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Risk factors for cognitive, motor and language development of preterm children in the first year of life

Fatores de risco para o desenvolvimento cognitivo, motor e de linguagem ao longo do primeiro ano de vida de crianças nascidas prematuras

Júlia Vicente Hass[a], Carolina Panceri[a], Renato Soibelmann Procianoy[a], Rita de Cássia Silveira[a], Nadia Cristina Valentini[a,*]

ABSTRACT

Objective: To perform a longitudinal investigation of risk factors in premature infants' cognitive, motor, and language development.
Methods: Thirty-three preterm infants were assessed at 4, 8, and 12 months of corrected age, using the Bayley-III Scales. Parents completed questionnaires regarding development opportunities at home, parenting practices and knowledge.
Results: Significant associations were found (1) at 4-months between cognitive scores and family income, variety of stimuli, availability of toys, parenting practices and knowledge; language and parenting practices; and motor skills and parenting practices; (2) at 8-months between cognitive score and length of stay in the Neonatal Intensive Care Unit (NICU), gestational age, birth weight, toys, and parenting knowledge; language and toys; and motor skills and toys and parenting knowledge; (3) at 12-months between cognitive scores and length of stay in the NICU, family income, breastfeeding, toys, and parenting knowledge; language and income and toys; and motor scores and length of stay in the NICU, gestational age, income, stimuli, toys, and parenting knowledge. Regression analyses indicated that: for (1) cognitive development, stimulus variety explained 72% of the model variance at 4 months of age; time at the NICU explained 67 and 43% at 8 and 12 months of age, respectively, and breastfeeding time explained 41% of the model variance at 12 months; (2) for language development, family income explained 42% of the model variance at 12 months; and for motor development (3), time at the NICU explained 80% of the model variance at 12 months.
Conclusions: The development over the first year of life is not explained by the severity of birth conditions and associated morbidities only, but also by parenting practices.
Keywords: Preterm birth; Child development; Developmental disability.

RESUMO

Objetivo: Investigar longitudinalmente os fatores de risco no desenvolvimento cognitivo, motor e de linguagem de prematuros.
Métodos: Participaram 33 crianças prematuras avaliadas aos quatro, oito e 12 meses de idade corrigida, com as escalas *Bayley III*. Os pais completaram questionários referentes às oportunidades do lar, práticas e conhecimento parentais.
Resultados: Associações significantes foram encontradas: (1) aos quatro meses, entre os escores cognitivos e renda familiar, variedade de estímulos, disponibilidade de brinquedos, práticas e conhecimento parental; e linguagem e motor com conhecimento parental; (2) aos oito meses, entre os escores cognitivos e tempo de Unidade de Terapia Intensiva (UTI), idade gestacional, peso ao nascer, brinquedos e conhecimento parental; linguagem e brinquedos; e motor e brinquedos e conhecimento parental; (3) aos 12 meses, entre os escores cognitivos com o tempo de UTI, renda, meses de amamentação, brinquedos e conhecimento parental; linguagem e renda e brinquedos; e motor e idade gestacional, tempo de UTI, renda, estimulação, brinquedos e conhecimento parental. Análises de regressão indicaram que: para o desenvolvimento (1) cognitivo, a variedade de estímulos explicou 72% da variância do modelo aos quatro meses; o tempo de UTI explicou 67 e 43% aos oito e 12 meses respectivamente, e o tempo de amamentação explicou 41% da variância do modelo aos 12 meses; (2) para o desenvolvimento da linguagem, a renda familiar explicou 42% da variância do modelo aos 12 meses; e para o desenvolvimento (3) motor, o tempo de UTI explicou 80% da variância do modelo aos 12 meses.
Conclusões: O desenvolvimento no primeiro ano de vida não é explicado apenas pela gravidade ao nascer e pelas morbidades clínicas associadas, mas também pelas práticas parentais.
Palavras-chave: Nascimento prematuro; Desenvolvimento infantil; Transtornos do desenvolvimento infantil.

