

Vital Surveillances

Longitudinal Trajectories of Growth and Development in HIV-Exposed Uninfected Children from a Long-Term Birth Cohort — 8 Regions, 3 PLADs, China, 2017–2024

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ABSTRACT

Objective: This study examined growth and development trajectories in Human Immunodeficiency Virus (HIV) exposed children aged 0–3 years, identified key influencing factors, and generated evidence to support early developmental promotion in this population.

Methods: This prospective cohort study enrolled pregnant women who delivered between January 2017 and June 2021 and followed their infants until 3 years of age. Participants were drawn from a mother-to-child HIV transmission cohort established across Guangxi Zhuang Autonomous Region, Yunnan Province, and Xinjiang Uygur Autonomous Region. Chi-square tests were used to compare differences between groups, and generalized estimating equations (GEE) were applied to identify factors influencing growth and nutritional outcomes in HIV-exposed children.

Results: The cohort comprised 1,227 mother-child pairs: 411 in the exposed group (HIV-infected mothers) and 816 in the control group (non-HIV-infected mothers). The malnutrition rate among HIV-exposed children in the study regions was 12.00%. Relative to the control group, HIV-exposed children demonstrated significantly lower height and weight gains and a higher prevalence of malnutrition ($P < 0.05$). GEE analysis identified a household per capita monthly income exceeding 3,000 yuan as a protective factor against malnutrition [adjusted odds ratio (aOR)=0.924, 95% confidence interval (CI): 0.877, 0.974], while a maternal history of stillbirth (aOR=1.055, 95% CI: 1.008, 1.104) and neonatal low birth weight (aOR=1.377, 95% CI: 1.267, 1.497) were independent risk factors across all follow-up periods. Female sex was also associated with a modestly elevated risk of malnutrition compared with male sex (aOR=1.048, 95% CI: 1.017, 1.079).

Conclusions: HIV-exposed children in the study regions demonstrated modestly poorer overall growth

and development compared with non-exposed peers. These findings underscore the importance of targeted nutritional interventions, early developmental surveillance, and timely correction of growth abnormalities in this vulnerable population.

The global implementation of prevention of mother-to-child transmission (PMTCT) of Human Immunodeficiency Virus (HIV) programs, combined with continuous advances in antiretroviral therapy (ART), has substantially strengthened the reproductive confidence of women living with HIV (1). As a result, the number of HIV-infected pregnant women and their infants has risen considerably worldwide. According to data released by UNAIDS in 2023, 84% of HIV-infected pregnant women received ART to prevent mother-to-child transmission (2), and the World Health Organization (WHO) estimated that approximately 1.2 million women were living with HIV during pregnancy or the postpartum period in 2022 (3). Within this global context, China faces a growing domestic challenge: approximately 4,000 HIV-exposed infants are born in the country each year. Children's growth and development is a complex, multidimensional process shaped by the interplay between intrinsic genetic determinants and a broad range of external environmental influences. Nevertheless, the existing literature has predominantly focused on vertical transmission outcomes, with comparatively limited attention paid to the growth trajectories and developmental status of HIV-exposed children. To address this gap, the present study examines the factors affecting the growth and development of HIV-exposed children aged 0–3 years in China, providing a scientific basis for promoting their normal growth and development and reducing the burden of mother-to-child transmission of HIV.

METHODS

Data Collection

The inclusion criterion required singleton pregnancy at delivery. Exclusion criteria were as follows: 1) severe maternal illness requiring hospitalization; 2) HIV-infected children born to HIV-infected women; and 3) diagnosis of mental illness or intellectual disability based on the diagnostic criteria for neuropsychiatric diseases in China.

From January 2017 to June 2021, the study was conducted across all healthcare facilities providing maternity care and midwifery services in eight regions spanning three provinces and autonomous regions: Yunnan Province, Guangxi Zhuang Autonomous Region, and Xinjiang Uygur Autonomous Region. These regions have a well-established foundation in preventing mother-to-child transmission of HIV, syphilis, and hepatitis B, and each has a relatively large population of HIV-exposed children.

