



Factors associated with early childhood development in municipalities of Ceará, Brazil: a hierarchical model of contexts, environments, and nurturing care domains in a cross-sectional study

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Summary

Background This study aims to identify the contexts, environments, and nurturing care predictors that determine whether a child is developmentally on track in Ceará, Brazil.

Methods We analysed data from a cross-sectional study conducted with caregivers of 6,447 children aged 0–59 months during a vaccination campaign in Ceará in October 2019. The validated Child Development Assessment Questionnaire was used to assess early childhood development (ECD) and children with a z-score ≥ -1 SD were considered developmentally on track. We conducted logistic regression models to understand the effects of contexts, environments, and nurturing care domains on ECD.

Findings Children in the early years (< 36 months) were more likely to meet the ECD milestones if they were not born with low birth weight (AOR: 0.64; 95% CI: 0.42–0.97), were exposed to manufactured toys in their house (2.68; 1.97–3.66), their heads of household were employed (1.61; 1.16–2.23), and their caregivers had read the Child Health Handbook (1.42; 1.13–1.77) and engaged them in stimulating activities (1.71; 1.26–2.32). Children aged 36–59 months were more likely to meet the ECD milestones if they were breastfed (never: ref. / < 3 months: 3.72; 1.91–7.26 / 3–5 months: 3.21; 1.74–5.93 / 6–11 months: 3.73; 1.95–7.16 / ≥ 12 months: 3.89; 2.25–6.72), had books at home (0: ref / 1–3: 1.71; 1.22–2.40 / 4–6: 2.24; 1.27–3.94 / 7+: 2.71; 1.05–7.00), and their caregivers received information about ECD (1.49; 1.11–2.01) and engaged them in stimulating activities (1.80; 1.27–2.56). Children aged 36–59 months were less likely to meet developmental milestones if they watched TV or used tablets/smartphones for more than two hours per day (0.61; 0.44–0.84), played with household objects (0.62; 0.41–0.92), participated in governmental early childhood programmes aimed at vulnerable families (0.62; 0.45–0.86), had families that participated in income transfer programmes (0.68; 0.47–0.99) (families living in poverty or extreme poverty), and their caregivers considered slapping (0.67; 0.48–0.94) a necessary disciplinary method.

Interpretation Having favourable socioeconomic conditions, breastfeeding, the absence of harsh discipline, caregivers who provide responsive care, and the provision of opportunities for early learning are the key factors that increase the likelihood of a child achieving their full developmental potential in Ceará, Brazil.

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Introduction

Early childhood development (ECD) provides a critical foundation for lifetime education, work productivity, physical and mental health, and social well-being.^{1–4}

Research in context

Evidence before this study

The Lancet series in 2007 highlighted a concerning statistic—that approximately 250 million children worldwide under the age of 5 years are not reaching their full developmental potential. It also suggested there is a massive gap in the literature regarding the factors affecting early child development (ECD) in the Brazilian context. Issues resulting from inequities and gaps in the implementation of interventions were reported in 2011, and recommendations related to promoting the agenda, scaling up programmes, and emphasising nurturing care were reported in 2017. It is clear that, to promote ECD programmes, it is necessary to monitor child development indicators and assess whether children are being provided with a nurturing care environment that spans the five domains of the Nurturing Care Framework. Since 2016, there has been increased focus on the ECD agenda and related investments in Brazil; however, the country lacks a systematic strategy to monitor ECD indicators and nurturing care environments. To highlight this gap, we searched PubMed studies published in English, Portuguese, and Spanish in the last five years to identify information about ECD in Brazil. The keywords used for the search were ‘child development’/‘early child development’, and ‘Brazil’. We reviewed the titles, abstracts, and full texts of the 443 studies that were retrieved to evaluate their eligibility. Several studies were excluded because they analysed only child health or anthropometric outcomes, while others were excluded because they were designed for the validation of scales and instruments to measure ECD in Brazil. As a result, 20 articles were included for analysis. Information on their objectives, samples, and results was extracted by one reviewer and checked by a second reviewer. Only five of the studies addressed the prevalence of ECD delays and four of them were cross-sectional studies. The study samples ranged in size from 282 to 3,566 children of up to six years of age and different instruments were used to measure the risk prevalence. Results varied from a 9.2% risk prevalence to a 32.0% prevalence. Using the Ages and Stages Questionnaire (ASQ), one cohort study reported a 30.3% risk of delayed development based on a sample of 1,292 children. Most studies investigated the influence of risk factors on specific domains of child development. They identified biological (i.e. low birth weight), nutritional (malnutrition, absence of breastfeeding in the first hour), environmental (adverse experiences, few stimuli), and socioeconomic risk factors (i.e. mothers’ poor educational attainment). We also reviewed the data from two cohort studies that involved large samples—MINA-Brasil and the 2015 Pelotas cohort. However, they did not contain ECD-related data. The few studies that have focused on ECD in Brazil in recent years used different measuring instruments, demonstrated a wide variation in the prevalence of delays, and indicated a strong association with socioeconomic conditions. This result indicates that more studies are needed in this field, with a larger sample and nationally representative data.

Added value of this study

The PIPAS study in Ceará was a cross-sectional study that collected data during multi-vaccination campaigns and used caregivers’ reports, presenting a quick and low-cost strategy for obtaining information about ECD at a population level. The data from the PIPAS study can be used at the municipality level when formulating health policies and programmes. Furthermore, we investigated the factors associated with the development of children aged < 36 and 36–59 months separately. This was done to provide additional knowledge regarding the determinants of ECD for each age group, recognising the importance of having valid instruments for assessing children’s ECD outcomes during the critical first 1,000 days of life. Additionally, to our knowledge, this is the first study in Brazil to identify the predictors of children who are developing appropriately using a holistic framework, extending the research in the ECD field to an upper middle-income economy setting by incorporating contexts, environments, and nurturing care domains within a large sample of municipalities in Ceará (n = 6,447). We found that an enabling and nurturing care environment for ECD consists of breastfeeding; receiving information about ECD; promoting stimulation activities, toys, and books; and protecting children from harsh disciplinary actions and prolonged exposure to screens.

Implications of all the available evidence

Brazil is the largest country in South America. It has a population of over 207 million, approximately 11% of whom are children under six years of age. In Brazil, initiatives to promote ECD are still incipient and limited studies have been conducted to measure child development and its associated factors. The results of this study can help decisionmakers in the fields of health, education, and social care looking to improve the quality of programmes that have already been implemented. Additionally, these results could facilitate the development of effective policies and strategies to promote ECD, guide efforts toward care domains where they are really needed, and ensure the best use of human and economic resources.

According to estimates published in a series of *Lancet* articles in 2017, approximately 250 million (43%) children aged under five years in 2010 and living in low- and middle-income countries (LMICs) were at risk of poor ECD⁵. A recent study conducted using the Early Childhood Development Index, although limited in the depth of its content, demonstrated that up to one-third of children globally are not reaching their developmental potential.^{2,6} Additionally, Lu et al. (2020)—using data from 135 demographic and health surveys and MICSSs conducted between 2010 and 2018 in 94 LMICs—identified no reduction in disparities over time in most countries for which trend data were available.⁶

The 2020 ‘Country Profiles for Early Childhood Development’, compiled by UNICEF in collaboration

with Countdown to 2030—Women’s, Children’s and Adolescents’ Health, also showed that fewer than half of the young children in a third of the countries received the benefits of early stimulation and responsive care from adults in their home, while more than three-quarters of the children aged one to four years experienced violent disciplinary action from their caregivers in almost half of the countries. These statistics highlight the need for urgent action and investment in ECD by governments and national and international organisations.⁷

Accordingly, ECD has been receiving increasing attention. For instance, the United Nations Sustainable Development Goals have placed ECD on the global policy agenda, highlighting the importance of enabling all children to reach their full developmental potential.⁸ ECD measurement can provide information on the challenges in reaching this target and inform evidence-based policies.⁹ However, relatively little systematic evidence is available to guide governments, donors, and civil society to identify which young children and families should be targeted by such policies.⁶

The ECD agenda and related investments in Brazil have expanded since 2016. However, few ECD studies have been conducted in the last few years.¹⁰ The estimated prevalence of children not reaching developmental milestones has varied from 9% to 32% in various studies.^{11–13} These studies have further identified biological (i.e. low birth weight), nutritional (malnutrition, absence of breastfeeding in the first hour), and environmental risk factors (adverse experiences, few stimuli)^{14–16} as contributing factors. They have also shown a strong association between socioeconomic indicators and the risk of delays in child development.^{14–16}

Additionally, Brazil lacks a systematic strategy for monitoring ECD indicators and obtaining a comprehensive view of nurturing care environments.¹⁰ To fill this gap, the PIPAS study (*Primeira Infância para Adultos Saudáveis*—Early Childhood for Healthy Adults) developed and validated an instrument to quickly and inexpensively evaluate the development of children under five years of age during multi-vaccination campaigns.^{17,18} In 2019, a large cross-sectional PIPAS study was conducted in 16 municipalities in the state of Ceará in northeast Brazil to provide data on child development surveillance and support interventions in this field.