*Corresponding author. E-mail: nadiacv@esef.ufrgs.br (N. C. Valentini).
[a]Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.
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INTRODUCTION

Preterm births, before 37 weeks of gestation, account for 11.5% of live births in Brazil.[1] Scientific and technological advances such as assisted ventilation, steroid therapy during pregnancy, exogenous surfactant, among others, contribute to the increase in survival of these babies.[2] The preterm infant has several risk factors that can pitch in to delays and sequelae in neurodevelopment.[2] Thus, prematurity and low birth weight are known to predispose the child to developmental impairments due to the immaturity of organs and systems at birth. Low weight, prolonged hospital stay and clinical complications can result in cognitive, motor and language difficulties.[3,4] Risk factors are defined as a series of biological or environmental conditions that increase the probability of deficits in the development of a child, namely: shorter gestation lenght, low birth weight or longer hospitalization time in Intensive Care Unit (ICU).[4] Combined with clinical outcomes, the characteristics of the physical environment, lower parental education and lower family income[5] can negatively impact child development. In addition to the physical characteristics of the home (space for free movement inside and outside, type of floor, stairs, ramps), the first environment experienced by the child in early life, the interaction with parents, the variety of stimuli and the availability of toys are also critical indicators of the quality of home environment.[4,5]

At home, the opportunities for development that objects, events and places provide to the individual potential for exploratory action and learning new skills, the diversity of toys,[4] the proper arrangement of objects (furniture, ramps, stairs, smooth or rough surfaces),[3,6] interactions with people and handling of objects,[3] practices (purchasing age-appropriate toys and encouraging more independent postures and behaviors in daily routine), and parental knowledge about child development have a positive impact on neurodevelopment. For example, a home that presents opportunities to manipulate small objects (plug-in toys, forks, spoons, touching sand and dirt) encourages greater activity and exploration of the environment with the hands, which positively influence motor and cognitive skills.

Therefore, the home is the primary space for the promotion of child development[7] and has the potential to prevent future damage resulting from previously established risks,[3] especially in early childhood — a critical period of neural plasticity.[3,7] Environments that are poor in stimuli or subject to socioeconomic vulnerability, on the other hand, have been shown ineffective in promoting child development, even though this is not an isolated factor. Child development is a multifactorial process, that is, several factors jointly affect its course. Knowing these factors is essential when it comes to the development of strategies to protect infants, especially the preterm ones, as they are weakened by clinical complications and often exposed to various unfavorable environmental conditions.[3,4]

A large number of studies focus on biological factors to the detriment of investigating environmental factors,[9] which are crucial to improve children's quality of life, especially in the first years of life. Environmental factors can act as moderators of the influence of biological factors on child development. However, few studies have investigated in a longitudinal way the dynamic interrelationship between environments experienced by a child and child development.[3,10] Therefore, the main objective of this study was to perform a longitudinal evaluation of the risk factors associated with cognitive, motor and language development of children. Preterm infants born before 32 weeks of gestation, and/or whose birth weight was less than 1500g, at 4, 8 and 12 months of corrected age. The secondary objective was to detect any associations between cognitive, motor and language development. The perspective adopted in this study assumes that preterm children are part of a heterogeneous universe, and that including children with different levels of risk and complications resulting from prematurity allows an analysis of current behaviors in specific environments by means of a discrete investigation, realistic and reliable method, and also approximates the research to the real world—thus strengthening its ecological validity. The following hypotheses were established: cognitive, motor and language development of preterm infants would be negatively affected by adverse biological factors (low birth weight, shorter gestation length, and prolonged stay at the Neonatal Intensive Care Unit, NICU) and by low family income; it would be positively affected by greater opportunities for development at home and appropriate parenting practices. As secondary hypothesis, we established that positive and significant associations between preterm infants' motor, cognitive and language development would be checked for.

METHOD

The intentional sample of the study was derived from a longitudinal cohort study on the neurodevelopment of children born prematurely (between 24 and 32 weeks of gestation) and/or with a birth weight of less than 1500g. This study was approved by the Research Ethics Committee of a tertiary referral hospital for high-risk pregnancies which is also part of the Baby-Friendly Hospital initiative, the Stork Network and the Kangaroo Method. The hospital services approximately 120 children born prematurely each year, and the present investigation comprised approximately 30% of this annual sample, including only children who had undergone at least three neurodevelopmental assessments (28.33%). Among children admitted to the clinic, four (3.33%) were excluded from the sample due to congenital malformations and abnormal foot test; 35.83% for not having attended the eight-month evaluation; and 32.51% for not having attended the 12-month evaluation. The primary sample size estimation was made using G-Power for linear regression, and the outcome was one factor (cognitive or language or motor) and a maximum of seven predictors, adopting a power of 0.80 and significance of 0.05 for an effect size of 0.25, with a minimum sample size of 34 children; the sample size was also based on previous studies with similar methodological approaches.[3,5] Initially, 37 preterm infants with very low birth weight (less than 1500g) or gestational age of less than 32 weeks, who had been assessed for their development in the three predetermined moments in this study (4, 8 and 12 months of corrected age).

