate diet and infection) from underlying causes (household food insecurity and inadequate maternal care) and basic causes rooted in the socio-economic and health-system context. In this framework, ART adherence, viral suppression and regimen line function as underlying causes specific to HIV-exposed infants, alongside the general socio-demographic causes, such as maternal age and employment, that Tesfaw and Fenta (2021) and Obasohan et al. (2024) found to be significant in Nigerian children generally. The Health Belief Model supplies a behavioural rationale for why adherence should translate into infant outcomes, and the Social Determinants of Health framework places maternal behaviour within the employment and income conditions that shape a mother's capacity to act (Amusa et al., 2023). Bronfenbrenner's ecological perspective adds that the six factors lie mostly at the individual and household levels, while the health-facility context is a constant in a single-site study.

2.2 Empirical Review

2.2.1 Methodological approaches and assumption testing

Studies of maternal and child nutritional status vary in methodological rigour. Kiilu et al. (2025) combined Fisher's exact test with multivariate logistic regression and WHO growth standards, but reported no Hosmer–Lemeshow test or variance inflation factors. Beni et al. (2024) used survey-weighted logistic regression that accounted for the stratification, clustering and weights of Demographic and Health Survey (DHS) data in five West African countries including Nigeria, and the same group extended this with quantile regression (Beni et al., 2025a) and a generalised additive mixed model for non-linear effects (Beni et al., 2025b). Vongsakit et al. (2025) applied multivariable logistic regression to secondary survey data from Laos, a close methodological parallel, but did not report a linearity-of-the-logit check. Across this literature, formal assumption testing, particularly for multicollinearity and linearity, is inconsistently reported. This matter, because correlated predictors can inflate standard errors and destabilise coefficients, and an untested continuous covariate can disguise a threshold or curvilinear relationship as a linear one.

2.2.2 Maternal age and socio-economic factors

Maternal age is a recurring predictor, particularly of wasting. Kiilu et al. (2025) found that infants of mothers aged 18 to 24 years had markedly higher adjusted odds of wasting than those of older mothers at every follow-up from six weeks to twelve months (adjusted odds ratios 4.31 to 5.49). Tesfaw and Fenta (2021) found maternal age at first birth to be a determinant of all

three outcomes in the 2018 Nigeria DHS, whereas Magerko et al. (2024) found maternal age non-significant once infant-level covariates were included. Employment and wealth also recur. Kiilu et al. (2025) found formal maternal employment protective against underweight, and Obasohan et al. (2024) listed maternal work status among the predictors of malnutrition across Nigerian states. Tesfaw and Fenta (2021) and Amusa et al. (2023) identified household wealth as a leading determinant, with children from the richest households having odds of stunting, underweight and wasting of 0.392, 0.540 and 0.786 times those of the poorest (Tesfaw & Fenta, 2021). Evidence from Ethiopia is less uniform: Amaha and Woldeamanuel (2021) reported that unemployed mothers were significantly less likely to have a stunted child. Maternal education is among the most consistent correlates (Ayelign & Zerfu, 2021; Tafesse et al., 2021; Desalegn et al., 2024), and Folson et al. (2024) identified younger, less-educated, lower-income mothers in Ghana as needing particular support for their HIV-exposed children.

2.2.3 Maternal HIV treatment factors and nutritional status

Treatment factors form a theme specific to HIV-exposed infants. Kiilu et al. (2025) reported that poor ART adherence and a second-line regimen were independently associated with higher odds of infant stunting, and that elevated maternal viral load was associated with underweight. Musuka et al. (2021) found maternal HIV-positive status associated with higher odds of child stunting (odds ratio 1.23) and underweight (1.69) in Zimbabwe, but Magerko et al. (2024) found that viral suppression was unrelated to any of the three outcomes once infant sex, age and initial weight-for-age were controlled. Okafor et al. (2021) showed that the relationship between nutrition and virological outcomes in HIV-positive children in Ibadan runs in both directions. This divergence shows that the strength of treatment-related associations is not consistent across settings and specifications. Maternal nutritional status is also relevant: infants of underweight mothers had substantially higher odds of stunting at six months in the Nairobi cohort (Kiilu et al., 2025), and maternal body mass index is an important determinant in Nigerian national data (Tesfaw & Fenta, 2021). More broadly, HEU infants experience elevated malnutrition risk whatever the predictor examined (Neary et al., 2022; Fowler et al., 2022; Pillay et al., 2021; Ekali et al., 2025; Tshiambara et al., 2025), and earlier cohorts identified maternal education, household possessions and birth weight as independent predictors of stunting, wasting and underweight among children of HIV-infected women (McGrath et al., 2012; Chalashika et al., 2017).

2.2.4 Magnitude of association

Where adjusted odds ratios are reported, their magnitude varies widely. Kiilu et al. (2025) reported values from about 3.7 to 6.3 for the significant maternal predictors, among the largest in the literature, whereas Magerko et al. (2024) reported near-null, non-significant odds ratios of 0.61 to 0.71 for viral suppression, and Musuka et al. (2021) a modest but significant 1.23 for maternal HIV status and stunting. This inconsistency, among studies using broadly similar methods, is what motivates local estimation of effect sizes with confidence intervals.

2.3 Gap in Literature

The literature establishes that HIV-exposed infants face an elevated risk of stunting, wasting and underweight, and that maternal age, socio-economic status, ART adherence, viral suppression, regimen line and nutritional status recur as plausible predictors. Three gaps remain. First, formal testing of the assumptions of the fitted logistic models is rarely reported. Second, only Kiilu et al.