Child development is influenced by many variables and ECD delays have multifactorial causes. This study aimed to investigate the predictors that determine whether a child is on track to meet their developmental milestones. It is hypothesised that better socioeconomic conditions and healthy nurturing care environments are associated with higher development scores in children living in Ceará, Brazil.

Methods

Study population and design

We analysed data from the PIPAS cross-sectional study, which was conducted with 7,017 child–caregiver pairs who attended the 2019 multi-vaccination campaign in Ceará. This semiarid state has a population of nine million and a per capita income of US\$ 5,770 in 2019, making it an upper-middle-income economy (those with a per capita income between US\$ 3,996 and \$ 12,375).¹⁹ A report analysing 26 indicators related to demographics, education, basic sanitation, the labour market, poverty, and inequalities in Ceará concluded that the state’s performance was worse in terms of illiteracy, sanitation, and per capita household income than Brazil overall.²⁰

We established a partnership with the Ceará state government through its Department of Health to obtain information on ECD from municipalities with different population sizes and geographic locations. Consequently, 16 municipalities (out of 184) in the state were identified—three in each of the five health macro-regions as well as the capital (Fortaleza). The primary aim behind this selection was to encapsulate diverse socioeconomic contexts rather than obtaining a representative sample of municipalities. The selected municipalities had differing population sizes and profiles of child health indicators, achieved good vaccination coverage in previous campaigns, and expressed an interest in participating in the study.

Multi-vaccination campaigns in Brazil, which are coordinated by the Ministry of Health, encourage all children under six years of age to have their vaccination calendar checked, regardless of whether they are monitored by the public health system. This strategy of conducting studies during vaccination campaigns has been widely recommended and used in the Brazilian setting because it enables relatively quick and inexpensive data collection. The campaigns generally last for two weeks, which includes large mobilisation on a Saturday (called D-day). In cities with a smaller population, the distribution of children who attend is relatively even throughout the campaign period. In larger cities, such as capitals, most children attend on D-day.^{21,22}

We planned a convenience sample that consisted of different populations and recruitment strategies to include children based on the population size of the municipalities. The required sample size was 1,000 children for municipalities with more than 1,000,000 inhabitants, 500 children for those with 1,000,000–100,000 inhabitants, and 300 children for municipalities with fewer than 100,000 inhabitants. A 95% confidence level, standard error of < 5%, and coefficient of variation < 30% were considered to be the accuracy criteria for estimating prevalence.

In the small- and medium-sized cities, all children under 59 months of age who visited the Immunisation

Units from 7 to 25 October 2019, and whose caregivers agreed to participate, were included in the study. In the capital, Fortaleza, participants were recruited only on 19 October 2019. This was done using a cluster sampling method with a single selection stage in which 24 Immunisation Units were stratified implicitly by region to include children with different socioeconomic profiles. Children aged 0–59 months who were accompanied by a primary caregiver (e.g., mother, father, grandmother) were included in the study, regardless of whether they had a disability.

Data were collected through face-to-face computer-assisted personal interviews with the caregiver, conducted by health professionals or trained undergraduate health students. This study used data from 6,447 child–caregiver pairs who completed the child development tool (6,447/7,017: 91.9%). [Figure 1](#) describes of the sample selection.

Ethics approval and participant consent statements

The Ethical Committee of the Secretariat of Health of Ceará (CAAE 15482319.0.3001.5051) approved this study. Written informed consent was obtained from all participating caregivers.

Assessment of outcome

The questionnaire to assess child development (QAD-PIPAS) was developed and validated with the support of the Brazilian Ministry of Health and the Bill & Melinda Gates Foundation. It represented a quick and low-cost strategy for obtaining information about ECD. The questionnaire is a culturally adapted tool that directly assesses population-level ECD across four domains (motor, cognitive, language, and socioemotional) and ten age groups (0–6, 7–9, 10–12, 13–15, 16–18, 19–24, 25–3, 31–36, 37–49, 49–59 months).^{17,18,23} The number of items by age group can vary from 9 to 24. The instrument's content validity was verified by a multidisciplinary group consisting of ECD experts. The psychometric properties focused on reliability as well as construct and concurrent validity are presented elsewhere.^{17,18}

In the first stage, the QAD-PIPAS generated a score for each child based on the sum of the answers to the questions. The expected answers were assigned a value of 1, whereas the absence of skill or behaviour expected from that age group was assigned a value of 0. The score of each child was standardised using the expression:

Score = $\sum_{i=1}^p \frac{Q_i}{p}$ where Q represents the *i*-th question, whose value is 0 (no) or 1 (yes), and *p* is the number of questions or items evaluated.

This standardised score ranged from 0 to 1; a value of 0 indicated inappropriate responses to all the items, whereas 1 indicated appropriate responses to all the items. As there were no standardised scores for the

Brazilian population, we created standardised scores by calculating z-scores based on the research sample. The z-score indicates how far above or below the sample mean the raw score is, in units of standard deviation (SD), which makes it useful for comparing the relative position of an individual's measure within the group to which they belong.⁹

In this study, we considered children with a z-score ≥ -1 SD (value of 1) to be on track to reach their developmental milestones (i.e. children whose development score was above or equal to -1 SD of the sample mean for their age group), and the outcome was treated as a dichotomous variable (yes/no).¹¹

Assessment of predictors

Given the importance of monitoring the quality of care children experience in their environment to help interpret their development scores, the characteristics of children and their families that can influence child development were included in the first part of the QAD-PIPAS questionnaire. These questions were based on the five domains of the Nurturing Care Framework (i.e. good health, adequate nutrition, opportunities for early learning, security and safety, and responsive caregiving). Variables related to the socioeconomic and family contexts were also included. Most questions were based on globally used instruments, such as the MICS (UNICEF); other questions were extracted from the forms of the National Information Systems (i.e. Live Birth Information System, Food and Nutrition Surveillance System); yet others came from validated instruments for the Brazilian population (Brazilian Scale of Food Insecurity). Owing to the limited timeframe within which the interviews had to be conducted during the vaccination campaign, it was not possible to include complete instruments, such as scales, to assess maternal depression. Finally, questions were formulated to capture certain outcomes based on the caregiver's report. This part of the questionnaire was also analysed by the group of ECD experts who validated the QAD-PIPAS.¹⁸ Details about this group of questions are presented in Supplementary Table 1, Supplementary Table 2, Supplementary Table 3, and Supplementary Table 4.

This manuscript is a retrospective analysis of data already collected as part of the PIPAS study. An adapted version of Black et al.'s life course conceptual framework of ECD was used to identify the predictors of a child who is reaching developmental milestones². The data collected in the PIPAS study were grouped to match each level of the proposed framework based on data availability ([Figure 2](#) and Supplementary Table 5).

