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Are there differences in child development and contextual factors between HIV-exposed and HIV-unexposed infant? A Brazilian interregional and cross-sectional study

Há diferenças no desenvolvimento infantil e fatores contextuais dos lactentes expostos e não expostos ao HIV? Um estudo inter-regional e transversal brasileiro

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ABSTRACT | OBJECTIVE: This study aimed to compare motor, cognitive, and language development domains, as well as contextual and home environment factors, between HIV-exposed and HIV-unexposed infants from different Brazilian regions. **METHODS:** It is an observational cross-sectional study, with participation of 104 infants from the Southeast Region (Santos-SP) and 80 from the North Region (Belém and Benevides-PA), divided into two groups, namely HIV-exposed and HIV-unexposed. Assessment of infant development was by the Bayley-III Scale, the home environment was assessed using the Affordances in the Home Environment for Motor Development-Infant Scale, and the Brazilian Economic Classification Criteria was used for economic class evaluation. **RESULTS:** No significant differences were observed between HIV-exposed and HIV-unexposed infants in motor, cognitive, or language performance. However, significant regional differences were identified. Infants from the North region showed lower cognitive performance and fewer home environment affordances, particularly regarding stimulation variety, gross and fine-motor opportunities, and total affordance scores. Additionally, language development was associated with maternal age, and home environment affordances were associated with household type and fine-motor opportunities. The findings suggest that regional contextual factors, rather than HIV exposure alone, may play a more prominent role in early developmental outcomes. Social vulnerability and reduced environmental stimulation appear to be relevant contributors, reinforcing the importance of contextual interventions in early childhood.

KEYWORDS: Child Development. Risk Factors. Infectious Disease Transmission, Vertical. HIV. Home Environment.

RESUMO | OBJETIVO: Verificar os domínios motor, cognitivo e de linguagem do desenvolvimento infantil bem como os fatores contextuais e as características do ambiente domiciliar de lactentes expostos e não expostos ao HIV de diferentes regiões brasileiras. **MÉTODOS:** Estudo observacional e transversal, no qual participaram 104 lactentes da Região Sudeste (Santos-SP) e 80 da Região Norte (Belém e Benevides-PA), divididos em dois grupos, exposto ao HIV e não exposto ao HIV. O desenvolvimento infantil foi avaliado por meio da Escala Bayley-III, o ambiente domiciliar pela *Affordances* no Ambiente Domiciliar para o Desenvolvimento Motor – Escala Bebê, e a classe econômica pelo Critério de Classificação Econômica Brasil. Foi utilizada a ANOVA e o teste Exato de Fisher. **RESULTADOS:** Não foram observadas diferenças significativas entre lactentes expostos e não expostos ao HIV nos domínios motor, cognitivo e de linguagem. Entretanto, foram identificadas diferenças regionais significativas. Lactentes da Região Norte apresentaram menor desempenho cognitivo e menos oportunidades de estimulação no ambiente domiciliar, especialmente quanto à variedade de estímulos, oportunidades para habilidades motoras grossas e finas e escore total de affordances. Além disso, o desenvolvimento da linguagem esteve associado à idade materna, e as oportunidades no ambiente domiciliar estiveram associadas ao tipo de moradia e às oportunidades para habilidades motoras finas. Os achados sugerem que fatores contextuais regionais, mais do que a exposição ao HIV isoladamente, podem exercer papel relevante nos desfechos do desenvolvimento infantil. A vulnerabilidade social e a menor oferta de estímulos ambientais mostram-se fatores importantes, reforçando a necessidade de intervenções contextuais na primeira infância.

PALAVRAS-CHAVE: Desenvolvimento Infantil. Fatores de Risco. Transmissão Vertical de Doenças Infecciosas. HIV. Ambiente Domiciliar.

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1. Introduction

Child development is a continuous and multifactorial process that results from the interaction between biological factors intrinsic to the individual and extrinsic environmental factors. These environmental components encompass physical, social, emotional, and cultural dimensions, which modulate the availability of stimuli and experiences offered to infants[1]. The quality and diversity of these opportunities directly influence motor, cognitive, and socio-emotional development, establishing the environment as a fundamental determinant in the trajectory of child development[2].

The presence of risk factors can negatively interfere with this process, manifesting itself through changes in bodily functions and structures, with potential repercussions on activity performance and social participation[2,3]. Traditionally, these factors are classified into three categories: (1) biological risk, such as low birth weight, prematurity, and exposure to the Human Immunodeficiency Virus (HIV); (2) established risk, which includes genetic syndromes, malformations, and congenital diseases; and (3) environmental risk, associated with unfavorable socioeconomic conditions, low parental education, and unstimulating physical and social environments[2,3].

In the context of biological risk, exposure to HIV and antiretroviral therapy (ART) during the pre- and perinatal period has been identified as a potential vulnerability factor for child neuropsychomotor development[4-6]. HIV has neurotropic and neurotoxic characteristics and can interfere with the development of the central nervous system, especially during critical periods of brain maturation[7,8].

Although advances in vertical transmission prevention strategies have significantly reduced pediatric infection, there has been a marked increase in the number of children exposed to HIV without infection, which has shifted the focus of research to the possible effects of viral and drug exposure on medium- and long-term development[9,10].