(2025) modelled all three outcomes in one logistic framework, and that study did not report the assumption diagnostics; the other studies examined a subset of the outcomes, a different outcome such as feeding practice, or used non-logistic methods. Third, no reviewed study applied this framework to HIV-exposed infants in a Nigerian teaching hospital; the only comparable sub-national evidence, Damar et al. (2025), concerned general-population school children. This study fills these gaps by testing the model assumptions, fitting separate models for the three outcomes and estimating local adjusted odds ratios from JUTH's own PMTCT and EID records.

Methodology

3.1 Research Design and Source of Data

The study used a quantitative, analytical cross-sectional design applied retrospectively to secondary data. The data were routinely recorded in the PMTCT and EID programme at JUTH, Jos, Plateau State, in the hospital's electronic medical record system and clinic registers, for the period January 2017 to December 2025. They comprise maternal socio-demographic and HIV treatment information and infant anthropometric measurements. Three separate multivariate logistic regression analyses were carried out, one each for stunting, wasting and underweight, because the three conditions can arise from different combinations of circumstances and need not co-occur. Each adjusted odds ratio therefore describes a snapshot association at the time of the recorded assessment, not a causal sequence.

3.2 Study Population and Eligibility

The population comprised the records of HIV-exposed infants aged 0 to 24 months and their biological mothers enrolled in the PMTCT and EID programme. An HIV-exposed infant was defined as one born to a mother who tested positive for HIV during pregnancy, labour, delivery or breastfeeding, irrespective of the infant's own HIV status. A record was eligible if it confirmed HIV exposure and an age of 0 to 24 months at the anthropometric assessment, contained complete data on the six maternal factors and the anthropometric indices, fell within the reference period, and belonged to a unique, non-duplicated mother–infant pair. Records were excluded for a congenital anomaly or chronic illness likely to affect growth independently, for missing values that could not be verified from the source document, or for duplication.

3.3 Sample Size

The minimum number of records was determined with the Cochran (1977) formula for a proportion,

$$n = \frac{Z^2\, p\,(1-p)}{d^2} \qquad \text{(Eq. 1)}$$

where Z = 1.96, p is the expected proportion with the outcome and d is the margin of error. Taking p = 0.35, informed by the 34.8% peak malnutrition prevalence of Kiilu et al. (2025) and the 43.6% national prevalence of Obasohan et al. (2024), and d = 0.05, gives about 350 records. With a finite population correction for the 1,438 records identified, the figure falls to 281, and a 10% allowance for data-quality exclusions raises it to 309. Because three models are fitted, and the rarest outcome must itself satisfy the rule of at least ten events per predictor, extraction was continued well beyond this minimum, to at least 1,000 eligible records.

3.4 Study Variables

Three binary outcomes were derived from the infant anthropometric measurements using the WHO (2006) Child Growth Standards. Stunting was coded 1 where length-for-age *z*-score (LAZ) was below −2 SD, wasting where weight-for-length *z*-score (WLZ) was below −2 SD, and underweight where weight-for-age *z*-score (WAZ) was below −2 SD; otherwise 0. Six predictors, common to all models, were retained on the basis of the literature reviewed: maternal age in completed years (X_1, continuous); employment status (X_2; 0 = formally employed, 1 = unemployed or informally employed); ART adherence classified from pharmacy refill and clinic attendance records (X_3; 0 = good, 1 = poor); viral load status from the most recent measurement (X_4; 0 = suppressed, below 1,000 copies/mL; 1 = unsuppressed); ART regimen line (X_5; 0 = first-line, 1 = second-line); and maternal nutritional status (X_6; 0 = body mass index of 18.5 kg/m² or more, 1 = underweight, below 18.5 kg/m²).

3.5 Statistical Analysis

Maternal age was summarised by its mean and standard deviation, and categorical variables by frequencies and percentages. Prevalence was reported with Wilson score 95% confidence intervals, which perform better than the normal approximation for low proportions such as wasting. Each maternal factor was first compared with each outcome using the Pearson chi-square test (categorical factors) or Welch's *t*-test (maternal age), and factors with $p < 0.25$ were retained for that outcome's multivariate model. For outcome *j*, the response of each infant was assumed to follow a Bernoulli distribution with probability P_j, modelled through the logit link,

$$\text{logit}(P_j) = \ln\left[\frac{P_j}{1-P_j}\right] = \beta_{0j} + \beta_{1j}X_1 + \beta_{2j}X_2 + \beta_{3j}X_3 + \beta_{4j}X_4 + \beta_{5j}X_5 + \beta_{6j}X_6 \quad \text{(Eq. 2)}$$

where β_{0j} is the intercept and β_{1j} to β_{6j} are the coefficients of X_1 to X_6 in the model for outcome *j*. Parameters were estimated by maximum likelihood, maximising

$$\ln L(\boldsymbol{\beta}) = \sum_{i=1}^{n} [Y_i \ln P_i + (1 - Y_i)\ln(1 - P_i)] \quad \text{(Eq. 3)}$$

with the Newton–Raphson algorithm,

$$\boldsymbol{\beta}^{(t+1)} = \boldsymbol{\beta}^{(t)} - \left[H\left(\boldsymbol{\beta}^{(t)}\right)\right]^{-1} U\left(\boldsymbol{\beta}^{(t)}\right) \quad \text{(Eq. 4)}$$

where *U* is the score vector and *H* the Hessian matrix, until successive log-likelihood values differed by less than 0.0001. Coefficients were exponentiated to give adjusted odds ratios (AOR), each adjusted for the other five factors in the same model, with 95% confidence intervals and Wald statistics,

$$\text{AOR} = e^{\hat{\beta}}, \qquad 95\%\ \text{CI} = \exp\left(\hat{\beta} \pm 1.96\,\text{SE}\right) \quad \text{(Eq. 5)}$$

$$W = \left(\frac{\hat{\beta}}{\text{SE}}\right)^2 \quad \text{(Eq. 6)}$$

where SE is the standard error. All tests were two-tailed at the 5% level. Analyses were run in Python 3.