The most distant hierarchical level represents contexts, which include the structural aspects of society at the social, economic, political, climatic, and cultural levels. The employment status of the head of household (unemployed or employed/retired/pensioner) was

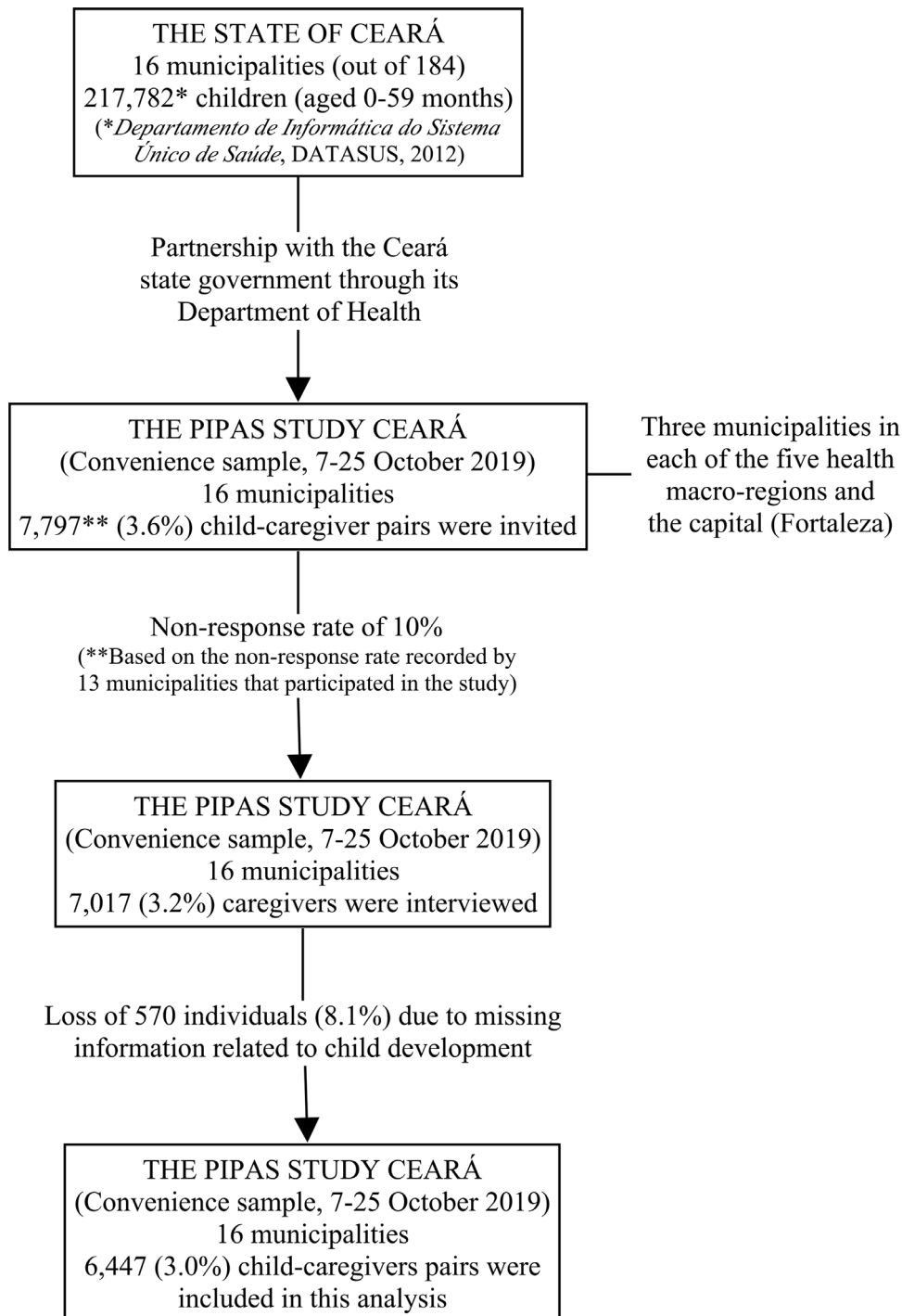


Figure 1. Description of the sample selection-PIPAS Ceará/Brazil, 2019.

included as a variable at this level. Food insecurity (yes, sometimes/frequently, or no)²⁴ and the sanitation status of the household (without clean water, wastewater treatment, and waste collection; yes or no) were used as a proxy for the economic context.²⁵ The question on

food insecurity (i.e. whether the participant had been worried about having no food and no money to afford more in the last 12 months) was adapted from the Brazilian Food Insecurity Scale (in Portuguese, *Escala Brasileira de Insegurança Alimentar*, EBIA).²⁴ The question

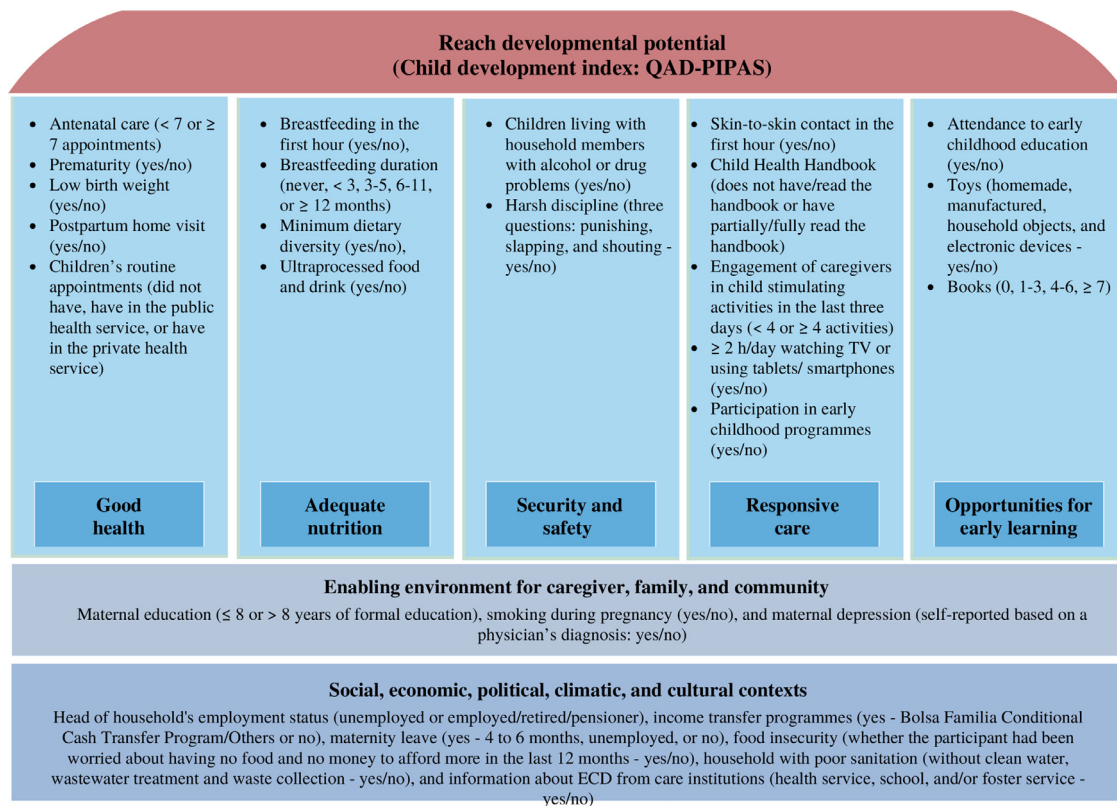


Figure 2. The effects of contexts, environments, and nurturing care within the PIPAS study through the multigenerational life course conceptual framework of early childhood development – PIPAS Ceará/Brazil, 2019. Source: Modified from Black et al.(2)

regarding household sanitation addressed three of the four components of the Brazilian regulatory framework for basic sanitation.²⁶ The fourth component is whether rainwater management is carried out by the public sector. Income transfer programmes (yes—*Bolsa Família* Conditional Cash Transfer Programme/others or no), maternity leave (yes—4 to 6 months; unemployed; or no), and information about ECD from care institutions (yes—health service, school, and/or foster service or no) were included to represent the commitment of the government and its family-supportive governance.

The second hierarchical level represents environments, which are personal resources (i.e. an enabling environment for the caregiver, family, and community). Black et al. proposed parental education and physical and mental health as components for this level². Based on data availability, maternal education (≤ 8 years or > 8 years), smoking during pregnancy (yes or no), and maternal depression (self-reported based on a physician's diagnosis; yes or no) were chosen to represent the children's environments.

The most proximal hierarchical level represents the WHO Nurturing Care Framework.^{3,27} The good health domain represents actions to prevent (e.g. immunisation actions) and treat children's diseases, such as

antenatal care and well-child visits. In this study, antenatal care (< 7 appointments or ≥ 7 appointments),²⁸ prematurity (yes or no), low birth weight (yes or no), a postpartum home visit (yes or no), and children's routine appointments (did not have, have in the public health service, or have in the private health service) were the variables that constituted this domain.