Recent evidence indicates that infants exposed to HIV, even if not infected, may be at greater risk of subtle changes in motor, cognitive, and language domains when compared to unexposed children, particularly in contexts marked by social vulnerability[8,11,12]. Longitudinal studies conducted in Brazil corroborate this trend, demonstrating that although the motor and cognitive development of infants exposed to HIV remains within normal limits, these individuals perform worse than their unexposed peers[7,11-13], with a greater impairment in language skills during the second year of life[7].

In addition to biological risk, environmental factors play a decisive role in modulating developmental outcomes. The home environment, in particular, can act as a facilitator or barrier to child development, depending on the availability of stimuli, the organization of physical space, and the quality of family interactions[2,3,14]. Disadvantaged home environments, whether due to economic constraints, a lack of suitable toys, or limited opportunities for interaction, can negatively impact the development of both HIV-exposed and HIV-unexposed infants[14,15]. Studies reinforce that exposure to HIV during pregnancy, when associated with adverse environmental conditions, is related to a higher probability of delays in infant neuropsychomotor development[8,16].

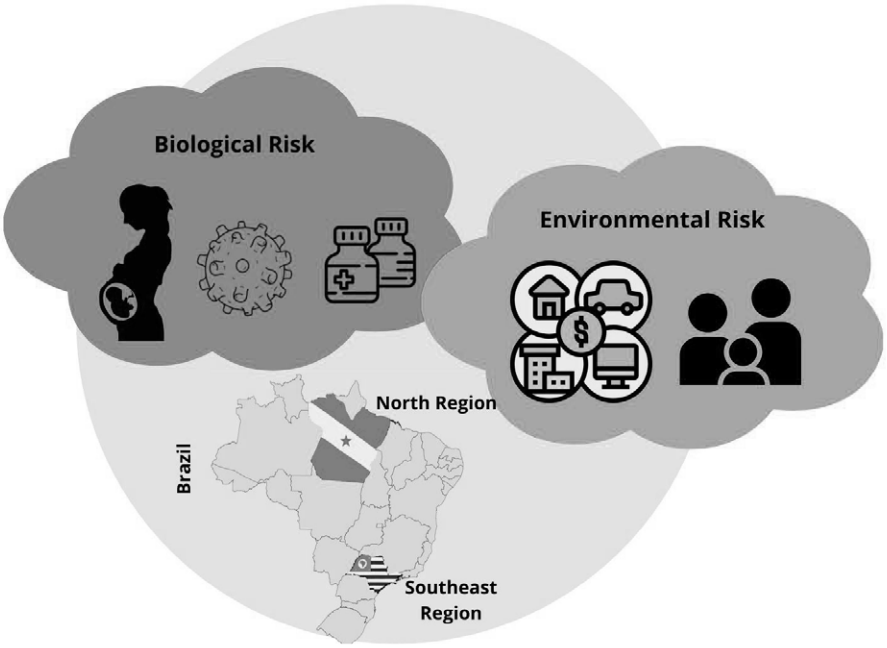
In this sense, the literature points to a cumulative effect of risk factors, in which simultaneous exposure to biological and environmental risks substantially increases the likelihood of developmental delays[14]. Despite this recognition, there are still few studies that investigate the interaction between these factors in socially heterogeneous populations in an integrated manner, particularly in countries with large territories and marked regional inequalities, such as Brazil.

In the Brazilian context, pronounced regional differences in socioeconomic conditions, cultural characteristics, and access to health services may significantly influence opportunities for child development. Regions with higher levels of social vulnerability tend to provide less supportive environments, which may amplify the effects of biological risk associated with HIV exposure. However, most available studies are concentrated in samples from specific regions, limiting the understanding of the impact of regional context on the development of infants exposed to HIV[7,8,11,12,17].

Understanding the interaction between HIV exposure, environmental conditions, and child development has relevant scientific, social, and clinical implications, contributing to the planning of public policies, developmental surveillance programs, and early intervention strategies, particularly within the scope of primary health care and pediatric rehabilitation. In this context, the development of regionalized studies is necessary to investigate health conditions associated with biological risk for HIV exposure, considering the interrelationship among multiple factors involved in child development[14].

Thus, the present study aimed to assess motor, cognitive, and language development, as well as family and social characteristics and opportunities in the home environment, in infants exposed and not exposed to HIV from the North and Southeast regions of Brazil. Additionally, the study sought to examine the influence of regional context in infants with similar birth conditions and biological risk. The study hypothesis was that infants from the Northern region would present lower availability of opportunities in the home environment and poorer developmental performance compared with infants from the Southeastern region (Figure 1).

Figure 1. Description of the influence of biological and environmental risk factors in two regions of Brazil (North and Southeast regions)



2. Method

Observational cross-sectional study. It was approved by the Research Ethics Committee at the University (n:1262/2018 and CAAE: 01741518.2.0000.5505).

2.1 Participants

The sample was chosen for convenience. In Santos, state of São Paulo (Southeast region), the recruitment of HIV-exposed infants was carried out at the Children Specialized Care Service; unexposed infants were recruited at Vila Nova Basic Health Unit. In the city of Belém, state of Pará (North Region), HIV-exposed infants were recruited at the Maternal, Child and Adolescent Reference Unit, where pregnant women receive care regarding HIV prevention, early diagnosis, and treatment. In the city of Benevides (PA), HIV-unexposed infants were recruited at Primary Health Care Unit - UBS-Centro (Unidade Básica de Saúde).