Pregnant women living with HIV were enrolled upon identification, prior to delivery, ensuring that baseline data were collected before birth. HIV-infected pregnant and postpartum women and their infants (referred to as HIV-exposed infants) were assigned to the exposed group. Following a 1:2 matching protocol, HIV-uninfected pregnant and postpartum women and their infants were selected from the same region to form the control group. Matching criteria included the same ethnicity, a gestational age at delivery within ± 2 weeks, and the same neonatal sex. When more than two eligible controls were available, HIV-uninfected women with the most similar sociodemographic characteristics were selected. A prospective cohort of exposed and non-exposed children was thereby established, and follow-up assessments were subsequently conducted at 1, 3, 6, 8, 12, and 18 months, as well as at 2 and 3 years of age to evaluate growth and development in both groups.

Structured questionnaires were administered to both HIV-infected and uninfected pregnant and postpartum women to collect data on general characteristics, family background, delivery details, HIV status, and antiretroviral medication use. Data on the growth and development of their children were also obtained.

Measures

Body weight, length, and head circumference were measured for children in both the HIV-exposed and HIV-unexposed groups at each specified age interval. Growth and development were assessed according to

the methods recommended by WHO in 2006 (4). Z-scores were calculated using WHO Anthro software (version 3.2.2, 2011) developed by WHO, Geneva, Switzerland included the following indices: Weight-for-Age Z-score (WAZ), Length-for-Age Z-score (LAZ), and Weight-for-Length Z-score (WLZ).

1) Underweight: $WAZ < -2$ was defined as underweight;

2) Stunting: $LAZ < -2$ was defined as stunting;

3) Wasting: $WLZ < -2$ was defined as wasting.

4) Malnutrition: Children were diagnosed with protein-energy malnutrition (PEM), hereafter referred to as malnutrition (5), if they presented with one or more of the following conditions: stunting, underweight, or wasting.

5) HIV-exposed children: Children born to HIV-infected women were classified as HIV-exposed. For this study, only the growth and development of HIV-exposed uninfected (HEU) children were analyzed.

6) Quality control: During the research implementation phase, relevant personnel received technical training, and investigators underwent pre-survey training. During the data entry phase, a double-entry method was employed alongside consistency checks; any forms with unclear entries were promptly clarified by contacting the responsible data collector. During the data analysis phase, sensitive identifying information was removed, and any anomalous data were cross-checked and either corrected or excluded, thereby ensuring the quality and authenticity of the dataset.

Statistical Analysis

Data were summarized, cleaned, and organized in Excel before being imported into SAS 9.4 (SAS Institute, Cary, NC, USA) for statistical analysis. Continuous variables were expressed as mean \pm standard deviation ($\bar{x} \pm s$) and compared using Student's *t*-test, while categorical variables were expressed as frequencies and proportions and compared using the chi-square test or Fisher's exact test, as appropriate. Generalized Estimating Equations (GEE) were applied to evaluate the associations between individual or multiple variables and the nutritional status of HIV-exposed children. Given that repeated measurement data may exhibit an autocorrelated structure, an autoregressive correlation matrix was specified to account for within-subject correlations across time points. All tests were two-sided, with a significance threshold set at $\alpha = 0.05$; $P < 0.05$ was considered statistically significant.

RESULTS

A total of 411 HIV-infected mother-child pairs were enrolled in the exposed group. Following a 1:2 matching protocol, 816 HIV-uninfected mother-child

pairs were selected for the control group, yielding a final cohort of 1,227 mother-child pairs.

As shown in Table 1, the two groups were comparable in terms of residential region, ethnicity, household registration type, and delivery mode, with

TABLE 1. Basic characteristics of HIV-infected and uninfected pregnant and postpartum women [n (%)].