In the adequate nutrition domain of the WHO Nurturing Care Framework, breastfeeding was represented by the following variables: breastfeeding during the first hour of life (yes or no) and breastfeeding duration (never, < 3 months, 3–5 months, 6–11 months, and ≥ 12 months). Breastfeeding duration was based on two questions: (1) Has the child ever been breastfed? (yes or no) and (2) Until when was the child breastfed? (answers varied between < 3 months, 3–5 months, 6–11 months, 12–24 months, > 24 months, and the child still breastfeeds). For those who answered that the child was still breastfeeding, the child's age at the time of the interview was noted as the breastfeeding duration. Children older than six months of age who had consumed at least one food item from each of the five groups (breast milk/other milk, fruits/vegetables/legumes, meat/eggs, beans, and cereals/tubers) during the day before the interview were considered to have

minimum dietary diversity.²⁹ Children older than six months of age who had consumed either soft drinks, cookies/crackers, snack packets, or candy/lollipops/chocolates/sweets during the day before the interview were considered to have consumed ultra-processed food or drinks. Food consumption markers were collected following the Brazilian Food and Nutrition Surveillance System (in Portuguese, *Sistema de Vigilância Alimentar e Nutricional*, SISVAN) questionnaire.³⁰

Harsh discipline (punishing, slapping, and/or shouting at the child; yes or no) and children living with household members with alcohol and/or drug problems (yes or no) were included as variables in the security and safety domain because these two situations represent whether the child is experiencing adversity (e.g. abuse, neglect, and/or violence).³¹ The caregiver's opinion on harsh discipline was investigated through the following question adopted from MICS-UNICEF: 'Do you think that it is necessary to occasionally punish, slap, and/or shout at the child in order to discipline them?'.³²

The number of stimulating activities (< 4 or ≥ 4 activities) such as reading books, storytelling, singing, going out, playing, and/or drawing with the child performed in the last three days by the caregiver or any other family member older than 15 years of age was included as a variable to indicate responsive caregiving (MICS-UNICEF).³² Watching TV or using tablets/smartphones for ≥ 2 h/day (yes or no) and reading the Child Health Handbook (yes—have partially or fully read; or no—have not read or do not have) were also included as variables. Skin-to-skin contact between the child and mother in the first hour of life (yes or no) was included owing to its potential to facilitate the creation of a parent and child bond as well as emotional development.³³ Participation in early childhood programmes, such as PADIN, *Criança Feliz*, *Mais Infância Ceará* (*Cartão Mais Infância*), *Cresça com seu Filho/Criança Feliz*, and others (yes or no), was included to represent home visiting and parenting programmes.

Regarding opportunities for early learning, attending early childhood education represents whether the child had access to childcare and preschool. Possession of books (0, 1–3, 4–6, 7 or more) and toys (homemade, manufactured, household objects, and electronic devices; yes or no) were also included as variables in this domain.³² Questions on the number of books and play materials were adopted from MICS-UNICEF.³²

Statistical analysis

Survey sample data were accounted for in all the analyses using robust estimation techniques by calculating the standard errors using the linearised variance estimator ('svy' command). The Immunisation Unit was the primary sampling unit, the municipality served as the stratum, and the sampling fraction served as the design weight in the analysis; the latter was defined by $f_i = \frac{n_i}{N_i}$, where n_i is the

sample size and N_i is the number of children in each municipality in 2015–2018 according to the Live Birth Information System.³⁴ The design weight was used to compensate for oversampling in some municipalities.

The absolute and relative frequencies of caregivers interviewed, maternal age, child ethnicity, child sex, contexts, environments, and nurturing care variables were described. Weighted Pearson chi-square statistics were calculated to compare children who were developmentally on track with those who were not.

Age-stratified multivariate logistic regression models (< 36 months and 36–59 months), which were fitted using survey sample data, were used to identify the predictors of children who were developmentally on track. The response variable (y_i) is dichotomous, taking the value of 1 for a z-score ≥ -1 SD and 0 for a z-score < -1 SD for child development. The general logistic regression model³⁵, taking the predictors as (x_i), is given by

$\log\left\{\frac{\pi(x)}{1-\pi(x)}\right\} = \beta_1 + \beta_2x_2 + \dots + \beta_px_p$ where:
 $x = (1, x_2, \dots, x_p)$ ' represents the vector of the covariates.

$\pi(x)$ is the probability that the child is developing on track given the characteristics x .

$\beta = (\beta_1, \beta_2, \dots, \beta_p)$ ' is the vector of the model parameters.

Initially, the effect of each predictor on child development was estimated by calculating their crude odds ratios at 95% confidence intervals. Variable selection methods that utilise significance thresholds between 0.15 and 0.25 are commonly used.^{35,36} This approach allows all the important predictors to be included in the modelling a priori despite their statistical significance being > 0.05.³⁵ In this study, the predictors associated with child development at a significance level of $p < 0.20$ were included in the multivariate logistic regressions using a backward stepwise method and obeying a hierarchical model that utilised the previously established conceptual framework (Figure 2).

As proposed by Victora et al.,³⁷ when the observation unit is the individual, explanatory variables can be organised into different hierarchical levels through a conceptual framework. This strategy prevents the underestimation of the distal level's effects in a theoretical model. Using the method proposed by Victora et al.,³⁷ the predictors associated with the outcome were included in the multivariate models based on the levels of determination (distal: contexts; intermediate: environment; and proximal: nurturing care). The predictors associated with the outcome ($p < 0.05$) were retained in the final model of each block. In this hierarchical multivariate analysis, the contextual predictors that were independently associated ($p < 0.05$) with the outcome were the first to be included in the model, serving as adjustments for the predictors hierarchically positioned in the lower levels. The environmental predictors associated with child development ($p < 0.20$) were added into the model alongside the contextual predictors but only

those with $p < 0.05$ remained in the model. At this point, the contextual predictors remained regardless of their p -value. Similarly, the nurturing care predictors were subsequently added into the model alongside the contextual and environmental predictors, which remained at $p < 0.05$. The previously selected contextual and environmental predictors were retained regardless of their p -value. A goodness-of-fit test (F-adjusted mean residual test) was conducted for the logistic regression model fitted using survey sample data.

Maternal age when the child was born and the child's sex were retained in the final models because these covariates might be important factors in the epidemiology of ECD.^{38,39} Owing to the statistically significant difference in the ratio of caregivers interviewed (mother, father, grandparents, other) between the studied sample and the lost information (Supplementary Table 6), this variable was also retained in the models.

All the analyses were performed using Stata Statistical Software.⁴⁰ The two-sided statistical significance was determined at $p < 0.05$.

Role of the funding source

This study was supported by the Maria Cecília Souto Vidigal Foundation (F0245), Brazil. The funder of this study had no role in the design, data collection, data analysis, interpretation, or writing of the report.

Results

The analysis results of the children's age distribution ($p = 1.0$) did not statistically differ from the data recorded by the Ministry of Health's Information Systems for the population of the selected municipalities but maternal education did ($p = 0.02$) (Supplementary Table 7). The PIPAS study included less educated mothers than those from the population of the selected municipalities. Moreover, there were no statistically significant differences between the samples with missing outcome data ($n = 570$, 8.1%) and the examined children ($n = 6,447$, 91.9%) regarding the child's sex, maternal age and education, the head of the household's employment status, food insecurity, and children's routine appointments; however, there were significant differences in the variables of the caregiver interviewed, child's age, and engagement of caregivers in stimulating activities (Supplementary Table 6).

Tables 1 and 2 respectively describe the sample and prevalence of children who were on track to reach their developmental milestones based on their characteristics (individual and maternal), contexts, environments, and nurturing care domains. In this study, most caregivers interviewed were the children's mothers (89.8%). Over half (59.0%) of the mothers had more than eight years of education and 83.2% had attended at least seven antenatal appointments when pregnant. Over half (59.0%)

of the heads of households were unemployed at the time of the interview. There was a predominance of boys (50.8 vs 49.2%) and children who were not attending early childhood education (59.1 vs 40.9%) in the examined group. Children who were < 36 months of age composed 64.8% of the sample, while those aged 36–59 months accounted for 35.2%. We found that 88.2% of the children aged < 36 months and 83.7% of those aged 36–59 months were tracking to reach their expected developmental milestones.

Children aged < 36 months who had employed (or retired/pensioner) heads of households had a higher likelihood of meeting their developmental milestones than those with unemployed heads of households (Table 3). In the most proximal hierarchical level, which represented the WHO Nurturing Care Framework, children < 36 months of age who did not have low birth weight, played with manufactured toys, and whose caregiver had read the Child Health Handbook and had interacted with the child in at least four stimulating activities in the three days before the interview had a greater chance of being on the right developmental path. The F-adjusted mean residual test suggested no evidence of a lack of fit ($p = 0.44$).