3.6 Assumption Tests and Model Diagnostics

Independence of observations was assessed from the data structure, with one record per mother–infant pair after de-duplication. Multicollinearity was assessed once, because the predictors are shared by the three models, with the variance inflation factor (VIF),

$$\mathrm{VIF}_i = \frac{1}{1 - R_i^2} \quad \text{(Eq. 7)}$$

where R_i^2 is the coefficient of determination from regressing X_i on the other predictors; a VIF above 10 was taken to indicate problematic collinearity (Hosmer et al., 2013). Linearity of the logit in maternal age, the only continuous predictor, was tested with the Box–Tidwell procedure, which adds the term $X_1 \ln X_1$ to each model,

$$\mathrm{logit}(P) = \beta_0 + \sum_{k=1}^{6} \beta_k X_k + \gamma\,(X_1 \ln X_1) \quad \text{(Eq. 8)}$$

where a significant γ indicates non-linearity. Sample size adequacy was judged by the events-per-variable ratio, with a minimum of 10 (Hosmer et al., 2013),

$$\mathrm{EPV} = \frac{\min(n_1, n_0)}{k} \quad \text{(Eq. 9)}$$

where n_1 and n_0 are the numbers with and without the outcome and k = 6 is the number of predictors. Cross-tabulations were inspected for zero cells (separation), and leverage, standardised Pearson residuals and Cook's distance were computed for every record. Overall significance of each model was tested with the likelihood-ratio statistic,

$$G = -2(LL_0 - LL_1) \quad \text{(Eq. 10)}$$

where LL_0 and LL_1 are the log-likelihoods of the constant-only and fitted models. Calibration was assessed with the Hosmer–Lemeshow test across deciles of predicted risk,

$$HL = \sum_{g=1}^{10} \frac{(O_g - E_g)^2}{E_g} \quad \text{(Eq. 11)}$$

where O_g and E_g are the observed and expected events in group g, and explanatory power with Nagelkerke's pseudo R^2,

$$R_N^2 = \frac{1 - (L_0/L_1)^{2/n}}{1 - L_0^{2/n}} \quad \text{(Eq. 12)}$$

where L_0 and L_1 are the likelihoods of the constant-only and fitted models and n is the sample size. Discrimination was summarised by the area under the receiver operating characteristic (ROC) curve (AUC), and classification performance was reported at the conventional 0.50 cut-off and at the Youden-optimal cut-off, which maximises sensitivity plus specificity minus one.

3.7 Data Quality and Ethical Considerations

The proportion of missing values was computed for every variable, and variables or records above a 10% missingness threshold were flagged for exclusion rather than imputed. Two trained extractors independently abstracted a 10% random subsample to assess inter-extractor agreement, and range and consistency checks (for example, maternal age outside 15 to 49 years) were verified against the source documents. Ethical clearance and a waiver of individual informed consent for retrospective record review were sought, and permission to access the records was obtained from JUTH management. Records were de-identified at extraction with study codes, the linkage key was held separately by the principal investigator, and only aggregated results are reported.

Results and Discussion

4.1 Analytic Sample and Descriptive Characteristics

After data quality screening, 1,047 of the 1,438 records identified (72.8%) were retained. Records were excluded for age outside the 0–24-month window, congenital anomaly or chronic illness affecting growth, duplication, missing maternal factors and incomplete anthropometry. No variable exceeded the 10% missingness threshold after these exclusions, and inter-extractor agreement on the verification subsample was 96.8%. The retained sample was about 3.4 times the corrected minimum of 309 records.

Maternal age was approximately symmetric (mean 28.22 years, SD 6.17; median 28; interquartile range 24 to 33; range 15 to 49). Of the 1,047 mothers, 255 (24.4%) were aged 18 to 24 years and 44 (4.2%) were adolescents below 18 years (Table 1). Viral suppression had been achieved in 83.8% of mothers, 81.5% were classified as adherent and 90.1% were on first-line therapy. Against this, 61.5% were unemployed or informally employed and 13.1% were themselves underweight. The sample therefore describes a population receiving reasonably well-functioning PMTCT care while facing considerable socio-economic disadvantage.

Table 1: Socio-demographic and HIV treatment characteristics of mothers of HIV-exposed infants (n = 1,047)

Maternal characteristic	*n*	%
Maternal age (X_1; analysed as continuous years): mean (SD) = 28.22 (6.17)		
Below 18 years	44	4.2
18–24 years	255	24.4
25–34 years	585	55.9
35 years and above	163	15.6
Employment status (X_2)		
Formally employed (reference)	403	38.5
Unemployed or informally employed	644	61.5
ART adherence (X_3)		
Good adherence (reference)	853	81.5
Poor adherence	194	18.5
Viral load status (X_4)		
Suppressed, < 1,000 copies/mL (reference)	877	83.8
Unsuppressed	170	16.2
ART regimen line (X_5)		
First-line (reference)	943	90.1
Second-line	104	9.9
Maternal nutritional status (X_6)		
Normal or overweight, BMI ≥ 18.5 (reference)	910	86.9
Underweight, BMI < 18.5	137	13.1

Note: ART = antiretroviral therapy; BMI = body mass index (kg/m²). Maternal age is banded here for description only; it entered all models as a continuous variable.

Stunting was the most prevalent indicator at 31.6%, followed by underweight at 20.2% and wasting at 10.9%; the confidence intervals did not overlap (Table 2, Figure 1). Overall, 525 infants (50.1%) were affected by at least one indicator. Of the 1,047 infants, 522 (49.9%) had none, 405 (38.7%) had exactly one, 108 (10.3%) had two and 12 (1.1%) had all three, so 11.5%

presented with two or more indicators concurrently.