Variable	Total	Exposed group (n=411)	Control group (n=816)	χ^2	P
Region				0.011	0.995
Guangxi Zhuang Autonomous Region	504 (41.08)	168 (40.88)	336 (41.18)		
Yunnan Province	416 (33.90)	140 (34.06)	276 (33.82)		
Xinjiang Uygur Autonomous Region	307 (25.02)	103 (25.06)	204 (25.00)		
Ethnicity				0.006	0.997
Han	757 (61.70)	253 (61.56)	504 (61.76)		
Uyghur	288 (23.47)	97 (23.60)	191 (23.41)		
Others	182 (14.83)	61 (14.84)	121 (14.83)		
Educational level				2.248	0.134
Junior high school or below	970 (79.06)	335 (81.51)	635 (77.82)		
Senior high school or above	257 (20.94)	76 (18.49)	181 (22.18)		
Marital status				24.789	<0.001
Unmarried	41 (3.34)	16 (3.89)	25 (3.06)		
Married	1,174 (95.68)	383 (93.19)	791 (96.94)		
Divorced or widowed	12 (0.98)	12 (2.92)	0 (0)		
Household registration type				0.496	0.481
Rural	1,054 (85.90)	349 (84.91)	705 (86.40)		
Urban	173 (14.10)	62 (15.09)	111 (13.60)		
Delivery age				62.548	<0.001
<35 years old	1009 (82.23)	288 (70.07)	721 (88.36)		
≥35 years old	218 (17.77)	123 (29.93)	95 (11.64)		
Delivery mode				0.261	0.609
Vaginal delivery	794 (64.71)	270 (65.69)	524 (64.22)		
Cesarean section	433 (35.29)	141 (34.31)	292 (35.78)		
Occupation				9.711	0.046
Farmer	815 (66.42)	288 (70.07)	527 (64.58)		
Unemployed	228 (18.58)	77 (18.73)	151 (18.50)		
Worker	15 (1.22)	6 (1.46)	9 (1.10)		
Commercial service staff	11 (0.90)	4 (0.97)	7 (0.86)		
Cadres, staff, and others	158 (12.88)	36 (8.76)	122 (14.95)		
Per capita monthly household income (CNY)				70.989	<0.001
<500	124 (10.10)	66 (16.06)	58 (7.11)		
500–	292 (23.80)	100 (24.33)	192 (23.53)		
1,000–	432 (35.21)	173 (42.09)	259 (31.74)		
≥3,000	284 (23.15)	63 (15.33)	221 (27.08)		
Unknown	95 (7.74)	9 (2.19)	86 (10.54)		

Abbreviation: CNY=Chinese Yuan.

no statistically significant differences observed ($P>0.05$). In contrast, the groups differed significantly with respect to marital status, occupation, age at delivery, and average monthly household income per capita ($P<0.05$).

Table 2 summarizes pregnancy-related conditions in

the exposed and control groups. Notably, the exposed group exhibited significantly higher incidences of adverse pregnancy outcomes, anemia, and preterm birth compared with the control group ($P<0.001$).

Neonatal characteristics are presented in Table 3. The two groups were similar in neonatal sex, delivery

TABLE 2. Comparison of pregnancy-related conditions among HIV-infected and uninfected pregnant and postpartum women [n (%)].

Variable	Total	Exposed group (n=411)	Control group (n=816)	χ^2	P
Adverse Pregnancy Outcomes				46.778	<0.001
Yes	287 (23.39)	144 (35.04)	143 (17.52)		
No	940 (76.61)	267 (64.96)	673 (82.48)		
Hypertensive Disorders of Pregnancy				0.056	0.812
Yes	31 (2.53)	11 (2.68)	20 (2.45)		
No	1196 (97.47)	400 (97.32)	796 (97.55)		
Anemia				20.939	<0.001
Yes	128 (10.43)	66 (16.06)	62 (7.60)		
No	1,090 (89.57)	345 (83.94)	754 (92.40)		
Preterm Birth				28.030	<0.001
Yes	99 (8.07)	57 (13.87)	42 (5.15)		
No	1,128 (91.93)	354 (86.13)	774 (94.85)		
Premature rupture of membranes				1.905	0.168
Yes	70 (6.00)	30 (7.30)	40 (5.29)		
No	1,097 (94.00)	381 (92.70)	716 (94.71)		

TABLE 3. Comparison of basic characteristics of HIV-exposed and unexposed neonates [n (%)].

Variable	Total	Exposed group (n=411)	Control group (n=816)	χ^2	P
Gender				0.007	0.936
Male	613 (49.96)	206 (50.12)	407 (49.88)		
Female	614 (50.04)	205 (49.88)	409 (50.12)		
Delivery mode				0.261	0.609
Vaginal delivery	794 (64.71)	270 (65.69)	524 (64.22)		
Cesarean section	433 (35.78)	141 (34.31)	292 (35.78)		
Birth weight (g, $\bar{x}\pm s$)		2925.55 \pm 511.46	3181.66 \pm 486.87	-8.462	<0.001
Birth length (cm, $\bar{x}\pm s$)		48.72 \pm 3.13	50.28 \pm 17.09	-1.838	0.066
Birth head circumference (cm, $\bar{x}\pm s$)		32.98 \pm 2.19	33.22 \pm 1.86	-4.779	0.076
Low birth weight				32.930	<0.001
Yes	99 (8.07)	59 (14.36)	40 (4.90)		
No	1,128 (91.93)	352 (85.64)	776 (95.10)		
Macrosomia				4.306	0.038
Yes	31 (2.53)	5 (1.22)	26 (3.19)		
No	1,196 (97.47)	406 (98.78)	790 (96.81)		
Neonatal asphyxia				12.862	<0.001
Yes	38 (3.10)	23 (5.60)	15 (1.84)		
No	1,189 (96.90)	388 (94.40)	801 (98.16)		

mode, mean birth length, and mean head circumference ($P>0.05$). However, significant between-group differences were identified in mean birth weight, incidence of macrosomia, incidence of low birth weight (LBW), and neonatal asphyxia rate ($P<0.05$).