Among children aged 36–59 months, the odds ratio of reaching their developmental milestones was lower when their families participated in income transfer programmes and higher when their caregivers received information about ECD from care institutions (Table 3). In this group, children who were breastfed (regardless of duration) and whose caregiver engaged them in at least four stimulating activities in the three days before the interview had a higher likelihood of meeting their developmental milestones. Likewise, children in this group that had one to three books were 71% more likely to reach their developmental milestones. The figure increased to 124% and 171% if the children had four to six or seven or more books, respectively. Children who watched TV or used tablets/smartphones for two or more hours per day and whose caregivers considered slapping a necessary disciplinary technique were less likely developmentally on track. Playing with household objects and taking part in early childhood programmes were both associated with a lower chance of hitting their developmental milestones among the children in this group. The trend effect calculated by treating variables as ordinal categorical variables in the multivariate logistic regressions showed that there is a significant trend of improvement in ECD with an increase in the duration of breastfeeding (trend effect, $p = 0.005$) and in the number of books (trend effect, $p = 0.008$). The F-adjusted mean residual test suggested no evidence of a lack of fit ($p = 0.41$).

Discussion

To the best of our knowledge, this is the first study in Brazil providing broad evidence of the predictors of child development that can be easily measured using a

	Total	Child development index														
		Total														
							< 36 months					36 - 59 months				
		Z-score		Z-score		p [†]	Z-score		Z-score		p [†]	Z-score		Z-score		p [†]
		< -1 SD	≥ -1 SD	< -1 SD	≥ -1 D		< -1 SD	≥ -1 SD	< -1 SD	≥ -1 SD						
%‡	n	%	n	%	n	%	n	%	n	%	n	%	n	%		
Caregiver interviewed	100.0	823	13.4‡	5624	86.6‡	-	466	11.8‡	3761	88.2‡	-	357	16.3‡	1863	83.7‡	-
Mother	89.8	721	12.8	4895	87.2	0.35	415	11.1	3318	88.9	0.97	306	16.3	1577	83.7	0.03
Father	2.3	23	9.3	225	90.7		15	10.6	127	89.4		8	7.6	98	92.4	
Grandparents	5.2	42	11.5	324	88.5		24	11.1	192	88.9		18	12	132	88	
Other	2.7	37	17.1	179	82.9		12	8.9	123	91.1		25	30.9	56	69.1	
Maternal and child characteristics																
Maternal age (years)^a																
< 20	17.5	160	15.5	875	84.5	0.18	96	14.4	570	85.6	0.14	64	17.3	305	82.7	0.91
20–34	68.7	528	12	3883	88.0		293	10.1	2618	89.9		235	15.7	1265	84.3	
> 34	13.8	112	12.7	770	87.3		65	11.1	520	88.9		47	15.8	250	84.2	
Child's sex																
Male	50.8	493	15.3	2735	84.7	<0.001	265	12.5	1856	87.5	0.005	228	20.6	879	79.4	0.001
Female	49.2	330	10.3	2886	89.7		201	9.6	1904	90.4		129	11.6	982	88.4	
Child's ethnicity^b																
Brown	67.63	536	12.8	3655	87.2	0.74	294	10.9	2397	89.1	0.91	242	16.1	1258	83.9	0.68
White	29.27	254	12.7	1751	87.3		152	11.1	1220	88.9		102	16.1	531	83.9	
Black	2.73	16	10.3	140	89.7		9	9.0	91	91.0		7	12.5	49	87.5	
Asian	0.36	6	16.7	30	83.3		4	17.4	19	82.6		2	15.4	11	84.6	
Indigenous	0.01	0	0.00	9	100.0		0	0.0	6	100.0		0	0.0	3	100.0	
Level 1 - Social, economic, political, climatic, and cultural contexts																
Head of household's employment status																
Unemployed	59.0	477	15.3	2637	84.7	<0.001	272	13.3	1775	86.7	<0.001	205	19.2	862	80.8	0.03
Employed/retired/pensioner	41.0	328	10.3	2866	89.7		181	8.7	1907	91.3		147	13.3	959	86.7	
Income transfer programmes																
No	27.3	217	9.8	1988	90.2	<0.001	142	9.5	1359	90.5	0.03	75	10.7	629	89.3	<0.001
<i>Bolsa Familia</i> Conditional Cash Transfer Program/Others	72.7	603	14.3	3618	85.7		323	11.9	2391	88.1		280	18.6	1227	81.4	

Table 1 (Continued)

	Total		Child development index													
			Total						< 36 months				36 - 59 months			
	Z-score		Z-score		p ⁱ	Z-score		Z-score		p ⁱ	Z-score		Z-score		p [†]	
	< -1 SD		≥ -1 SD			< -1 SD		≥ -1 D			< -1 SD		≥ -1 SD			
	%‡	n	%	n	%	n	%	n	%	n	%	n	%	n	%	
Maternity leave																
No	54.1	441	14.9	2521	85.1	0.002	263	13.2	1724	86.8	0.02	178	18.3	797	81.7	0.03
Unemployed	28.0	236	12.3	1680	87.7		125	9.9	1134	90.1		111	16.9	546	83.1	
Yes (4 to 6 months)	17.9	135	9.1	1344	90.9		73	7.9	846	92.1		62	11.1	498	88.9	
Food insecurity^c																
No	45.7	330	10.5	2808	89.5	<0.001	190	9.3	1846	90.7	0.04	140	12.7	962	87.3	<0.001
Yes	54.3	486	14.9	2784	85.1		272	12.6	1894	87.4		214	19.4	890	80.6	
Households with poor sanitation^d																
No	86.0	740	12.7	5109	87.3	0.76	416	10.8	3429	89.2	0.69	324	16.2	1680	83.8	0.03
Yes	14.0	82	13.8	514	86.2		50	13.1	331	86.9		32	14.9	183	85.1	
Information about ECD from care institutions^e																
No	35.9	392	15.7	2113	84.3	<0.001	223	13.8	1395	86.2	0.004	169	19.1	718	80.9	<0.001
Yes	64.1	419	10.8	3453	89.2		235	9.1	2335	90.9		184	14.1	1118	85.9	
Level 2 - Enabling environment for caregiver, family, and community																
Maternal education																
≤ 8 years	41.0	398	17.3	1909	82.7	<0.001	225	14.9	1283	85.1	<0.001	173	21.7	626	78.3	<0.001
> 8 years	59.0	408	10.2	3611	89.8		236	8.9	2406	91.1		172	12.5	1205	87.5	
Smoking during pregnancy																
No	95.6	752	12.2	5392	87.8	0.001	426	10.6	3608	89.4	0.15	326	15.5	1784	84.5	0.001
Yes	4.4	66	23.3	217	76.7		37	20.4	144	79.6		29	28.4	73	71.6	
Maternal depression																
No	94.8	764	12.6	5278	87.4	0.56	438	11.0	3551	89.0	1.00	326	15.9	1727	84.1	0.32
Yes	5.2	54	14.8	312	85.2		25	11.5	193	88.5		29	19.6	119	80.4	

Table 1: Number and percentage of children aged 0–59 months according to their contexts and environments, age categories, and child developmental status - PIPAS Ceará/Brazil, 2019.