For both groups, the assessed ages were 4, 8, 12, and 18 months. The selection of these ages is justified by the typical acquisition period of infant developmental milestones: at 4 months, head control, midline reaching, gazing at the reference adult, interacting, and producing sounds are expected; at 8 months, crawling, transferring objects between hands, and imitating sounds and gestures are anticipated; at 12 months, standing without support, lateral walking, independent walking acquisition, and pointing to desired objects are expected; and at 18 months, the infant is expected to kick a ball, say "daddy" and "mommy," and attempt to use a spoon[18].

In the HIV-exposed group, the following were included: infants between four and 18 months old, whose mothers had a serological diagnosis for HIV+; included in a vertical HIV transmission monitoring program at a reference service; who received ART during the gestational period and post-uterine life; who were born at term (≥37 weeks of gestational age); whose breastfeeding has not occurred, and with absence of associated diseases[19]. The HIV-unexposed group had as inclusion criteria the search for a matchup with the HIV-exposed group infants in relation to age, gender, socioeconomic status, and absence of associated diseases.

In both groups, the following were not included: HIV+ positive mothers' infants who were born prematurely (below 37 weeks of gestational age); whit malformations, genetic syndromes, congenital alterations, postural deformities, or other alterations that could harm their neuropsychomotor and socio-cognitive development; those whose measurements did not comply with those recommended by the Ministry of Health of Brazil[19]; those whose parents and/or guardians did not sign the Informed Consent Form or who, for whatever reason, did not complete the evaluation protocol.

An a priori sample calculation was performed, using G*Power (version 3.1). Calculation was performed based on data from previous studies carried out by the same research group[11], considering a mean comparison test (Student's t test) for the variable motor development, 0.8 power, 0.25 effect size and 5% significance level. The calculation indicated that a 26-participant sample was necessary, with 13 infants in each group and in each region. Further analyses were conducted on an exploratory basis.

To assess motor, cognitive, and language performance, one used the Bayley Scales of Infant and Toddler Development Scale – Third Edition (Bayley-III)[20]. The scale allows identifying, measuring, and assessing child development between 16 days and 42 months old. The tests consist of standardized tasks, and infants are scored according to the performance of each item requirements following the established criteria. The Composite Score was used in this study, which allows comparison between the subscales. Infants had their development classified as: "extremely low", "borderline", "low average", "average", "high average", "superior", and "very superior". "Extremely low", "borderline" and "low average" developments were grouped into "below average" development; "average" development was maintained; "high average", "superior", and "very superior" developments were grouped into "above average" development.

To assess the quality of home environment affordances, Affordances in the Home Environment for Motor Development-Infant Scale (AHEMD-IS)[21] was used. It is a questionnaire with 35 questions that assesses four dimensions of the home environment: (1) physical space, (2) variety of stimulation, (3) gross-motor toys, and (4) fine-motor toys. Then, the four dimensions were summed up to obtain the total score. AHEMD-IS classifies the environment as "less adequate", "moderately adequate" – here grouped into "inadequate environment" –, and "adequate" and "excellent" – grouped into "adequate environment".

For sample economic characterization, the Brazilian Criterion of Economic Classification (CCEB) of the Brazilian Association of Research Companies[17] was applied. The questionnaire is scored according to the items, and the total sum of these characteristics is categorized into classes A, B1, B2, C1, C2, D/E (A is the class with the highest economic level and D/E the lowest). This study grouped classes A, B1 and B2 into class A/B; and classes C1, C2 and D-E into class C/D-E[22].

Data collection in the Southeast region took place from July 2018 to November 2020, in person in individual rooms. In the cities of North region, collection took place from February 2021 to July 2022, in person in individual rooms. The researcher in charge read the instruments together with the families. Collections took place in compliance with the protection measures against COVID-19. In 2021, public service was reduced due to the significant increase in COVID-19 cases, and as a result of the lockdown established by the Government of Pará as a major protective measure.

The attendance of eligible participants at the assessments was ensured, as missed appointments trigger notification and active follow-up. Additionally, to minimize losses, strategies such as flexible scheduling, active contact with caregivers, continuous monitoring of the database, and rigorous standardization of instrument administration were implemented.

The two-way ANOVA was used to assess whether there was an effect of the dependent variables assessed by the Bayley- III Scale (cognitive composite, motor composite, and language composite) and the AHEMD-IS (physical space, variety of stimulation, gross-motor skills, fine-motor skills, and total score) according to the independent variables (HIV-exposed and HIV-unexposed groups, and Southeast and North regions), as well as whether there was an effect of the interaction between group*region.; the test was chosen given that the normality parameters and sample homogeneity were achieved. An analysis was performed for each dependent variable, considering a 5% significance level, and effect sizes presented in eta-squared (η^2), with the following reference values: 0.01 to 0.05, indicating small effect size; 0.06 to 0.13, medium effect size; values equal to or greater than 0.14, large effect size.

Fisher's exact test was used to verify the association between the classifications of development assessed by the Bayley-III Scale, the home environment affordances in the AHEMD-IS and the other study variables, with adjusted residual analysis to detect associations. A 5% significance level was considered. All analysis were performed using SPSS Statistics version 24.