Table 4 presents longitudinal comparisons of WAZ, LAZ, and WLZ, respectively, between the exposed and control groups across successive age intervals.

Univariate analysis identified ten variables significantly associated with malnutrition in HIV-exposed children. Maternal and socioeconomic factors included residential region ($\chi^2=7.871$, $P=0.020$), ethnicity ($\chi^2=7.652$, $P=0.022$), occupation ($\chi^2=16.056$, $P=0.003$), and household monthly per capita income ($\chi^2=16.064$, $P=0.003$). Obstetric and clinical factors included duration of antiretroviral therapy (ART; $\chi^2=11.520$, $P=0.021$), history of

stillbirth ($\chi^2=27.827$, $P<0.001$), preterm birth ($\chi^2=24.989$, $P<0.001$), and premature rupture of membranes ($\chi^2=119.856$, $P<0.001$). Neonatal characteristics, specifically sex ($\chi^2=4.005$, $P=0.045$) and LBW ($\chi^2=79.026$, $P<0.001$), were also significantly associated with malnutrition. Because all HIV-exposed children received exclusive formula feeding, the influence of feeding method on growth and development could not be evaluated in this cohort.

Table 5 presents the multivariate analysis results from the generalized estimating equations, identifying several significant predictors of malnutrition across all follow-up periods. Higher household income was identified as a protective factor: compared with families earning less than 500 yuan per capita monthly, those earning more than 3,000 yuan had significantly lower odds of malnutrition in HIV-exposed children

TABLE 4. Comparison of WAZ, LAZ, and WLZ for children at different ages ($\bar{x}\pm s$).

Variable	Age in months	Exposed group	Control group	t	P
WAZ	0	-0.84±1.14	-0.26±1.05	-8.494	<0.001
	1	-0.11±1.09	0.25±1.09	-5.400	<0.001
	3	-0.39±1.05	-0.05±1.04	-5.380	<0.001
	6	-0.29±1.12	-0.13±1.00	-2.614	0.009
	8	-0.19±1.12	-0.03±1.01	-2.412	0.016
	12	-0.21±1.07	-0.08±0.96	-2.140	0.033
	18	-0.23±1.12	-0.11±0.97	-1.878	0.061
	24	-0.16±1.05	-0.04±0.92	-1.912	0.056
	36	-0.31±0.96	-0.15±0.88	-2.638	0.009
LAZ	0	-0.35±1.21	0.10±1.02	-6.408	<0.001
	1	-0.23±1.34	0.26±1.28	-6.113	<0.001
	3	-0.36±1.29	0.03±1.21	-5.184	<0.001
	6	-0.28±1.23	-0.04±1.19	-3.253	0.001
	8	-0.19±1.20	0.05±1.15	-3.339	0.001
	12	-0.33±1.13	-0.16±1.08	-2.525	0.012
	18	-0.57±1.15	-0.47±1.03	-1.362	0.174
	24	-0.35±1.07	-0.28±1.01	-1.092	0.275
	36	-0.53±1.05	-0.38±0.94	-2.349	0.019
WLZ	0	-0.88±1.06	-0.47±0.97	-6.550	<0.001
	1	0.10±1.23	0.02±1.18	1.017	0.309
	3	-0.06±1.11	-0.00±1.15	-0.800	0.424
	6	-0.06±1.10	-0.02±1.05	-0.563	0.574
	8	-0.01±1.13	0.03±1.05	-0.658	0.511
	12	-0.07±1.09	-0.01±1.03	-0.872	0.383
	18	0.05±1.17	0.16±1.06	-1.604	0.109
	24	-0.01±1.13	0.10±1.03	-1.666	0.096
	36	-0.05±1.10	0.06±0.98	-1.734	0.083

TABLE 5. Multivariate analysis of malnutrition in HIV-exposed children.