ⁱWeighted Pearson chi square statistics (svy) were implemented to compare children who were developmentally on track (z-score ≥ -1 SD) to those who were not (< -1 SD) as per the framework's variables. [†]Weighted prevalence (svy). (a) Maternal age when the child was born. (b) Based on self-reported skin colour. (c) If the participant was worried about having no food and no money to afford more in the last 12 months. (d) Without clean water, wastewater treatment, and waste collection. (e) Health service, school, and/or foster service

Nurturing care domains	Total	Child development index														
		Total				p ⁱ	< 36 months				p ⁱ	36 - 59 months				p ⁱ
		Z-score < -1 SD		Z-score ≥ -1 SD			Z-score < -1 SD		Z-score ≥ -1 SD			Z-score < -1 SD		Z-score ≥ -1 SD		
		% [‡]	n	%	n	n	%	n	%	n	%	n	%	n	%	
Good health																
Antenatal care																
< 7 appointments	16.8	139	13.2	915	86.8	0.92	84	12	625	88.1	0.99	55	15.9	290	84.1	0.89
≥ 7 appointments	83.2	614	12.3	4372	87.7		354	11	2948	89.3		260	15.4	1424	84.6	
Prematurity																
No	91.8	713	12.2	5114	87.8	0.01	404	11	3412	89.4	0.06	309	15.4	1702	84.6	0.12
Yes	8.2	106	17.5	499	82.5		59	15	342	85.3		47	23.0	157	77.0	
Low birth weight^a																
No	92.4	702	12.1	5099	87.9	0.13	391	10	3438	89.8	0.03	311	15.8	1661	84.2	0.91
Yes	7.6	85	17.4	405	82.6		56	17	266	82.6		29	17.3	139	82.7	
Postpartum home visit																
No	15.1	251	13.4	1619	86.6	0.03	144	11	1118	88.6	0.09	107	17.6	501	82.4	0.049
Yes	84.9	555	12.4	3913	87.6		316	11	2599	89.2		239	15.4	1314	84.6	
Children's routine appointments																
Did not have	25.7	272	14.9	1557	85.1	0.004	120	13	795	86.9	0.17	152	16.6	762	83.4	0.05
In the public health service	70.3	493	12.5	3458	87.5		311	11	2584	89.3		182	17.2	874	82.8	
In the private health service	4.0	54	8.6	572	91.4		33	8.4	361	91.6		21	9.1	211	90.9	
Adequate nutrition																
Breastfeeding in the first hour																
No	20.7	218	15.3	1208	84.7	0.004	125	13.3	813	86.7	0.16	93	19.1	395	80.9	0.005
Yes	79.3	597	12.0	4367	88.0		338	10.4	2918	89.6		259	15.2	1449	84.8	
Breastfeeding duration^b																
Never	4.3	48	18.4	213	81.6	0.001	18	11.8	134	88.2	0.08	30	27.5	79	72.5	0.001
< 3 months	19.8	190	15.7	1024	84.3		121	14.7	700	85.3		69	17.6	324	82.4	
3–5 months	12.3	86	10.6	725	89.4		50	8.2	558	91.8		36	17.7	167	82.3	
6–11 months	22.5	137	9.4	1321	90.6		86	8.1	980	91.9		51	13.0	341	87.0	
≥ 12 months	41.1	315	12.6	2187	87.4		164	11.2	1296	88.8		151	14.5	891	85.5	

Table 2 (Continued)

Nurturing care domains	Total	Child development index														
		Total						< 36 months						36 - 59 months		
		Z-score < -1 SD		Z-score ≥ -1 SD		p ⁱ	Z-score < -1 SD		Z-score ≥ -1 SD		p ⁱ	Z-score < -1 SD		Z-score ≥ -1 SD		p [†]
		n	%	n	%		n	%	n	%		n	%	n	%	
Minimum dietary diversity^c																
No	46.9	431	16.5	2188	83.5	<0.001	229	14.4	1367	85.6	<0.001	202	19.8	821	80.2	<0.001
Yes	53.1	322	10.6	2717	89.4		168	9.1	1682	90.9		154	13.0	1035	87.0	
Ultra-processed food and drink^d																
No	24.8	206	13.0	1384	87.0	0.13	187	13.2	1235	86.8	<0.001	19	11.3	149	88.7	0.41
Yes	75.2	615	12.7	4217	87.3		278	10.0	2510	90.0		337	16.5	1707	83.5	
Security and safety																
Household members with alcohol or drug problems																
No	89.4	704	12.3	5006	87.7	0.01	409	10.9	3357	89.1	0.53	295	15.2	1649	84.8	0.03
Yes	10.6	116	16.2	602	83.8		55	12.3	393	87.7		61	22.6	209	77.4	
Harsh discipline^e																
Punishing																
No	26.0	220	14.4	1308	85.6	0.23	154	13.5	985	86.5	0.05	66	17.0	323	83.0	0.84
Yes	74.0	597	12.3	4269	87.7		306	10.0	2742	90.0		291	16.0	1527	84.0	
Shouting																
No	75.4	574	11.8	4279	88.2	0.04	355	10.6	2983	89.4	0.85	219	14.5	1296	85.5	0.002
Yes	24.6	244	15.6	1320	84.4		108	12.4	760	87.6		136	19.5	560	80.5	
Security and safety (Continued)																
Harsh discipline^e																
Slapping																
No	50.8	389	12.0	2843	88.0	0.32	272	11.5	2089	88.5	0.15	117	13.4	754	86.6	0.01
Yes	49.2	430	13.5	2748	86.5		192	10.4	1651	89.6		238	17.8	1097	82.2	
Responsive care																
Skin-to-skin contact in the first hour																
No	30.7	253	13.8	1586	86.2	0.53	139	11.6	1060	88.4	0.64	114	17.8	526	82.2	0.1
Yes	69.3	554	12.3	3937	87.7		321	10.8	2645	89.2		233	15.3	1292	84.7	
Child Health Handbook																
Have not read or does not have the handbook	21.7	249	17.6	1163	82.4	<0.001	145	15.5	789	84.5	<0.001	104	21.8	374	78.2	0.001
Yes, have partially or fully read	78.3	569	11.4	4429	88.6		317	9.7	2957	90.3		252	14.6	1472	85.4	

Table 2 (Continued)

Nurturing care domains	Total	Child development index														
		Total				p [†]	< 36 months				p [†]	36 - 59 months				p [†]
		Z-score < -1 SD		Z-score ≥ -1 SD			Z-score < -1 SD		Z-score ≥ -1 SD			Z-score < -1 SD		Z-score ≥ -1 SD		
		% [‡]	n	%	n	n	%	n	%	n	%	n	%	n	%	
Engagement of caregivers in at least four stimulating activities^f																
< 4	2.2	417	18.1	1886	81.9	<0.001	270	16	1460	84.4	<0.001	147	25.7	426	74.3	<0.001
≥ 4	4.9	402	9.8	3719	90.2		193	7.8	2289	92.2		209	12.8	1430	87.2	
≥ 2 h/day watching TV or using tablets/smartphones																
No	87.3	635	12.1	4626	87.9	0.001	408	11	3273	88.9	0.65	227	14.4	1353	85.6	0.02
Yes	12.7	162	16.5	821	83.5		45	11	357	88.8		117	20.1	464	79.9	
Participation in early childhood programmes^g																
No	76.5	657	12.6	4563	87.4	0.74	369	11	2962	88.9	0.49	288	15.3	1601	84.7	0.04
Yes	23.5	158	13.5	1011	86.5		93	11	763	89.1		65	20.8	248	79.2	
Opportunities for early learning																
Attendance to early childhood education																
No	59.1	479	12.3	3424	87.7	0.43	423	12	3213	88.4	<0.001	56	21	211	79	0.03
Yes	40.9	341	13.6	2166	86.4		40	7.2	517	92.8		301	15.4	1649	84.6	
Toys																
Homemade																
No	48	434	14.1	2638	85.9	0.25	263	12	1887	87.8	0.29	171	18.6	751	81.4	0.21
Yes	52	388	11.5	2973	88.5		202	9.8	1865	90.2		186	14.4	1108	85.6	
Manufactured																
No	11	145	22.7	494	77.3	<0.001	124	23	417	77.1	<0.001	21	21.4	77	78.6	0.3
Yes	89	677	11.7	5116	88.3		341	9.3	3331	90.7		336	15.8	1785	84.2	
Household objects																
No	48.4	403	13.1	2668	86.9	0.49	269	13	1851	87.3	0.01	134	14.1	817	85.9	0.02
Yes	51.6	418	12.5	2940	87.5		196	9.4	1899	90.6		222	17.6	1041	82.4	
Electronic devices																
No	69.9	565	13.8	3535	86.2	0.004	381	12	2691	87.6	<0.001	184	17.9	844	82.1	0.45
Yes	30.1	258	11	2082	89		85	7.4	1065	92.6		173	14.5	1017	85.5	
Books																
0	56.2	513	15.5	2789	84.5	<0.001	339	13	2272	87	<0.001	174	25.2	517	74.8	<0.001
1 to 3	25.8	196	12.2	1409	87.8		92	10	817	89.9		104	14.9	592	85.1	
4 to 6	9.3	61	8.8	632	91.2		20	6.1	307	93.9		41	11.2	325	88.8	
7 or more	8.7	46	6	727	94		13	3.9	324	96.1		33	7.6	403	92.4	

Table 2: Number and percentage of children aged 0–59 months according to the nurturing care domains, age categories, and child developmental status - PIPAS Ceará/Brazil, 2019.