Table 2: Prevalence of stunting, wasting and underweight among HIV-exposed infants (n = 1,047)

Indicator	Definition	*n* affected	%	95% CI (Wilson)
Stunting	LAZ < −2 SD	331	31.6	28.9–34.5
Wasting	WLZ < −2 SD	114	10.9	9.1–12.9
Underweight	WAZ < −2 SD	212	20.2	17.9–22.8
Any of the three	—	**525**	**50.1**	**47.1–53.2**

Note: LAZ = length-for-age z-score; WLZ = weight-for-length z-score; WAZ = weight-for-age z-score; CI = confidence interval. The categories are not mutually exclusive.

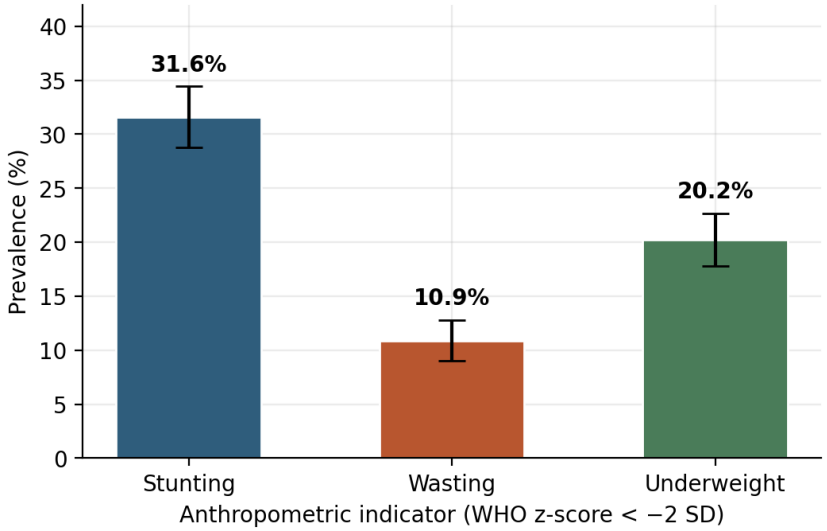


Figure 1: Prevalence of stunting, wasting and underweight among HIV-exposed infants, with 95% confidence intervals.

4.2 Test of the Statistical Assumptions

All four assumptions were satisfied (Table 3). Independence was established by design: each record is a unique mother–infant pair, duplicates having been removed at extraction, and all records came from a single facility, so no clustering arises. Multicollinearity was absent, with all VIFs between 1.007 and 1.098 and all tolerances above 0.91; the two largest, for unsuppressed viral load (1.098) and poor adherence (1.089), reflect the expected link between non-adherence and virological failure but are far too small to destabilise the estimates. The Box–Tidwell term was non-significant in all three models, so maternal age was retained in untransformed continuous form. The events-per-variable ratio was lowest for wasting (19.0), well above the minimum of 10. Had extraction stopped at the corrected Cochran minimum of 309 records, the wasting model would have had about 6 events per variable and would have failed this criterion.

Table 3: Summary of assumption tests and diagnostics for the three logistic regression models

Assumption or diagnostic	Result	Conclusion
Independence of observations	One record per mother–infant pair; duplicates removed; single site	Satisfied
Multicollinearity (VIF)	VIF 1.007–1.098; tolerance > 0.91	Satisfied
Linearity of the logit (Box–Tidwell, maternal age)	p = 0.780 (stunting), 0.473 (wasting), 0.877 (underweight)	Satisfied
Events per variable (minimum 10)	55.2 (stunting), 19.0 (wasting), 35.3 (underweight)	Satisfied
Separation	No zero cells in any cross-tabulation; convergence within 8 iterations	None detected
Leverage and influence	Maximum leverage 0.0437; maximum Cook's D 0.0215	No influential record
Standardised Pearson residuals > 3	0 (stunting), 44 [4.2%] (wasting), 24 [2.3%] (underweight)	Poorly fitted subset in wasting and underweight

Note: VIF = variance inflation factor. The large residuals in the wasting and underweight models were infants who had the outcome despite a low predicted probability.

4.3 Maternal Factors Independently Predicting Each Outcome

In the bivariate analysis, every maternal factor met the $p < 0.25$ threshold for every outcome (Appendix Table A2), so all six factors entered all three models and the models are comparable term for term. The adjusted results are shown in Table 4 and Figure 2, and the full coefficients in Appendix Table A1. The stunting model was significant overall ($\chi^2(6) = 93.81$, $p < 0.001$). Four factors were independently significant: maternal underweight (AOR 2.60; 95% CI 1.78–3.81), second-line ART (2.58; 1.68–3.97), poor ART adherence (1.87; 1.32–2.63) and unemployment or informal employment (1.66; 1.24–2.22). Unsuppressed viral load was significant in the crude analysis (crude OR 1.92, $p < 0.001$) but not after adjustment for adherence and regimen line (AOR 1.33; 0.92–1.92; $p = 0.133$), and maternal age was likewise non-significant (0.98; 0.96–1.00; $p = 0.124$). The wasting model was significant overall ($\chi^2(6) = 25.33$, $p < 0.001$), but only maternal age was independently significant, inversely (AOR 0.95 per year; 0.92–0.98; $p = 0.001$); each additional year of maternal age reduced the odds of wasting by 5.3%. The other five factors were non-significant, although all five odds ratios exceeded 1.00, including poor adherence (1.52; 0.95–2.44; $p = 0.081$) and maternal underweight (1.40; 0.83–2.37; $p = 0.207$). For a mother who was unemployed or informally employed, adherent, virally suppressed, on first-line therapy and of normal weight, the predicted probability of wasting fell from about 15.4% at 18 years of age to 5.2% at 40 years (Figure 3).