In the case of missing data, these did not refer to sample attrition but rather to the absence of specific information in certain sociodemographic variables (e.g., ABEP classification and maternal age), resulting from incomplete completion by caregivers. Analyses were conducted using the available-case method, a procedure automatically implemented by the SPSS software, whereby each test included all participants with valid data for the variables analyzed. Given that the study's primary variables showed adequate completeness, the missing data were not considered to have compromised the results.

3. Results

The sample consisted of 184 infants, 104 from the Southeast Region (52 in the HIV-exposed group and 52 in the HIV-unexposed group) and 80 from the North Region (43 infants in the HIV-exposed group and 37 in the group HIV-unexposed group). Table 1 presents the descriptive measurements referring to the infant characteristics at birth (weight, height, Apgar score at 1 and 5 minute after birth, and age in months) and environment (number of adults and children in the same household, parents' schooling, whether the infant attends daycare and/or school, and economic class), according to group and region.

Table 1. Sample characterization: characteristics of the infant birth and characteristics of the home environment

	GROUPS			
	Exposed to HIV (*n* = 52)	Unexposed to HIV (*n* = 52)	Exposed to HIV (*n* = 43)	Unexposed to HIV (*n* = 37)
	Southeast Region	Southeast Region	North Region	North Region
Characteristics of the infant				
Birth weight (g)	3193 (± 411)	3375 (± 417)	3065 (± 481)	3217 (± 433)
Length at birth (cm)	48.3 (± 2)	49.1 (± 2.1)	49.1 (± 2.3)	49.4 (± 2)
Apgar 1st min	8.5 (± 0.7)	8.2 (± 1.5)	8.3 (± 0.7)	8.7 (± 0.7)
Apgar 5th min	9.4 (± 0.5)	9.3 (± 0.3)	9.3 (± 0.7)	9.0 (± 0.2)
Age (months)	10.5 (± 5.2)	10.5 (± 5.2)	10.2 (±5.7)	8.3 (± 4.2)
Characteristics of the home environment				
Number of adults	2.4 (± 1.0)	2.6 (± 0.8)	2.3 (± 0.8)	2.5 (± 0.9)
Number of children	1.9 (± 0.9)	2.2 (± 1.3)	2.2 (± 1.1)	1.7 (± 0.8)
Time to home				
Less than 3 months	15%	16%	8%	9%
3-6 months	27%	31%	23%	21%
7-12 months	6%	5%	5%	4%
more than 12 months	3%	-	2%	2%
Father's schooling				
Middle school	38%	36%	29%	25%
Complete elementary	8%	6%	4%	4%
Doesn´t know	3%	-	2%	-
Uneducated or incomplete elementary	3%	10%	8%	8%
Mother's schooling				
Middle school	8%	2%	2%	5%
Complete elementary	24%	17%	10%	20%
Doesn´t know	3%	15%	15%	2%
Uneducated or incomplete elementary	14%	9%	10%	8%
Child attends childcare/school				
Never	4%	7%	10%	-
Less than 3 months	14%	16%	15%	10%
3-6 months	28%	27%	16%	23%
7-12 months	6%	2%	1%	4%
Economic class*				
A	1,9%	-	-	-
B1	-	-	2,3%	-
B2	11,5%	3,8%	-	13,5%
C1	28,8%	38,5%	4,7%	21,6%
C2	19,2%	36,5%	34,9%	21,6%
D-E	1,9%	21,2%	58,1%	43,2%

*Presence of 19 missing values in the group exposed to HIV in the Southeast Region; and 6 missing values in the group unexposed to HIV in the North Region.

For the development variables measured by the Bayley-III Scale, the analysis of variance revealed that there was no effect of the group, the region and the group*region interaction on the motor and language composite, indicating that HIV-exposed and HIV-unexposed groups presented similar development regardless of region (Table 2). As for the cognitive composite, there was no significant difference between HIV-exposed and HIV-unexposed groups, but a significant difference was observed for region ($p = 0.031$; $\eta^2 = 0.025$ [small effect size]). In this case, infants from the Southeast region performed better in the cognitive composite compared to the North region, regardless of the group.

Table 2. Descriptive measures of development variables and home environment according to group and region