† Weighted Pearson chi square statistics (svy) were implemented to compare children who were developmentally on track (z-score ≥ -1 SD) to those who were not (z-score < -1 SD) as per the framework's variables. ‡ Weighted prevalence (svy). (a) Birth weight < 2.5 kg. (b) The age of the child was noted as the breastfeeding duration for those who were still breastfeeding at the time of the interview. (c) Children older than 6 months of age. (d) Children older than 6 months of age who had consumed at least one ultra-processed item, such as soft drinks, cookies/crackers, snack packets, or candy/lollipops/chocolate/sweets, on the day prior to the interview. (e) Do you think that it is occasionally necessary to punish, slap, and/or shout at the child in order to discipline them? (f) Number of stimulating activities, such as reading books, storytelling, singing, going out, playing, and/or drawing with the child, conducted by the caregiver or any other family member older than 15 years in the last three days. (g) PADIN, Criança Feliz, Mais Infância Ceará (Cartão Mais Infância), Cresça com seu Filho/Criança Feliz, or others

Independent variables	Child development index (Z-score ≥ -1 SD)			
	< 36 months		36-59 months	
	AOR (95% CI)	p	AOR (95% CI)	p
Level 1 - Contexts				
Head of household's employment status				
Unemployed	1.00	-	-	-
Employed/retired/pensioner	1.61 (1.16,2.23)	0.01	-	-
Income transfer programmes				
No	-	-	1.00	-
<i>Bolsa Familia</i> Conditional Cash Transfer Program/Others	-	-	0.68 (0.47,0.99)	0.04
Food insecurity^a				
No	-	-	1.00	-
Yes	-	-	0.79 (0.56,1.11)	0.17
Information about ECD from care institutions^b				
No	1.00	-	1.00	-
Yes	1.43 (1.00,2.04)	0.05	1.49 (1.11,2.01)	0.01
Level 2 - Environments				
Maternal education				
≤ 8 years	1.00	-	1.00	-
> 8 years	1.17 (0.90,1.52)	0.23	1.19 (0.84,1.69)	0.32
Nurturing care - Good health				
Low birth weight^c				
No	1.00	-	-	-
Yes	0.64 (0.42,0.97)	0.03	-	-
Nurturing care - Adequate nutrition				
Breastfeeding duration^d				
Never	-	-	1.00	-
< 3 months	-	-	3.72 (1.91,7.26)	<0.001
3-5 months	-	-	3.21 (1.74,5.93)	<0.001
6-11 months	-	-	3.73 (1.95,7.16)	<0.001
≥ 12 months	-	-	3.89 (2.25,6.72)	<0.001
Nurturing care - Security and safety				
Harsh discipline:^e slapping				
No	-	-	1.00	-
Yes	-	-	0.67 (0.48,0.94)	0.02
Nurturing care - Responsive care				
Child Health Handbook				
Have not read or does not have the handbook	1.00	-	-	-
Yes, read partially or fully	1.42 (1.13,1.77)	0.003	-	-
Engagement of caregivers in at least four stimulating activities^f				
< 4	1.00	-	1.00	-
≥ 4	1.71 (1.26,2.32)	0.001	1.80 (1.27,2.56)	0.001
≥ 2 h/day watching TV or using tablets/smartphones				
No	-	-	1.00	-
Yes	-	-	0.61 (0.44,0.84)	0.003
Participation in early childhood programmes^g				
No	-	-	1.00	-
Yes	-	-	0.62 (0.45,0.86)	0.004

Table 3 (Continued)

Independent variables	Child development index (Z-score ≥ -1 SD)			
	< 36 months		36-59 months	
	AOR (95% CI)	p	AOR (95% CI)	p
Nurturing care - Opportunities for early learning				
Toys: manufactured				
No	1.00	-	-	-
Yes	2.68 (1.97,3.66)	<0.001	-	-
Toys: household objects				
No	-	-	1.00	-
Yes	-	-	0.62 (0.41,0.92)	0.02
Books				
0	1.00	-	1.00	-
1-3	0.95 (0.70,1.29)	0.78	1.71 (1.22,2.40)	0.002
4-6	1.27 (0.66,2.45)	0.48	2.24 (1.27,3.94)	0.01
7+	2.14 (1.01,4.54)	0.049	2.71 (1.05,7.00)	0.04
Adjustment variables				
Caregiver interviewed				
Mother	1.00	-	1.00	-
Father	1.37 (0.73,2.55)	0.33	6.12 (1.59,23.6)	0.01
Grandparents	0.69 (0.41,1.14)	0.15	1.53 (0.62,3.79)	0.36
Other	0.97 (0.42,2.26)	0.94	1.57 (0.54,4.56)	0.41
Maternal age (years)				
< 20	0.87 (0.66,1.14)	0.32	1.03 (0.62,1.70)	0.92
20-34	1.00	-	1.00	-
> 34	0.90 (0.61,1.30)	0.57	0.73 (0.43,1.24)	0.24
Child's sex				
Male	1.00	-	1.00	-
Female	1.30 (1.04,1.61)	0.02	2.10 (1.36,3.24)	0.001

Table 3: Adjusted associations between contexts, environments, and nurturing care characteristics and child development - PIPAS Ceará/Brazil, 2019.

AOR: adjusted odds ratio; 95% CI: 95% confidence interval. All models were adjusted by caregiver interviewed, maternal age and child's sex. Loss of 381 individuals (n=3,846) in the model of children aged < 36 months due to missing information related to head of household's employment status (92), information about ECD from care institutions (39), maternal education (77), low birth weight (76), Child Health Handbook (19), engagement of caregivers in stimulating activities (15), toys from a store (14), books (43), maternal age (65), child's sex (1), and caregiver interviewed (1). Loss of 308 individuals (n=1,912) in the model of children aged \geq 36 months due to missing information related to income transfer programme (9), food insecurity (14), information about ECD from care institutions (31), maternal education (44), breastfeeding duration (81), harsh discipline: slapping (14), engagement of caregivers in stimulating activities (8), \geq 2 h/day watching TV or using tablets/smartphones (59), participation in early childhood programmes (18), household objects as toys (6), books (31), maternal age (54), and child's sex (2). The F-adjusted mean residual test suggested no evidence of lack of fit in the multivariate logistic regression model for children aged < 36 months (p = 0.44) or for those aged \geq 36 months (p = 0.41). (a) If the participant was worried about having no food and no money to afford more in the last 12 months. (b) Health service, school, and/or foster service. (c) Birth weight < 2.5 kg. (d) The age of the child was noted as the breastfeeding duration for those who were still breastfeeding at the time of the interview. (e) Do you think that it is occasionally necessary to punish, slap, and/or shout at the child in order to discipline them? (f) Number of stimulating activities, such as reading books, storytelling, singing, going out, playing, and/or drawing with the child, conducted by the caregiver or any other family member older than 15 years in the last three days. (g) PADIN, Criança Feliz, Mais Infância Ceará (Cartão Mais Infância), Cresça com seu Filho/Criança Feliz, or others.

holistic framework incorporating contexts, environments, and all the nurturing care domains. Recognition of the importance of ECD has been growing recently and valid instruments for assessing children's ECD outcomes, especially during the critical first 1,000 days of their lives, are necessary.⁴¹ Thus, we investigated the factors associated with the development of children aged < 36 and 36-59 months separately to provide additional knowledge on the determinants of ECD in both age groups. Interestingly, the magnitude and

predictors of favourable child development for both groups differed. Children aged < 36 months were less likely to reach their developmental milestones if they had low birth weight, but their odds ratios increased if their heads of households were employed (or retired/pensioners) and could purchase manufactured toys for them as well as if their caregiver had read the recommendations of the Child Health Handbook and engaged them in stimulating activities. In the group aged 36-59 months, the children whose caregivers received

information about ECD from care institutions and those who were breastfed, were engaged in stimulating activities, and possessed books had a higher chance of achieving their developmental milestones. By contrast, the children in this group who were enrolled in early childhood programmes, used screens for two hours or more every day, came from families that participated in income transfer programmes, and whose caregivers considered slapping a necessary disciplinary method were less likely to achieve their milestones.