To assess the infants' motor, cognitive and language development, the Bayley Scales of Infant Development III (BSID-III)[11] was used at the corrected ages of 4, 8 and 12 months of age. The cognitive scale assesses aspects related to sensorimotor development, exploration and manipulation, relationships with objects, concept formation, among other aspects of cognitive processing. The motor scale, divided into fine and gross motor subtests, assesses prehension, perceptual-motor integration, motor planning and motor speed (fine), as well as limb and trunk movements and static positioning, dynamic movements including locomotion and coordination, balance and motor planning (gross). The language scale assesses receptive and expressive language and social skills, and the ability to learn speech sounds and their meanings, in addition to active interaction with the environment. Composite scores and performance categorizations were used (very superior: >130; superior: 120 to 129; high average: 110 to 119; average: 90 to 109; low average: 80 to 89; borderline: 70 to 79; extremely inferior: <70). The BSID-III was translated and adapted for the Brazilian population and evidence show its internal consistency, temporal stability, construct and convergent validities.[12] This scale is widely used in child health research in Brazil.[13]

For the evaluation of parenting practices in relation to the opportunities provided to the child for postural control in antigravity positions and exploration of movements in the environment during routine different tasks of the child in the first year of life, the Daily Activities of Infants Scale (DAIS)[14] was answered by the parents at the corrected age of 8 months of the child. The DAIS has eight domains (eating, bathing, changing clothes, holding, calm and active play, walking, and sleeping) with questions that address the position adopted by the child in each activity. In all domains, the responses are organized on a three-point ordinal scale: "A" refers to fewer opportunities (highly supportive postures — score 1); "B" refers to partial opportunities (partially supported postures — score 2); and "C" refers to the greatest opportunities (unsupported postures — score 3) for the development of antigravity postures, exploration and movement control by the child. Scores can be obtained for each subscale independently. The total DAIS score is obtained by summing the eight dimensions (0–24 points). The DAIS was translated into Portuguese and cross-culturally adapted, being used in several Brazilian studies.[3,10]

In order to analyze the quality of opportunities for child development in the home environment, the questionnaire Affordances in the Home Environment for Motor Development – Infant Scale (AHEMD-IS)[15] was used for children aged between 3 and 18 months, being answered by parents at the corrected age of 12 months of the child. The AHEMD-IS has five subscales with questions about the exterior and interior spaces of the house, the variety of stimuli, and fine and gross motor materials available for the child to play with. After applying the questionnaire, the data were introduced and sorted in a Microsoft Excel spreadsheet (AHEMD Calculator VPbeta1.5.xls) developed by the authors of the AHEMD. The AHEMD, in its version adapted to Portuguese, had its predictive validity and objectivity for Brazilian children proven by evaluators.[16]

The Knowledge of Infant Development Inventory (KIDI),[17] in its Portuguese version ("Conhecimento do Desenvolvimento Infantil"),[17] was used to assess parental knowledge about child development in the first year of life. The KIDI was filled in by the parents at 8 months of corrected age of the child. It contains 20 questions addressing specific moments of motor skill acquisition. The total score is obtained by the ratio between the number of questions answered correctly and the total number of questions answered, ranging from 0 (little knowledge) to 1 (a lot of knowledge). Evidence shows the unidimensional structure and adequate internal consistency of the Portuguese version of KIDI for Brazilian children.[17]

The age and education of parents, as well as the monthly family incomes, were reported by them. Biological data of each child were extracted from their medical records (namely gestational age [GA], birth weight, head circumference, 5th minute Apgar, days of stay in the NICU, days of mechanical ventilation, early and late sepsis, antibiotic use in the NICU, seizures in the NICU, periventricular hemorrhage, periventricular leukomalacia, neurological examination, and bronchopulmonary dysplasia). All clinical and biological variables are from the peri- and neonatal periods only.