The underweight model was the strongest by omnibus test ($\chi^2(6) = 99.63$, $p < 0.001$). Four factors were significant: unsuppressed viral load (AOR 3.18; 2.17–4.66), unemployment or informal employment (2.24; 1.56–3.22), poor adherence (1.77; 1.21–2.58) and maternal underweight (1.77; 1.16–2.68). Maternal age (0.98; 0.96–1.01) and second-line ART (1.13; 0.68–1.87) were not. No factor was significant in all three models, and the wasting model shared no significant predictor with the other two.

Table 4: Adjusted odds ratios (AOR) and 95% confidence intervals from the three multivariate logistic regression models

Maternal factor	Stunting AOR (95% CI)	*p*	Wasting AOR (95% CI)	*p*	Underweight AOR (95% CI)	*p*
Maternal age (per year)	0.98 (0.96–1.00)	0.124	**0.95 (0.92–0.98)**	**0.001**	0.98 (0.96–1.01)	0.164
Unemployed or informally employed	**1.66 (1.24–2.22)**	**< 0.001**	1.40 (0.91–2.15)	0.127	**2.24 (1.56–3.22)**	**< 0.001**
Poor ART adherence	**1.87 (1.32–2.63)**	**< 0.001**	1.52 (0.95–2.44)	0.081	**1.77 (1.21–2.58)**	**0.003**
Unsuppressed viral load	1.33 (0.92–1.92)	0.133	1.31 (0.79–2.18)	0.299	**3.18 (2.17–4.66)**	**< 0.001**
Second-line ART regimen	**2.58 (1.68–3.97)**	**< 0.001**	1.32 (0.72–2.42)	0.377	1.13 (0.68–1.87)	0.632
Maternal underweight (BMI < 18.5)	**2.60 (1.78–3.81)**	**< 0.001**	1.40 (0.83–2.37)	0.207	**1.77 (1.16–2.68)**	**0.008**

Note: Bold values are significant at $p < 0.05$. Each AOR is adjusted for the other five factors in the same model. Maternal age is per additional completed year; the other factors are relative to the reference categories in Table 1.

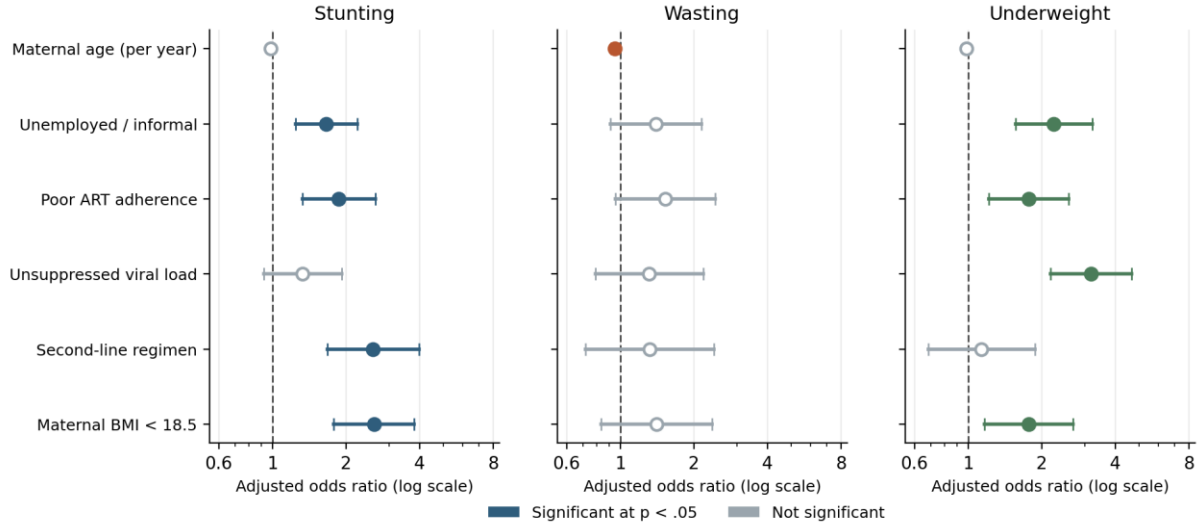


Figure 2: Adjusted odds ratios with 95% confidence intervals for the six maternal factors in the three models (log scale; filled markers p < 0.05).

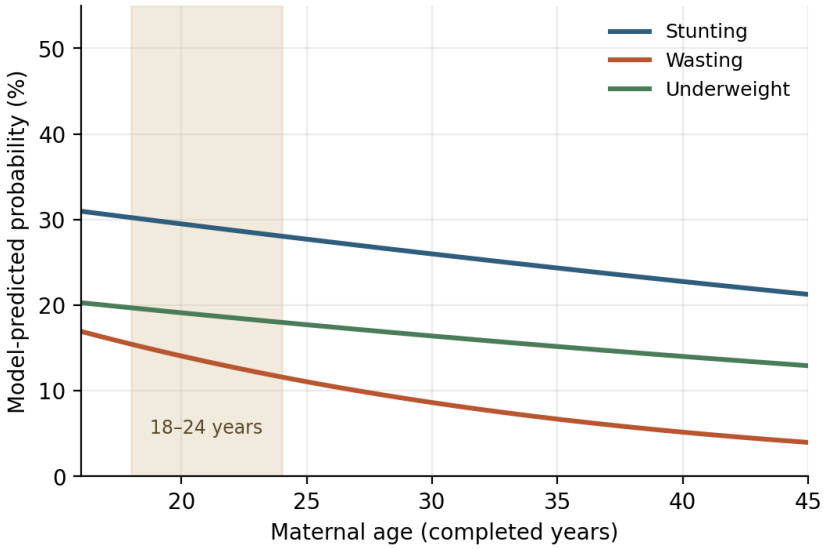


Figure 3: Model-predicted probability of each outcome by maternal age for the reference maternal profile described in the text (shaded band: ages 18–24 years).