Although the literature on the effects of poverty on child development is considerable, such studies mainly explore children's cognitive and educational outcomes. Poverty and low income can lead to material hardship and family stress as well as reduce parental cognitive input and spending.^{42–45} The head of household's unemployment, inability to buy manufactured toys, and participation in income transfer programmes were factors associated with low ECD scores in this study. This association can be explained by the fact that these factors indicate an unfavourable social context.¹¹ This finding is in agreement with the results of the Pelotas cohort in the south of Brazil, which indicated that socioeconomic factors are significantly more important than biological ones are in determining a child's development and cognitive ability.⁴⁶ Similarly, Correia et al.¹¹ showed a high prevalence of developmental delays among children with low socioeconomic status in a population-based cross-sectional study of 3,566 children from Ceará between 2 and 72 months of age. Our study found that children taking part in early childhood programmes were more likely to experience developmental delays as well. Importantly, our study design is not suitable for assessing the impact of such programmes, as we did not examine the type of intervention or length of time spent in the programme. A possible explanation for this result is that these programmes target children from the most socially vulnerable families, who are, therefore, less likely to meet the expected developmental milestones. Additionally, in a study that evaluated the impact of a large home visiting programme in Brazil, no significant differences between the experimental and control groups were found. The authors pointed out that the lower income levels of the families in the programme increased the vulnerability of children to poor developmental outcomes. Thus, without the programme, these children would have scored considerably lower. This finding highlights the challenges in addressing the complex social conditions of high-risk families, necessitating a comprehensive and consistent social support system.⁴⁷

Concerning the children's environments, we identified that receiving information about ECD from care institutions and reading the Child Health Handbook—an important strategy of the Ministry of Health to provide information about childcare⁴⁸—were positively associated with ECD outcomes. The handbook can

therefore help enhance caregivers' health literacy, allowing them to utilise this information to maintain and improve their children's health and development.⁴⁹ This is especially important given the fact that 87% of mothers from a nationwide sample claimed to have read the handbook, suggesting their interest in better informing themselves, but not all of them read it completely.⁴⁸ Only a few studies of caregivers' health literacy have been conducted in Brazil. A recent article evaluating health literacy among adolescent and young adult pregnant women from a low-income area of Brazil's northeast region, the same region as in our study, showed that 95% of the adolescents and 53% of the adults had inadequate health literacy.⁵⁰ This finding confirms the importance of the handbook as a health communication tool that can be used to establish a dialogue between children's caregivers and health professionals to promote and provide education on children's health.⁴⁹

In the good health domain of the Nurturing Care Framework, low birth weight was negatively associated with child development for those aged < 36 months, which is consistent with studies that have indicated worse motor and cognitive performance in children who were preterm and had a low birth weight.^{51,52} Low birth weight can be avoided through appropriate antenatal care, a universal recommendation for ensuring positive pregnancy outcomes.⁵³ Our results indicate the importance of antenatal policies and post-natal assistance as well as the implementation of services to follow ECD.⁵³ If we want to improve ECD, we should not disregard the potential of public health services to inform caregivers.

In the adequate nutrition domain, an association between breastfeeding duration and ECD could be seen in children aged 36–59 months. A body of research confirms the link between breastfeeding experience and cognitive development. Scaling up breastfeeding programmes could thus have short- and long-term effects on ECD outcomes.^{54–56} By using the stimulating items from UNICEF's MICS ECD module, we found a robust association between ECD and the variables related to the responsive care domain (e.g. stimulating activities), as shown in other studies.^{46,57,58} Longer screen time, which may reduce the child's interaction with caregivers, was negatively associated with ECD. Studies have shown that a substantial amount of screen exposure can be associated with developmental delays in young children.^{59,60} Having more books at home was positively associated with the ECD of children aged 36–59 months. This aligns with research that describes the profound developmental benefits of reading.^{58,61}

Moreover, we found that most caregivers in both groups used harsh psychological and physical disciplining methods and this was associated with lower ECD scores for children aged 36–59 months. The UNICEF report on Child Disciplinary Practices at Home analysed

data from 35 LMICs and confirmed the widespread use of violence at home—a setting where children should be provided with a secure environment and special protection. This happens because occasionally delivering physical punishment to a child is considered necessary within such societies, as shown in UNICEF's 2014 report, where the proportion of adults that physically punish their children varied from 3% (Armenia) to 82% (Swaziland).³¹ Studies in the harsh discipline field are of paramount importance to support government planning and budgeting for universal and effective child protection services as well as inform the development of evidence-based legislation, policies, and actions for violence prevention and response. In particular, meting out harsh punishment is a learned and accepted violent behaviour that is often replicated and passed onto successive generations. Concerted efforts are thus necessary for this cycle to be broken.³¹

As previously stated, this study helps fill important gaps related to the study of children's development in Brazil. The use of caregivers' reports and the collection of data during multi-vaccination campaigns were the study's major strengths. This approach enabled us to administer rapid and low-cost surveys to monitor ECD. Additionally, the use of the Nurturing Care Framework enabled comparisons with other studies that used the same framework. To improve the assessment, interpretability, and comparability of our results, we have addressed in this manuscript all the items suggested by the STROBE guidelines (Supplementary Table 8).⁶²

This study also has some limitations. First, it only included children from 16 municipalities of a single state in Brazil who had attended the 2019 vaccination campaign, thereby limiting generalisability for the state or of the Brazilian population. Second, the children from the PIPAS study had less educated mothers than those from the population of the selected municipalities (Supplementary Table 7). Including the design weight and maternal education as covariates in the analysis may have minimised the impact of the difference found between the groups of children. Third, the studied sample included more mothers as the interviewed caregivers (87.1% vs 80.5%), younger children (< 36 months, 65.6% vs 55.1%), and caregivers more engaged in stimulating activities (≥ 4 activities, 64.2% vs 60.0%) (Supplementary Table 6) than samples with missing outcome data. This indicates that the population studied may have been more concerned about health. Fourth, although the non-response rate was less than 10%¹⁸ in the validation study of the QAD-PIPAS, we failed to record the non-response rate in all the municipalities, an oversight that must be corrected in future surveys. On average, the non-response rate recorded for 13 of the studied municipalities was 9.9%; it is important to consider that if the caregivers in this group were illiterate, older, Indigenous, or spoke a minority language, their characteristics might impact the

findings of the study. Fifth, the difference in the duration of data collection could mean that in Fortaleza, where data were collected only on the vaccination campaign's D-day, there could be more children who do not regularly attend the public health system. Furthermore, the inclusion of children with disabilities may have affected the association between child development outcomes and exposure because this may have led to a higher proportion of children with developmental delays.

As the questionnaire was designed for administration during vaccination campaigns, it was not possible to include a large set of questions to assess certain exposure factors (e.g. proxy variables were selected to measure the food insecurity and harsh punishment variables). This fact can be another limitation of this study. However, this format makes it possible to carry out large-scale surveys for monitoring ECD in Brazil. In terms of measures for the predictors, another limitation was that it was not possible to include indicators for all the domains of the conceptual model, as it was defined retrospectively, after data collection.

The Nurturing Care Framework, aligning with the Sustainable Development Goals, provides a roadmap based on how children develop as well as which policies and interventions improve ECD. In this study, we identified the impact of contexts, environments, and the Nurturing Care Framework domains on the development of children living in a poor Brazilian area. A favourable socioeconomic condition, breastfeeding, absence of harsh discipline, caregivers who provide responsive care, and the provision of opportunities for early learning are the key factors that increase the likelihood of a child achieving their developmental potential, even in an upper middle-income country, such as Brazil. These findings provide an important foundation on which policies and programmes on ECD may be planned, implemented, and scaled up in Brazil and other nations with similar characteristics.

Contributors

Dr Sonia Venancio designed the data collection instruments, coordinated and supervised data collection, conceptualised and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript.

Dr Juliana Teixeira conceptualised and designed the study, carried out the analyses, drafted the initial manuscript, and reviewed and revised the manuscript.

Dr Maritsa de Bortoli designed the data collection instruments, coordinated and supervised data collection, conceptualised and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript.

Dr Regina Bernal designed the data collection instruments, coordinated and supervised data collection, conceptualised and designed the study, and critically reviewed the manuscript for important intellectual content.

All the authors approved of the final manuscript as submitted and agreed to be accountable for all aspects of the work.

Data sharing statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Declaration of interests

The authors have no conflicts of interest to disclose.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.lana.2021.100139](https://doi.org/10.1016/j.lana.2021.100139).

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