Children's neurodevelopmental assessments (motor, cognitive and language) were conducted at corrected ages 4, 8 and 12 months. The time required for each assessment varied between 30 and 60 minutes, depending on the child's age and disposition. Other assessment tools (DAIS, AHEMD-IS, KIDI) were filled in by parents during the first year of the infants' lives: DAIS and KIDI (shortest questionnaires) at eight months and AHEMD (longer questionnaire) at 12 months, so the interviews would ot become tiring. Two professionals trained and experienced in using the questionnaires for more than three Years and who are part of the study team conducted the neurodevelopment assessments of in a quiet environment at the Neonatology Follow-up Oupatient Clinic of a tertiary hospital in southern Brazil, always in the presence of the mother and/or legal guardian. The BSID-III was applied by an evaluator and observed by a second one; both were blinded to the child' history and scored their performance independently. The rate of agreement between raters for the BSID-III scores was high (intraclass correlation coefficient=0.96). The same evaluators were responsible for applying the other instruments to parents. Evaluations were carried out on the same days of the medical appointments and, in exceptional cases, scheduled for a different day.

The study was approved by the research ethics committee of the hospital (Certificate of Presentation for Ethical Review, CAAE: 16098719300005327), and all parents signed an informed consent form.

Data were analyzed using the statistical program Statistical Package for the Social Sciences (SPSS), version 18.0. Descriptive statistics with frequency distribution, measures of central tendency and variability were used. The normality distribution of quantitative variables was verified using the Shapiro-Wilk test. Preliminary analyses were based on the Student's t test to compare neurodevelopmental scores (cognitive, motor, and language) of children with altered initial neurological examinations (altered neurological examination, leukomalacia, and periventricular hemorrhage) and those of other children. Pearson's (for continuous variables) or Spearman's (for classification variables) correlation coefficients and the chi-square test were used to analyze partial associations between neurodevelopmental scores (cognitive, motor and language) and all risk factors. Only multiple independent variables with significant p-values were added to the linear regression model. The regression effect size was estimated using the Cohen f2 criterion; a value lower than 0.15 was considered small, between 0.15 and 0.34 was considered moderate, and 0.35 or greater was considered large. The significance level adopted was 5% ($p \leq 0.05$).

RESULTS

Among the 37 children selected, two had congenital malformations (congenital myopathy and aortic stenosis) and two had an altered heel prick test. Thus, four children were excluded from the study, remainig 33 children in total. Most infants came from low-income families, none attended daycare during the first year of life, and all had their mother as their main caregiver. The children were follwed-up by a multidisciplinary team in a follow-up clinic of a public university hospital. All 37 participants were evaluated at the corrected ages of 4, 8 and 12 months in 2018. Table 1 lists the sociodemographic features of participants.

Two strategies were adopted to control intervening factors. Comparative analyses were carried out for the qualitative variables between the group of children of different categories in each variable (small for gestational age, early and late sepsis, antibiotic use, periventricular hemorrhage, periventricular leukomalacia, seizure in the NICU, altered neurological examination and bronchopulmonary dysplasia), and no significant differences were observed between neurodevelopmental scores (cognitive, motor and language) at any of the three ages (p values ranging from 0.056 to 0.977). Partial associations were conducted between all investigated risk factors and neurodevelopmental scores; non-significant associations were not considered in the regression model. These two procedures allowed the maintenance of a single group in the regression analysis and made it possible to investigate the associative phenomenon in a heterogeneous group of preterm infants, strengthening the ecological validity of the study. Table 2 shows the non-significant partial associations between cognitive, motor and language development and the intervening risk factors.

For parental knowledge, the KIDI questionnaire was used and the mean score of the children evaluated was 0.63 (standard deviation — SD=0.09). In the evaluations of parenting practices with the DAIS questionnaire, the mean score of children evaluated was 12.97 (SD=5.22). The categorization of development affordances in the home environment and the description of cognitive, language and motor performance at 4, 8 and 12 months of age are presented in Table 3. Regarding the physical space within the home, the variety of stimuli, access to fine and gross motor toys, most babies had a space considered adequate and excellent, moderately adequate and less than adequate for development, respectively, as reported by the parents. Most of the children had an average performance at 4, 8 and 12 months, but the motor scores at 12 months remained in the low average categorization.