4.4 Model Fit, Calibration and Predictive Performance

All three models were significant against the constant-only model and passed the Hosmer–Lemeshow test (p = 0.890, 0.583 and 0.329), indicating acceptable calibration (Table 5). Discrimination was modest but above chance, with AUC values of 0.671 for stunting, 0.631 for wasting and 0.711 for underweight (Figure 4), and Nagelkerke R^2 ranged from 0.048 to 0.143. At the conventional 0.50 cut-off, accuracy was highest for the wasting model (89.1%), yet its sensitivity was 0.0%: because only 10.9% of infants were wasted, classifying every infant as not wasted would give the same accuracy while identifying no case. At the Youden-optimal cut-off of 0.134, the wasting model reached 43.9% sensitivity and 77.0% specificity; the corresponding results were 50.2% and 74.2% for stunting (cut-off 0.316) and 58.5% and 74.5% for underweight (cut-off 0.197).

Table 5: Fit, calibration and classification performance of the three logistic regression models

Statistic	Stunting	Wasting	Underweight
Omnibus χ^2 (df = 6)	93.81	25.33	99.63
p (omnibus)	< 0.001	< 0.001	< 0.001
−2 log-likelihood (constant-only / fitted)	1306.50 / 1212.70	720.70 / 695.36	1055.01 / 955.38
Cox and Snell R^2	0.086	0.024	0.091
Nagelkerke R^2	0.120	0.048	0.143
Hosmer–Lemeshow χ^2 (df = 8)	3.61	6.58	9.16
p (Hosmer–Lemeshow)	0.890	0.583	0.329
Area under ROC curve	0.671	0.631	0.711
Accuracy at 0.50 cut-off (%)	71.3	89.1	80.4
Sensitivity / specificity at 0.50 cut-off (%)	23.3 / 93.4	0.0 / 100.0	14.6 / 97.1
Youden-optimal cut-off	0.316	0.134	0.197
Sensitivity / specificity at optimal cut-off (%)	50.2 / 74.2	43.9 / 77.0	58.5 / 74.5

Note: ROC = receiver operating characteristic. A non-significant Hosmer–Lemeshow statistic indicates acceptable calibration.

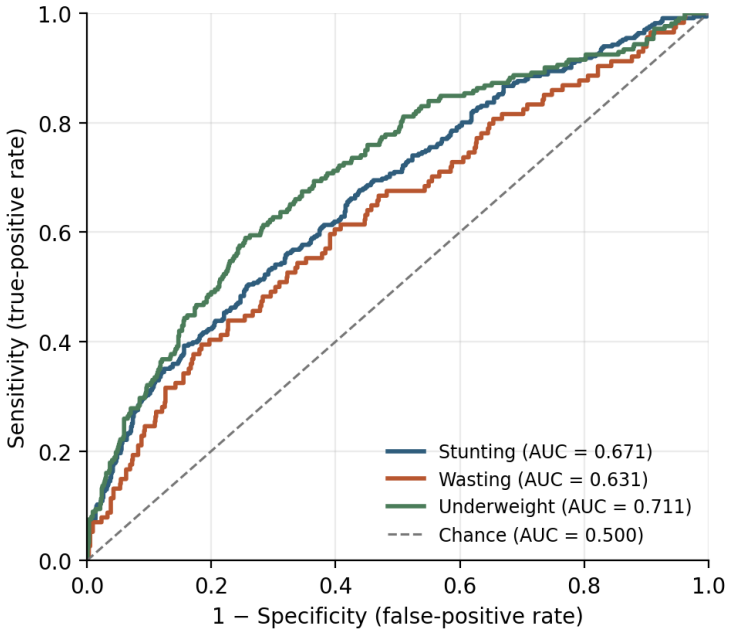


Figure 4: Receiver operating characteristic curves for the three logistic regression models.

4.5 Discussion of Findings

4.5.1 Assumptions and methodological findings

The models could be estimated and interpreted without transformation or respecification, because every assumption held and the supplementary diagnostics disclosed no separation and no influential observation. This addresses a gap in the recent literature. Kiilu et al. (2025), the closest study in design, modelled all three outcomes but reported neither multicollinearity nor linearity checks, so a reader cannot tell whether its very wide confidence intervals reflect genuine imprecision in a sample of 166 infants or unreported collinearity among correlated treatment variables. Magerko et al. (2024) likewise reported no documented assumption sequence, while the large DHS analyses handled independence through multilevel or survey-weighted specifications (Obasohan et al., 2024; Beni et al., 2024).

The linearity result is substantive. The non-significant Box–Tidwell terms show that the log-odds of each outcome change linearly with maternal age across the 15 to 49 year range, so the risk linked with young motherhood is continuous rather than threshold-based. The dichotomy at 24 years used by Kiilu et al. (2025) is convenient for reporting but imposes an artificial discontinuity and discards information. The events-per-variable result also carries a general lesson: where several outcomes of different prevalence are modelled separately, sample size must be set by the rarest outcome, not by a composite or the average.

4.5.2 Distinct determinants and maternal nutritional status

The central result is that the three outcomes have distinct maternal determinants. A study that collapsed them into one malnutrition indicator would have reported an averaged and less actionable set of predictors, and would have hidden the fact that acute wasting is not explained by the circumstances that explain chronic and composite growth failure. Maternal underweight predicted stunting (AOR 2.60) and underweight (1.77). This agrees in direction with Kiilu et al. (2025), who reported an adjusted odds ratio of 4.76 (95% CI 1.36–16.65) for stunting at six

months among infants of underweight mothers; the present estimate is smaller but far more precise. Folson et al. (2024), Tshiambara et al. (2025) and Desalegn et al. (2024) likewise located the main determinants of growth in HEU infants in maternal and household diet quality, so the mother's own nutritional state emerges as the most modifiable and most transferable target.