	GROUPS				ANOVA
	Exposed to HIV	Unexposed to HIV	Exposed to HIV	Unexposed to HIV	
	Southeast Region	Southeast Region	North Region	North Region	
Development					
Composite Cognitive	94.3 (± 10.7)	96.1 (± 10.1)	91.0 (± 11.2)	92.8(± 7.22)	Group: $F = 1.38$; $p = 0.242$; $\eta^2 = 0.007$ Region: $F = 4.70$; $p = 0.031$*; $\eta^2 = 0.025$ Group*Region: $F = 4.08$; $p = 0.984$; $\eta^2 = 0.000$
Composite Motor	97.8 (± 14.8)	98.2 (± 10.9)	94.7 (± 5.80)	95.6 (± 7.03)	Group: $F = 0.13$; $p = 0.713$; $\eta^2 = 0.001$ Region: $F = 3.20$; $p = 0.075$; $\eta^2 = 0.017$ Group*Region: $F = 0.02$; $p = 0.881$; $\eta^2 = 0.000$
Composite Language	92.8 (± 13.1)	94.9 (± 9.80)	91.1 (± 5.26)	91.4 (± 6.25)	Group: $F = 0.66$; $p = 0.417$; $\eta^2 = 0.004$ Region: $F = 3.50$; $p = 0.063$; $\eta^2 = 0.019$ Group*Region: $F = 0.37$; $p = 0.539$; $\eta^2 = 0.002$
Home Environment					
Physical Space	3.35 (± 1.79)	3.12 (± 1.87)	3.05 (± 1.41)	3.26 (± 1.17)	Group: $F = 1.66$; $p = 0.685$; $\eta^2 = 0.001$ Region: $F = 0.45$; $p = 0.50$; $\eta^2 = 0.003$ Group*Region: $F = 1.45$; $p = 0.229$; $\eta^2 = 0.009$
Variety of Stimulation	14.6 (± 3.37)	14.9 (± 1.99)	15.5 (± 2.04)	15.7 (± 2.08)	Group: $F = 0.73$; $p = 0.392$; $\eta^2 = 0.004$ Region: $F = 21.82$; $p = 0.001$*; $\eta^2 = 0.109$ Group*Region: $F = 1.77$; $p = 0.185$; $\eta^2 = 0.009$
Gross Motor	5.50 (± 3.10)	4.69 (± 2.50)	3.51 (± 1.90)	3.33 (± 1.86)	Group: $F = 0.73$; $p = 0.392$; $\eta^2 = 0.004$ Region: $F = 21.82$; $p = 0.001$*; $\eta^2 = 0.109$ Group*Region: $F = 1.77$; $p = 0.185$; $\eta^2 = 0.009$
Fine Motor	5.66 (± 3.97)	5.23 (± 3.52)	3.51 (± 2.63)	3.33 (± 1.74)	Group: $F = 0.38$; $p = 0.534$; $\eta^2 = 0.002$ Region: $F = 17.00$; $p = 0.001$*; $\eta^2 = 0.091$ Group*Region: F:0.06; p=0.798; $\eta^2 = 0.000$
Total Score	28.8 (± 7.95)	27.5 (± 6.87)	24.3 (± 4.92)	25.4 (± 4.49)	Group: $F = 0.04$; $p = 0.841$; $\eta^2 = 0.000$ Region: $F = 12.01$; $p = 0.001$*; $\eta^2 = 0.062$ Group*Region: F=1.56; p=0.212; $\eta^2 = 0.008$

*Significant difference ($p \leq 0.05$); gray highlights: medium effect size (Cohen, 1988)[31].

Regarding the home environment affordances assessed using the AHEMD-IS, ANOVA revealed that, in the physical space dimension, there was no significant difference according to region, group and group*region interaction. In the variety of stimulation, gross-motor skills, fine-motor skills and total score dimensions, there was a significant difference only between regions. Thus, infants from the Southeast region had a greater variety of stimulation received at home ($p = 0.001$; $\eta^2 = 0.109$ [mean effect size]) (Table 2), greater availability of affordances to develop gross-motor skills ($p = 0.001$; $\eta^2 = 0.109$ [mean effect size]) (Table 2), greater fine-motor skills development ($p = 0.001$; $\eta^2 = 0.091$ [mean effect size]) (Table 2); and higher total score in the AHEMD-IS, indicating more affordances in general ($p = 0.001$; $\eta^2 = 0.062$ [mean effect size]) (Table 2).

The results presented in table 3, measured by the Bayley-III Scale, indicated that HIV-exposed and HIV-unexposed groups of participants from the Southeast and North regions presented an average classification for the cognitive, motor and language domains.

Table 3. Classification of development of domains da Bayley III and home environment evaluated by AHEMD-IS according to group and region

	GROUPS			
	Exposed to HIV	Unexposed to HIV	Exposed to HIV	Unexposed to HIV
	Southeast Region	Southeast Region	North Region	North Region
Development - Bayley III Cognitive				
Extremely low	1%	-	-	-
Borderline	1%	1%	-	-
Below average	10%	13%	15%	13%
Average	36%	32%	28%	24%
Above average	4%	4%	-	-
Superior	-	2%	-	-
Very superior	-	-	-	-
Motor				
Extremely low	-	-	-	-
Borderline	-	-	-	-
Below average	6%	6%	6%	9%
Average	35%	38%	37%	27%
Above average	11%	8%	-	1%
Superior	-	-	-	-
Very superior	-	-	-	-
Language				
Extremely low	2%	-	-	-
Borderline	7%	2%	1%	-
Below average	7%	17%	17%	16%
Average	32%	27%	25%	21%
Above average	3%	5%	-	-
Superior	1%	1%	-	-
Very superior	-	-	-	-
Home Environment - AHEMD-IS				
Physical Space				
Less than adequate	19%	21%	21%	8%
Moderately adequate	16%	11%	12%	17%
Adequate	9%	14%	9%	11%
Excellent	8%	6%	1%	1%
Variety of Stimulation				
Less than adequate	-	-	1%	-
Moderately adequate	12%	2%	1%	1%
Adequate	9%	14%	4%	6%
Excellent	30%	36%	37%	30%
Gross Motor-Toys				
Less than adequate	23%	31%	31%	26%
Moderately adequate	12%	14%	9%	8%
Adequate	14%	7%	3%	3%
Excellent	2%	-	-	-
Fine Motor-Toys				
Less than adequate	18%	25%	32%	25%
Moderately adequate	5%	1%	1%	1%
Adequate	18%	15%	6%	9%
Excellent	10%	11%	4%	2%
Total Score				
Less than adequate	11%	7%	3%	5%
Moderately adequate	12%	21%	25%	17%
Adequate	19%	14%	5%	10%
Excellent	10%	10%	10%	5%