Figure 1 shows the percentage of children with inferior (low average, borderline and extremely low), average and superior performance (high average, superior and very superior) in the cognitive (Figure 1A), language (Figure 1B) and motor (Figure 1C) domains in BSID III. The results point to an increase in the percentages of difficulties and a higher prevalence of delays at 12 months in the cognitive and motor domains, while, for language, the percentage of delays remained relatively stable.

Table 1 Demographic information of children and their families.

		n (%) or mean (SD)
Gender — n (%)	Male	23 (69.7)
Birth weight (g) — mean (SD)		1,053.4 (280.9)
Weight categorization — n (%)	Low	1 (3.0)
	Very low	18 (54.6)
	Extremely low	14 (42.4)
Gestational age in weeks — mean (SD)		28.6 (2.4)
Head circumference — mean (SD)		25.7 (2.5)
Apgar 5th minute — mean (SD)		7.5 (2.0)
NICU days — mean (SD)		70.9 (29.2)
Mechanical ventilation days — mean (SD)		5.0 (11.8)
Small for gestational age — n (%)		9 (27.3)
Early sepsis — n (%)		21 (63.6)
Late sepsis — n (%)		20 (60.6)
Antibiotic use in the NICU — n (%)		24 (72.7)
Seizures in the NICU — n (%)		5 (15.1)
Periventricular hemorrhage — n (%)	Absent	21 (63.6)
	Grade I	6 (18.2)
	Grade II	4 (12.1)
	Grade IV	2 (6.1)
Periventricular leukomalacia — in (%)		3 (9.1)
Changes in neurological examination — na (%)		6 (18.2)
Bronchopulmonary dysplasia — no (%)		6 (18.2)
Participation in intervention — n (%)	Monthly guidance for parents	15 (45.4)
	Weekly physical therapy	12 (36.4)
	No assistance	5 (15.2)
	No information	1 (3.0)
Family income (R$) — mean (SD)		2,672.1 (1,426.8)
Mother's age — mean (SD)		28.9 (6.2)
Father's age — mean (SD)		32.4 (8.6)
Mother's education — n (%)	Incomplete elementary school	5 (15.2)
	Complete elementary school	6 (18.2)
	Incomplete high school	5 (15.2)
	Complete high school	11 (33.2)
	Incomplete higher education	2 (6.1)
	Complete higher education	4 (12.1)
Father's education — n (%)	Incomplete elementary school	7 (21.2)
	Complete elementary school	3 (9.1)
	Incomplete high school	4 (12.1)
	Complete high school	17 (51.5)
	Incomplete higher education	1 (3.0)
	Complete higher education	1 (3.0)

SD: standard deviation; NICU: Neonatal Intensive Care Unit.

Table 2 Non-significant partial associations between cognitive, motor and language development scores and risk factors not added to the regression model.

Risk factors	Cognitive			Language			Motor		
	4 months	8 months	12 months	4 months	8 months	12 months	4 months	8 months	12 months
Head circumference[a]	0.40	0.47	0.51	0.16	0.27	0.23	0.73	0.30	0.06
Apgar 5th minute[a]	0.54	0.16	0.96	0.24	0.59	0.96	0.64	0.28	0.23
Mechanical ventilation days[b]	0.65	0.07	0.99	0.99	0.42	0.96	0.88	0.63	0.21
Small for gestational age[c]	0.28	0.49	0.37	0.37	0.96	0.58	0.83	0.70	0.40
Early sepsis[c]	0.58	0.44	0.84	0.20	0.53	0.32	0.86	0.24	0.58
Late sepsis[c]	0.36	0.28	0.59	0.06	0.52	0.64	0.75	0.25	0.48
Use of antibiotics[c]	0.89	0.42	0.44	0.29	0.21	0.66	0.56	0.38	0.39
Seizure[c]	0.16	0.29	0.06	0.40	0.20	0.20	0.27	0.34	0.49
Periventricular hemorrhage[c]	0.53	0.13	0.17	0.83	0.16	0.20	0.27	0.08	0.61
Periventricular leukomalacia[c]	0.33	0.38	0.12	0.19	0.08	0.21	0.09	0.29	0.44
Neurological exam[c]	0.71	0.95	0.81	0.29	0.62	0.98	0.94	0.62	0.77
bronchopulmonary Dysplasia[c]	0.06	0.27	0.61	0.43	0.70	0.79	0.48	0.23	0.40
Participation in intervention[c]	0.28	0.79	0.39	0.18	0.45	0.47	0.21	0.37	0.82
Mother's age[a]	0.36	0.54	0.45	0.17	0.58	0.45	0.48	0.32	0.38
Father's age[a]	0.43	0.20	0.27	0.27	0.64	0.27	0.61	0.25	0.80
Mother's education[c]	0.67	0.25	0.53	0.11	0.31	0.25	0.70	0.42	0.75
Father's education[c]	0.34	0.77	0.43	0.07	0.38	0.51	0.41	0.24	0.06