4.5.3 Maternal HIV treatment factors

Poor ART adherence predicted stunting (AOR 1.87) and underweight (1.77), consistent in direction with the adjusted odds ratio of 4.11 for stunting at twelve months in Kiilu et al. (2025). Second-line therapy predicted stunting alone (2.58), against 3.68 in the same study. The smaller magnitudes here are the expected result of estimating the same associations in a sample more than six times larger and of adjusting for maternal nutritional status, which partly mediates the treatment–growth relationship. The regimen finding calls for caution. Glanzmann et al. (2026), in rural Tanzania, found that HEU infants tracked below the WHO reference irrespective of whether their mothers took dolutegravir- or efavirenz-based therapy, which argues against a pharmacological effect of the drugs themselves. The reading consistent with both studies is that second-line therapy marks a longer and more difficult treatment history, with prior virological failure, more severe disease and often more socio-economic instability.

The viral load result helps to reconcile a divergence in the literature. Unsuppressed viral load was strongly associated with stunting in the crude analysis but not after adjustment (AOR 1.33), while it remained the strongest independent predictor of underweight (3.18). Magerko et al. (2024) found viral suppression unrelated to any outcome, whereas Kiilu et al. (2025) found high viral load associated with underweight at six weeks. The present analysis is consistent with both: viraemia has no independent association with linear growth once adherence and regimen are controlled, because it operates through them, but it keeps an independent association with weight-for-age deficit. The apparent contradiction between the two studies thus partly reflects which outcome each examined, which is visible only when the outcomes are modelled separately.

4.5.4 Socio-economic status

Unemployment or informal employment predicted stunting (AOR 1.66) and underweight (2.24). This matches the protective effect of formal maternal employment against underweight in Kiilu et al. (2025) and the well-established Nigerian and West African finding that household economic position is among the most consistent determinants of child undernutrition (Amusa et al., 2023; Beni et al., 2024, 2025a; Obasohan et al., 2024), as well as evidence from Laos that household wealth predicts stunting independently of maternal characteristics (Vongsakit et al., 2025).

4.5.5 Maternal age and wasting

Maternal age was the only independent predictor of wasting (AOR 0.95 per year) and was not significant for the other outcomes. This is closer to Kiilu et al. (2025) than it may first appear: they found that young maternal age raised the odds of wasting at all three assessments (adjusted odds ratios 4.31 to 5.49), while their significant findings for stunting and underweight rested on treatment and employment variables. The present analysis reproduces that outcome-specific pattern with a continuous rather than a categorical specification. Expressed comparably, a mother of 21 years carries about 1.64 times the odds of infant wasting of an otherwise identical mother of 30, a smaller effect than reported by Kiilu et al. but estimated with greater precision and

without dependence on an age cut-point. The wasting model is nonetheless the weakest, with a Nagelkerke R^2 of 0.048 and an AUC of 0.631, and five of six odds ratios above 1.00 but none significant. Two readings are available. The first is statistical: with only 114 events the model is the least powered, and non-significance is not evidence of absence, particularly for maternal underweight and poor adherence, whose *p* values (0.207 and 0.081) lie close to the threshold. The second is substantive: acute wasting reflects recent insults, such as infection, feeding interruption or acute food insecurity, which the six routine maternal variables do not capture. The 44 large standardised residuals (4.2%) in this model support the second reading. Th
e two readings are not exclusive, and both point to a larger sample and a richer variable set.

4.5.6 Strength of association and practical use

The adjusted odds ratios are moderate: the largest is 3.18, well below the 6.33 reported by Kiilu et al. (2025). Estimates from small samples are more dispersed, and the very wide intervals around the Nairobi estimates are compatible with effects of the size found here. Large but imprecise estimates from small HEU cohorts converging on more moderate values in larger analyses is what the meta-analyses describe, with consistent but modest growth deficits among HEU children (Ekali et al., 2025; Modjadji et al., 2025). The intervals for the significant predictors are narrow enough to support decisions; the interval for maternal underweight and stunting (1.78–3.81) excludes any trivial effect, whereas that for maternal underweight and wasting (0.83–2.37) spans the null and should not guide action. Because stunting is common (31.6%), odds ratios overstate relative risk, so predicted probabilities (Figure 3) are a useful complement. With AUC values of 0.631 to 0.711 and sensitivities of 43.9% to 58.5% at the optimal cut-offs, the models are suited to ranking mother–infant pairs by relative risk to prioritise follow-up, not to use as stand-alone diagnostic screening tools.

Conclusion

5.1 Conclusion

Stunting, wasting and underweight among HIV-exposed infants at JUTH are distinct conditions with different maternal determinants. No maternal factor predicted all three, and the wasting model shared no significant predictor with the other two; together with the 11.5% concurrence rate, this justifies modelling the outcomes separately. In a PMTCT population where treatment performance is already reasonably good, with 83.8% of mothers virally suppressed, the dominant modifiable influences on chronic and composite growth failure are maternal nutritional status, treatment adherence and regimen history, and household economic circumstance. Unsuppressed viral load had no independent effect on linear growth once adherence and regimen line were accounted for, and its independent association was confined to underweight. Acute wasting was not well explained by the routinely recorded maternal factors, with maternal age its only independent predictor; whether this reflects limited power for the rarest outcome or causes outside the maternal record cannot be settled by this design. Methodologically, the assumptions of logistic regression can be tested simply and should be reported routinely, and the fitted models are appropriate for ranking risk, not for binary diagnosis.