Variable	Wald χ^2	aOR (95% CI)	P	Variable	Wald χ^2	aOR (95% CI)	P
Region				Duration of antiviral treatment			
Guangxi Zhuang Autonomous Region	1.000			Pre-pregnancy	1.000		
Yunnan Province	0.029	0.996 (0.954–1.040)	0.865	First trimester of pregnancy	0.006	1.002 (0.958–1.047)	0.941
Xinjiang Uygur Autonomous Region	0.010	0.995 (0.910–1.088)	0.919	Second trimester of pregnancy	1.852	0.960 (0.905–1.018)	0.174
Ethnicity				Third trimester of pregnancy			
Han	1.000			Postpartum	0.047	1.006 (0.950–1.067)	0.828
Uyghur	0.019	1.005 (0.937–1.078)	0.892	Stillbirth or neonatal death			
Others	2.135	1.038 (0.987–1.091)	0.144	No	1.000		
Occupation				Yes			
Farmer	1.000			Preterm birth	5.263	1.055 (1.008–1.104)	0.022
Unemployed	2.009	0.967 (0.923–1.013)	0.156	No	1.000		
Worker	0.059	0.989 (0.903–1.083)	0.808	Yes	0.366	0.980 (0.918–1.046)	0.545
Commercial service staff	0.134	1.012 (0.950–1.078)	0.714	Premature rupture of membranes			
Cadres, staff, and others	3.469	0.934 (0.870–1.004)	0.063	No	1.000		
Per capita monthly household income (CNY)				Yes			
<500	1.000			Gender	2.928	1.168 (0.978–1.397)	0.087
500–	0.135	0.990 (0.940–1.043)	0.713	Male	1.000		
1,000–	0.709	1.021 (0.973–1.072)	0.400	Female	9.440	1.048 (1.017–1.079)	0.002
≥3,000	8.677	0.924 (0.877–0.974)	0.003	Low birth weight			
Unknown	0.025	1.010 (0.890–1.146)	0.874	No	1.000		
				Yes	56.390	1.377 (1.267–1.497)	<0.001

[adjusted odds ratio (aOR)=0.924, 95% confidence interval (CI): 0.877, 0.974]. Regarding maternal obstetric history, children born to mothers with a prior history of stillbirth or neonatal death faced a significantly elevated risk of malnutrition across all periods compared with children of mothers without such history (aOR=1.055, 95% CI: 1.008, 1.104). Sex-based differences were also observed: HIV-exposed female infants had a consistently higher risk of malnutrition than their male counterparts at each assessment period (aOR=1.048, 95% CI: 1.017, 1.079). Finally, low birth weight emerged as a strong independent risk factor; compared with neonates of normal birth weight, those with low birth weight had 1.377 times the odds of malnutrition across all periods — representing a 37.7% increase in risk (aOR=1.377, 95% CI: 1.267, 1.497).

DISCUSSION

Neonatal birth weight serves as both a reflection of maternal health status and a key indicator of fetal well-being. LBW is associated with neonatal mortality, impaired physical growth, neurodevelopmental delays in childhood, and elevated risk of adult chronic diseases including obesity, hypertension, and diabetes (6–8). In the present study, the LBW rate in the exposed group was 14.36% — lower than that reported for HIV-exposed children in Kunming (19.6%) (9) but higher than that of the control group (4.90%), and comparable to the rate observed in Chengdu (14.17%) (10). These findings underscore the importance of strengthening prenatal care for HIV-infected pregnant women, enabling early detection of fetal growth restriction, and delivering evidence-based perinatal interventions to reduce the incidence of LBW

and support optimal child growth and development.

The prevalence of malnutrition among HIV-exposed children varies considerably across countries and regions, likely reflecting differences in geographical environment, household socioeconomic status, health literacy, and the capacity of regional healthcare systems. In the present study, the wasting rate among HIV-exposed children exceeded that reported in comparable studies, which may be partly attributable to the study setting: county- and district-level medical institutions in economically underdeveloped western regions where urban–rural disparities and unequal distribution of healthcare resources are prevalent. Future research should examine the developmental status of HIV-exposed children across regions with varying economic conditions to better characterize these disparities. Notably, malnutrition was more pronounced among HIV-exposed children than among their non-exposed counterparts, highlighting the need for targeted intervention strategies that address the specific nutritional vulnerabilities of this population and work to reduce malnutrition rates while improving overall growth outcomes.