Values presented as: [a]Pearson's correlation, [b]Spearman's correlation (p); [c]chi-square test (p).

Table 3 Affordances in the home environment for development and cognitive, motor and language development.

AHEMD-IS	Affordances in the home environment for development			
	Physical space	Variety of stimuli	Toys	
			Fine motor skills	Gross motor skills
Less than adequate — n (%)	5 (15.2)	3 (9.1)	9 (27.3)	12 (36.4)
Moderately adequate — n (%)	31 (33.3)	6 (18.2)	1 (3.0)	6 (18.2)
Adequate — n (%)	13 (39.4)	8 (24.2)	12 (36.4)	8 (24.2)
Excellent — n (%)	4 (12.1)	16 (48.5)	11 (33.3)	7 (21.2)
Gross Score — M (SD)	4.25 (1.26)	10.75 (2.06)	5.25 (1.71)	6.25 (2.63)
	BSID-III Development Scores			
BSID III	Cognitive	Language	Motor	
4 months — M (SD)	97.69 (15.27)	92.24 (9.10)	97.07 (13.28)	
8 months — M (SD)	94.58 (12.96)	93.53 (13.83)	90.25 (15.86)	
12 months — M (SD)	93.79 (18.37)	92.52 (16.17)	83.68 (18.25)	

AHEMD-IS: Affordances in the Home Environment for Motor Development - Infant Scale; BSID-III: Bayley Scale of Infant Development - Third Edition. M (SD): mean (standard deviation).

Table 4 presents the partial associations between cognitive, language and motor development and risk variables, and the results of the regression model.

Risk factors and cognitive development: significant and moderate correlations between cognitive scores and family income, variety of stimuli, availability of gross motor toys, parenting practices and parental knowledge were found at 4 months; at 8 months, time in the NICU, gestational age, birth weight, availability of fine motor toys and parental knowledge; and, at 12 months, time in the NICU, family income, months of

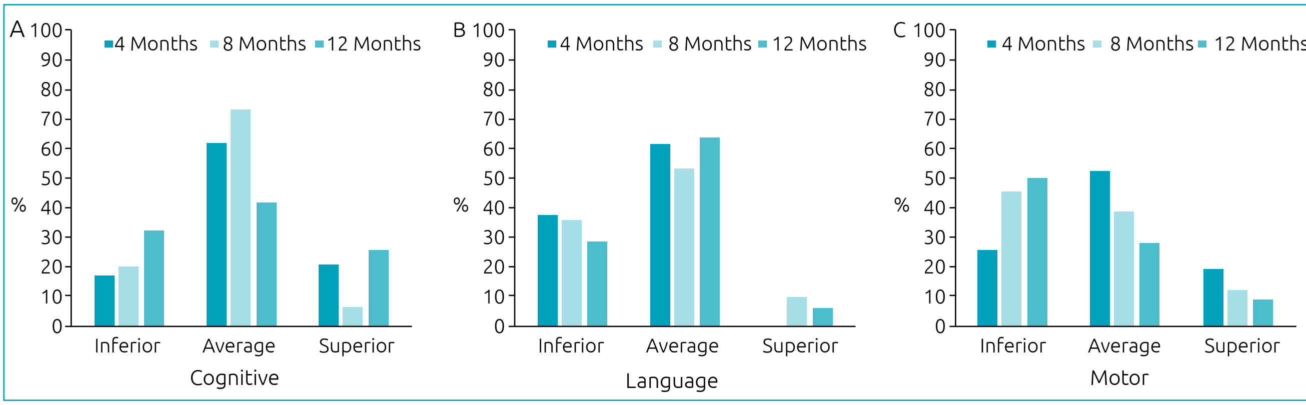

Figure 1 Percentage of children with inferior (low average, borderline and extremely low), average and superior performance (high average, superior and very superior) in the cognitive (A), language (B) and motor (C) domains according to BSID-III.