5.2 Recommendations

On the basis of these findings, the authors recommend that:

i. maternal body mass index be measured and acted on at every PMTCT contact, and mothers with a body mass index below 18.5 kg/m² be referred to nutrition support, with their infants' length-for-age measured and plotted at every visit;

ii. adherence counselling be framed explicitly as an infant growth intervention as well as a transmission-prevention intervention, and infants of mothers on second-line regimens or with unsuppressed viral load be flagged for closer linear growth and weight-for-age monitoring respectively;

iii. where the models are used to prioritise follow-up, the Youden-optimal cut-offs be applied and the output treated as a risk ranking, not a diagnosis;

iv. routine records be extended to capture infant feeding practice, dietary diversity, birth weight and a household food security indicator;

v. state and national PMTCT monitoring report stunting, wasting and underweight separately, integrate nutritional and livelihood support for mothers living with HIV into the service package, and give adolescent and young mothers a differentiated service with attention to acute wasting; and

vi. future work replicates the analysis across several Nigerian PMTCT sites with a multilevel specification, use a prospective design to establish temporal order, study wasting with more events and a richer variable set, and model regimen composition and treatment history separately.

5.3 Contribution to Knowledge

The study makes four contributions. It provides, to the authors' knowledge, the first multi-outcome multivariate logistic regression analysis of maternal determinants of nutritional status among HIV-exposed infants at JUTH. It demonstrates a complete assumption-testing and diagnostic sequence that other Nigerian teaching hospitals with comparable PMTCT records can adapt. It offers a resolution of the divergence in the literature on maternal viral suppression, showing that the crude association operates through adherence and regimen line and that any independent association is confined to underweight. And it shows that the maternal age gradient is continuous rather than threshold-based and specific to wasting.

5.4 Limitations

The cross-sectional design supports association, not causation. The data were collected for routine care, so measurement error could be screened for but not corrected, and adherence, classified from refill and attendance records, is a proxy that is likely to attenuate its coefficients toward the null. Records with missing values were excluded rather than imputed, which may have introduced selection bias. Infant feeding, dietary diversity, birth weight, household food security, sanitation and infant morbidity were unavailable, and their omission probably explains the modest pseudo R^2 values; residual confounding cannot be excluded. The wasting model, with 114 events, had the widest intervals, and its non-significant results are inconclusive rather than evidence of no effect. Standardised residuals above 3 occurred for 44 infants in the wasting model and 24 in the underweight model, so the models fit affected infants less well than unaffected ones. No HIV-unexposed comparison group was available. Eighteen coefficient tests were made without correction for multiplicity, as each model had a pre-specified outcome and variable set. Finally, the findings come from one tertiary referral hospital and should be

generalised cautiously.

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Appendix

Table A1: Coefficients of the three multivariate logistic regression models (n = 1,047)

Predictor	*B*	SE	Wald	*p*	AOR
Stunting model					
Constant	−1.027	0.348	8.72	0.003	—
Maternal age (per year)	−0.018	0.011	2.36	0.124	0.98
Unemployed or informally employed	0.506	0.149	11.60	< 0.001	1.66
Poor ART adherence	0.625	0.175	12.71	< 0.001	1.87
Unsuppressed viral load	0.282	0.188	2.25	0.133	1.33
Second-line ART regimen	0.948	0.220	18.56	< 0.001	2.58
Maternal underweight	0.956	0.195	24.08	< 0.001	2.60
Wasting model					
Constant	−1.046	0.493	4.50	0.034	—
Maternal age (per year)	−0.055	0.017	10.63	0.001	0.95
Unemployed or informally employed	0.335	0.219	2.33	0.127	1.40
Poor ART adherence	0.421	0.241	3.05	0.081	1.52
Unsuppressed viral load	0.270	0.260	1.08	0.299	1.31
Second-line ART regimen	0.274	0.311	0.78	0.377	1.32
Maternal underweight	0.337	0.267	1.59	0.207	1.40
Underweight model					
Constant	−1.878	0.411	20.90	< 0.001	—
Maternal age (per year)	−0.019	0.013	1.94	0.164	0.98
Unemployed or informally employed	0.807	0.184	19.15	< 0.001	2.24
Poor ART adherence	0.570	0.192	8.79	0.003	1.77
Unsuppressed viral load	1.157	0.195	35.38	< 0.001	3.18
Second-line ART regimen	0.123	0.258	0.23	0.632	1.13
Maternal underweight	0.568	0.214	7.07	0.008	1.77

Note: *B* = unstandardised coefficient; SE = standard error; AOR = adjusted odds ratio; df = 1 for each Wald test.

Table A2: Bivariate (crude) association between maternal factors and each outcome (n = 1,047)

Maternal factor	Stunting crude OR (95% CI)	Wasting crude OR (95% CI)	Underweight crude OR (95% CI)
Maternal age (years), mean (SD): affected vs unaffected	27.67 (6.22) vs 28.47 (6.14); *p* = 0.051	26.31 (6.21) vs 28.45 (6.13); *p* < 0.001	27.51 (6.12) vs 28.40 (6.18); *p* = 0.061
Unemployed or informally employed	1.84 (1.39–2.43)	1.54 (1.01–2.35)	2.45 (1.73–3.47)
Poor ART adherence	2.38 (1.73–3.27)	1.86 (1.19–2.89)	2.66 (1.88–3.75)
Unsuppressed viral load	1.92 (1.37–2.68)	1.62 (1.01–2.60)	3.87 (2.72–5.51)
Second-line ART regimen	2.71 (1.80–4.09)	1.44 (0.80–2.58)	1.52 (0.96–2.41)

Maternal factor	Stunting crude OR (95% CI)	Wasting crude OR (95% CI)	Underweight crude OR (95% CI)
Maternal underweight	3.09 (2.14–4.46)	1.70 (1.03–2.82)	2.36 (1.59–3.49)

Note: OR = odds ratio; CI = confidence interval. Maternal age was compared with Welch's *t*-test and the categorical factors with the Pearson chi-square test. Every factor met the $p < 0.25$ threshold for entry into every model.

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