Regarding the home environment affordances presented in table 3 – evaluated using the AHEMD-IS –, it was observed that in the physical space dimension, HIV-exposed and HIV-unexposed groups and Southeast and North regions were classified as less adequate. In the variety of stimulation dimension, both groups and regions were classified as excellent. However, for the gross-motor skills and fine-motor skills dimensions, both groups and regions were classified as less adequate. Finally, in the total score dimension, both groups and regions were classified as moderately adequate.

Regarding the association between the development variable measured by the Bayley-III Scale and the home environment variables, Fisher's exact test (Table 4) demonstrated that there are no significant associations between cognitive development and motor development and the household type, father's schooling, mother's schooling, number of children living in the same household, maternal age, and economic class. Nevertheless, there was a significant association (p = 0.009) between language (below average and average) and maternal age (16 to 19 years old).

As for the home environment affordances evaluated using the AHEMD-IS, the classification results of the physical space, variety of stimulation, gross-motor skills and total score dimensions did not have a significant association with household type, father's schooling, mother's schooling, number of children living in the same household, maternal age, and economic class. There was a significant association (p = 0.011) between fine-motor skills (inadequate environment) and household type (apartment and house) (Table 4).

Table 4. Association of development classification and opportunities at home with context characteristics (to be continued)

Associations of variables		Fisher's exact test	Adjusted residuals from contingency table
Classification of cognitive development	Type of residence	= 5.040; p = 0.254	-
	Father's schooling	= 6.671; p = 0.323	-
	Mother's schooling	= 4.139; p = 0.634	-
	Number of children	= 6.831; p = 0.136	-
	Mother's age	= 9.574; p = 0.108	-
	ABEP	= 0.874; p = 0.704	-
Classification of motor development	Type of residence	= 1.773; p = 0.780	-
	Father's schooling	= 4.077; p = 0.671	-
	Mother's schooling	= 7.571; p = 0.237	-
	Number of children	= 1.803; p = 0.789	-
	Mother's age	= 8.256; p = 0.155	-
	ABEP	= 3.048; p = 0.166	-
Classification of language development	Type of residence	= 3.665; p = 0.420	-
	Father's schooling	= 4.958; p = 0.533	-
	Mother's schooling	= 1.500; p = 0.976	-
	Number of children	= 1.779; p = 0.792	-
	Mother's age	= 15.490; p = 0.009*	16-19 years x below average (3.3); average (2.9)
	ABEP	= 0.772; p = 0.702	-
Classification of physical space	Type of residence	= 2.898; p = 0.248	-
	Father's schooling	= 2.810; p = 0.420	-
	Mother's schooling	= 1.586; p = 0.674	-
	Number of children	= 1.188; p = 0.569	-
	Mother's age	= 1.918; p = 0.620	-
	ABEP	= 1.320; p = 0.390	-

Table 4. Association of development classification and opportunities at home with context characteristics (conclusion)

Associations of variables		Fisher's exact test	Adjusted residuals from contingency table
Classification of variety of stimulation	Type of residence	= 0.379; p = 1.000	-
	Father's schooling	= 7.215; p = 0.053	-
	Mother's schooling	= 1.617; p = 0.657	-
	Number of children	= 0.276; p = 0.904	-
	Mother's age	= 1.275; p = 0.732	-
	ABEP	= 3.963; p = 0.081	-
Classification of gross motor	Type of residence	= 2.667; p = 0.251	-
	Father's schooling	= 6.247; p = 0.095	-
	Mother's schooling	= 1.347; p = 0.722	-
	Number of children	= 1.270; p = 0.515	-
	Mother's age	= 0.539; p = 0.947	-
	ABEP	= 0.395; p = 0.461	-
Classification of fine motor	Type of residence	= 8.226; p = 0.011*	apartment x inadequate environment (2.9); house x inadequate environment (2.8)
	Father's schooling	= 1.493; p = 0.706	-
	Mother's schooling	= 3.799; p = 0.290	-
	Number of children	= 0.514; p = 0.817	-
	Mother's age	= 0.743; p = 0.879	-
	ABEP	= 0.261; p = 1.000	-
Classification of total score	Type of residence	= 2.350; p = 0.333	-
	Father's schooling	= 5.704; p = 0.124	-
	Mother's schooling	= 3.885; p = 0.279	-
	Number of children	= 1.187; p = 0.534	-
	Mother's age	= 0.756; p = 0.873	-
	ABEP	= 1.470; p = 0.271	-

*Significant difference ($p \leq 0.05$).

4. Discussion

The present study aimed to examine the motor, cognitive, and language domains of infant development, as well as contextual factors and home environment characteristics of infants exposed and unexposed to HIV from different Brazilian regions. The results showed no significant differences between groups regarding performance across the assessed developmental domains, indicating that HIV exposure alone was not associated with developmental impairment in this sample. However, relevant regional differences were identified, with infants from the North Region demonstrating lower cognitive performance and fewer opportunities for stimulation in the home environment compared to those from the Southeast Region. Additionally, language development was associated with maternal age, and home environment opportunities were associated with housing type and opportunities for fine motor skills. Taken together, these findings suggest that contextual and environmental factors play a central role in infant developmental outcomes, outweighing the influence of HIV exposure alone.