Prior research has demonstrated (11) that early-life malnutrition and stunting can have lasting adverse effects on adult stature and cognitive development. Children's growth trajectories are closely shaped by family socioeconomic background, which simultaneously reflects population health status and broader socioeconomic conditions. To support adequate nutrition during critical developmental periods, caregivers should introduce complementary foods in a timely manner and maintain a supportive feeding environment at home. Beyond dietary practices, sustained monitoring of children's growth and development is essential. Health education efforts targeting caregivers should be strengthened to raise awareness of nutritional needs, foster nurturing home environments, and ultimately promote healthy growth and development in HIV-exposed children.

The elevated risk of stunting observed in children born to mothers with a history of stillbirth or neonatal death may reflect underlying maternal health vulnerabilities, including compromised immune function or reduced engagement with child healthcare services. This hypothesis, however, remains speculative given the limited supporting data available, and further investigation is warranted. These findings nonetheless underscore the importance of strengthening pre-pregnancy and prenatal care within medical institutions, including standardized antenatal examinations and comprehensive pre-pregnancy risk

assessment. Targeted perinatal interventions should be extended to high-risk populations — including women with prior adverse pregnancy outcomes and older pregnant women — through stratified clinical management protocols aimed at reducing adverse pregnancy outcomes and safeguarding maternal and infant health.

LBW serves as a key indicator of intrauterine nutritional adequacy. Suboptimal fetal nutrition disrupts postnatal growth trajectories and substantially elevates the risk of malnutrition in early childhood relative to the general pediatric population (12). Evidence further suggests that interventions targeting birth weight improvement may meaningfully reduce stunting rates among HIV-exposed children (13). Given that LBW remains disproportionately prevalent among neonates born to HIV-infected women, it is essential to strengthen antenatal care services for this population, intensify monitoring of fetal growth and development, and implement timely interventions to minimize LBW occurrence — thereby improving the overall health trajectory of HIV-exposed children.

The relationship between sex and malnutrition risk in children is inconsistent across the literature. A meta-analysis by Guo Bingbing (14) found that boys in China face a higher risk of malnutrition than girls, whereas a study conducted in rural China (15) reported the opposite pattern. Consistent with the latter, the present study found that HIV-exposed girls had a higher risk of malnutrition than boys across all assessment periods. This finding may reflect several intersecting factors, including gender-differentiated caregiving practices such as disparities in dietary allocation, healthcare-seeking behavior, and the distribution of caregiving resources. Sociocultural norms that may favor male children in certain contexts could further contribute to these disparities. Additionally, sex-based differences in morbidity patterns and healthcare access may play a role, though the underlying mechanisms remain incompletely understood and merit further investigation.

This study has several limitations. The questionnaire data lacked information on maternal pre-pregnancy and delivery weight, as well as the timing of complementary food introduction in infants, which precluded calculation of pre-pregnancy and gestational body mass index (BMI). Consequently, we were unable to evaluate the effects of these factors — including gestational weight gain — on children's growth and development. Furthermore, feeding behavior data were not collected for children in the control group, preventing a comparative assessment of the impact of

REFERENCES

feeding practices on growth outcomes across groups.

HIV-exposed children in the study regions exhibited a relatively high rate of malnutrition. Multivariate analysis identified four significant determinants of malnutrition across all follow-up periods: per capita monthly household income exceeding 3,000 yuan (protective), maternal history of stillbirth or neonatal death (risk), female sex (risk), and neonatal low birth weight (risk). These findings underscore the importance of targeted, evidence-based interventions. During pre-pregnancy and prenatal care for HIV-infected women, priority should be given to those with a history of adverse pregnancy outcomes, with close monitoring of fetal growth and timely intervention upon detection of intrauterine growth restriction to reduce the incidence of low birth weight. For HIV-exposed infants born with low birth weight, early nutritional support programs should be implemented, and families with low household income should receive integrated economic assistance alongside nutritional guidance to optimize child growth trajectories.

Conflicts of interest: No conflicts of interest.

Ethical statement: The collection of monitoring data was approved by the Ethics Committee of the National Center for Women and Children's Health, Chinese Center for Disease Control and Prevention (No. FY2015-005). This study received additional approval from the Ethics Committee of the National Center for Women and Children's Health, National Health Commission (No. 2025FY02). All surveys involving pregnant women and children were conducted in accordance with the principles of informed consent, respect, confidentiality, and beneficence. Before participation, the study purpose, significance, and procedures were clearly explained to all participants to ensure that voluntary informed consent was obtained.

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