Regarding child development assessed by the Bayley-III Scale, the results indicated that HIV-exposed and HIV-unexposed groups did not differ in motor, cognitive, and language performance, corroborating findings in the literature[7,10,12,13,23]. Previous studies suggest that exposure to HIV during pregnancy, in the absence of infection, may not be independently associated with developmental alterations. Instead, some evidence indicates that developmental impairments have been more frequently observed in cases of HIV infection itself, possibly due to viral effects on the central nervous system, although this does not occur in all cases. Moreover, infants exposed to HIV during pregnancy but not infected may present developmental alterations that appear to be associated with environmental and contextual factors, as reported in the scoping review by Guedes-Granzotti et al.[8].

The lower cognitive performance observed among infants from the North region may be associated with environmental characteristics, as these infants also demonstrated fewer opportunities for home stimulation. This finding is consistent with the study by Silva et al.[11], which reported lower cognitive scores among HIV-exposed infants. However, given the cross-sectional design, these findings should be interpreted as association rather than causal relationships.

This finding may be associated with fewer opportunities for adequate stimulation and the lower socioeconomic conditions observed among infants from the North region, factors that have been described in the literature as being associated with increased vulnerability to developmental delays. In addition, cognitive development among infants from the North region was observed between cognitive development classification and economic class in the present study, which limits further interpretation on this relationship. Furthermore, child development should be understood as multifactorial process, influenced by a complex interplay of economic, environmental, genetic and biological fators[24].

It is important to highlight that biological risk factors such as exposure to HIV and ART can impact the functionality of infants[24], that is, we reinforce and encourage monitoring and surveillance of child development as a protective factor, that is, neutralizing the impacts caused by vertical exposure.

In this context, our findings support that home environment variables and socioeconomic status act cumulatively and impact child development. The findings reinforce that social vulnerability can impact child development and home environment affordances. In addition to the predominantly lower economic class in the North region, the low maternal schooling of both groups and regions also stood out. Studies have identified that maternal schooling is an important variable for all domains of child development[25], and that higher levels of maternal schooling are associated with better outcomes for the cognitive domain[26]. Therefore, mothers with a higher educational level recognize the infant's needs, in addition to having better access to information about development and providing more stimulating and enriching environments[14].

The influence of unfavorable economic conditions can limit the resources available in the home environment, such as the provision of toys and adequate physical space, becoming a barrier to the exploration and construction of learning for infant development. It is considered that higher income is associated with greater acquisition of resources such as toys, adequate physical space to provide environmental exploration opportunities, and consequently, it contributes to motor, cognitive, and language development[14,15]. Thus, it is possible that the environment, represented by the lower family income, promoted less stimulating environments for infants with and without biological risk for HIV in the North region (represented by the cities of Belém and Benevides).

A significant association was observed between below average and average language development and maternal age in the 16-19 age group. This finding is consistent with the literature suggesting that older mothers may have greater life experience and may provide more opportunities for stimulation, which could be associated with more favorable developmental outcomes. Additionally, older mothers may demonstrate greater sensitivity to their infant's needs[14]. These findings are aligned with previous studies indicating that contexts of poverty and social vulnerability, which are more frequently observed among adolescents mothers, may be associated with increased vulnerability in infant development[14,26]. Furthermore, mother-child interaction may function as either a facilitating or limiting factor in child functionally, potentially being associated with variations in cognitive, motor, and language performance[27].

Limited maternal interaction has also been described in the literature as being associated with differences in language performance, particularly among infants at biological risk[16,27].

Regarding home environment affordances, results found significant differences between the regions in the variety of stimulation, gross and fine-motor skills, and total score dimensions. These findings reinforce that regional differences in home environments highlight the pertinence of using the AHEMD-IS to assess different contexts and discrepancies in development stimulus affordances. Almeida et al.[28] compared the characteristics of the home environment of infants living in the city of Marabá, North region, and in the city of Piracicaba, Southeast region, and observed that infants in the North region were subject to lower availability of home affordances, that is, an unfavorable environment for child development. The findings of this study can be supported because there is diversity between the regions of Brazil, which influences the quality and quantity of resources available in the home environment, indicating that the North region may be in a disadvantageous situation.

The results here show that the inadequate development of fine-motor skills is associated with the household type, be it an apartment or a house. It reinforces that inadequate home environments impact on basic needs, such as food insecurity, access to sanitation, and provision of adequate toys[29]. Thus, regardless of the household type, it is necessary to provide safe spaces and adequate stimuli according to the availability of toys, in addition to interactions with caregivers in order to foster child development.

According to Freitas et al.[15], the offer and availability of toys occur after the first year of life. This study infants aged 13 to 18 months were more stimulated and had access to more toys than infants aged 3 to 12 months. This study did not evaluate the infants by age group, which limits comparisons, but the more skills infants acquire, the greater the need to offer a variety of stimulation and toys.

No significant association was observed between developmental outcomes, home environment affordances, and economic class in the present study. Nevertheless, previous studies have highlighted the potential relevance of family income in relation to these variables[14,15,25,26]. When analyzing mean developmental scores in the motor, cognitive, and language domains, both HIV-exposed and HIV-unexposed groups from the North region were predominantly classified within the average range. Similarly, home environment affordances in the domains of physical space, gross motor skills, fine motor skills, and total score were most frequently classified as less adequate, followed by moderately adequate.

The literature points out that, the higher the family income, the greater the opportunities for adequate resources and providing stimulating physical space to favor and build the motor, cognitive, and language repertoire[12,15]. A study that compared the differences of environmental of infants with and without biological risk living in middle-income countries (Brazil) and high-income countries (Italy) observed that Brazilian infants inserted in a family context with lower maternal schooling and economic status had less variety of stimulation of motor development when compared to Italian infants who had high income and, consequently, better stimulation opportunities[30]. Poverty has been correlated with changes in brain structure and function in early childhood[30]. Studies have shown that economic disadvantage is associated with changes in language and cognitive development and executive function[29].

Therefore, the home environment can be a facilitator or a barrier in child development. Home characteristics, such as adequate physical space and the availability of appropriate toys, are associated with better motor performance in the first year of life[14]. That is, the greater the supply of stimuli and resources, the more opportunities for motor action and exploration[14,28-30]. On the other hand, unfavorable environments can become barriers to development, preventing the infant from having experiences such as moving around and interacting with the environment.

Considering the findings of the present study, the results suggest disparities that are consistent with previously documented social and income inequalities in Brazil, which may have been exacerbated during the COVID-19 pandemic. These conditions appear to be associated with adverse influences on child development, particularly in the presence of risk factors. The coexistence of such factors may contribute to cumulative effects, potentially worsening the health status of the infant and their family context. Thus, the findings underscore the relevance of public policies in health, education, social assistance, and the protection and promotion of human rights, with particular emphasis on comprehensive investment in early childhood.

Few studies compare the development and home environment affordances of infants at biological risk for HIV in different Brazilian regions, and this gap limits the understanding of developmental behaviors in relation to cultural diversities. In this way, one reinforces that the monitoring and surveillance of the biological risk for exposure to HIV in assessments that include the biopsychosocial model can favor the understanding and guidance for guidelines centered on the family context in order to enrich the environment and, consequently, favor child development.

We believe that the health programs of the Brazilian Unified Health System (Sistema Único de Saúde - SUS) for the care and monitoring of infants at biological risk for HIV, the SAE/Children in the city of Santos/SP and the UREMIA in the city of Belém/PA, act as protective factors and facilitators for child development, providing opportunities for development through clinical and laboratory monitoring. It is worth noting that mapping and monitoring infants at biological risk for HIV can favor early intervention in cases of changes in functionality. Both health services for the treatment of HIV were considered facilitators for the monitoring and detection of infants with biological risk factors.

The results of this study allowed reflection on the monitoring and surveillance of HIV-exposed and HIV-unexposed infants, as well as on the environmental factor that may have been a barrier to the home environment affordances. It is noteworthy that infants from the North region, regardless of whether they are at biological risk for HIV or not, seem to be at a disadvantage. Regional inequalities express the inequities in relation to full development, mainly of families made vulnerable by poverty and the stigma of HIV and the North region's riverside and quilombola communities.

Those results can be seen in the context of public health, that is, one reinforces that the training of health professionals who work in different development scenarios can promote the early identification and monitoring of infants who present alterations in functionality.

Therefore, exposure to HIV plus unfavorable home environment affordances can hinder full development. The contribution of this study is to stimulate monitoring and surveillance strategies for the development of HIV-exposed infants, as well as the assessment of contextual factors.

As a limitation of this study, the cross-sectional design precluded the monitoring of changes in motor, cognitive, and language performance over time, as well as the evolution of home environment characteristics within Brazil's intracultural context. Additionally, developmental assessment was conducted in infants up to 18 months of age, a stage at which cognitive outcomes may not yet be fully established, potentially limiting the detection of more subtle or later-emerging deficits. Therefore, longitudinal studies are recommended to follow infants with and without biological risk for HIV beyond 18 months of age, enabling a more comprehensive understanding of developmental trajectories and the influence of contextual factors over time.

Despite being a convenience sample, which limits generalizations, the sample was diverse and can contribute with information about the groups of HIV-exposed and HIV-unexposed infants in the North and Southeast regions.

However, further studies suggested that more analysis regarding the influence of biological and/or environmental factors and the impact on development in different aspects are carried out. The importance of assessing the characteristics of the home environment as mediators of the functionality of HIV-exposed infants is highlighted. Thus, enriched environments with opportunities for exploration and offering stimuli become facilitators for child development.

One concludes that there are regional differences in the home environment affordances evidenced by social vulnerability between the North region, represented in this study by the cities of Belém and Benevides, and the Southeast region, represented by the city of Santos. HIV-exposed and HIV-unexposed infants did not show differences in child development and home environment affordances.

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Authors' contributions

The authors declared that they have made substantial contributions to the work in terms of the conception or design of the research; the acquisition, analysis or interpretation of data for the work; and the writing or critical review for relevant intellectual content. All authors approved the final version to be published and agreed to take public responsibility for all aspects of the study.

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