breastfeeding, availability of fine motor toys, and parental knowledge. The regression models were significant at 4, 8, and 12 months, which means that the variety of stimuli explained 72% of the model's variance at 4 months and time in NICU explained 67 and 43% at 8 and 12 months of age, respectively. Furthermore, the duration of breastfeeding explained 41% of the model variance at 12 months of age.

Risk factors and language development: significant and moderate correlations between language scores and parental knowledge were found at 4 months of age; at 8 months, they were related to the availability of fine and gross motor toys; and, at 12 months, to family income and availability of fine and gross motor toys. The regression model was significant at 8 and 12 months and showed that family income explained 42% of the model variance at 12 months. At 8 months, no variable remained significant at the end of the model.

Risk factors and motor development: significant and moderate correlations between motor scores and parental knowledge were found at 4 months of age; at the age of 8 months, it was related to the availability of fine motor toys and parental knowledge; and, at 12 months ofage, with gestational age, time in NICU, family income, variety of stimuli, availability of fine and gross motor toys, and parental knowledge. The regression model was significant at 8 and 12 months and pointed to 80% of the model variance at 12 months being expalined by the time in NICU. At 8 months, no variable remained significant at the end of the model.

Among the motor and cognitive scores, significant, positive and moderate correlations were found at 4 months of age ($r=0.56$; $p\leq0.0001$) and strong correlations at 8 ($r=0.77$; $p\leq0.001$) and 12 months of age ($r=0.76$; $p\leq0.001$). Significant, positive and moderate to strong correlations were found between motor and language scores at 4 months ($r=0.63$; $p\leq0.001$), 8 months ($r=0.54$; $p=0.002$) and 12 months of age ($r=0 .56$; $p\leq0.0001$). Significant, positive and strong correlations were identified at 4 months ($r=0.71$; $p\leq0.001$) between the cognitive and language scores, and moderate correlations at 8 ($r=0.46$; $p=0.010$) and 12 months ($r=0.51$; $p=0.003$).

DISCUSSION

Our study aimed to verify the risk factors associated with cognitive, motor and language development in preterm infants and the associations between cognitive, motor and language development at three different momentos. Time in the NICU was the predictor most frequently associated with neurodevelopment in preterm infants—at 8 and 12 months with cognitive development and at 12 months with motor development. However, environmental variables during the first year of life were also relevant: variety of stimuli at 4 months for cognitive development, months of breastfeeding at 12 months for cognitive development and family income at 12 months for language. Regarding the associations between motor, cognitive and language development, the results show longitudinal interdependence of the domains.

A longer stay in the NICU and a lower gestational age were associated with lower cognitive and motor scores in the first year of life, while low weight was associated with motor development. Time in the NICU was shown to be inversely associated with cognitive and motor development, being a significant predictor in the regression model. The time that infants spend in the NICU reflects the severity of their morbidities and a greater number of necessary clinical interventions, often associated with lower gestational age and lower birth weight.

With their stay in the ICU, these infants experience deprivation of adequate sensory stimuli that are essential for the maturation of systems, with limited interactions and long stays in positions of low demand for postural control, compromising

Table 4 Significant partial associations between cognitive, motor and language development and risk factors.

BSID-III outcome	Age (months)	Regression model variables	Pearson (p) or chi-square (p)	Regression
Cognitive score	4	Family income (R$)	r=0.41 (0.034)	R^2=0.70. f^2=2.33### F=8.26. p=0.001 Variety of stimuli: β=0.72. p≤0.001
		Variety of stimuli	r=0.37 (0.048)	
		Toys: broad motor skills	r=0.40 (0.030)	
		Parenting practices	r=0.44 (0.020)	
		Parental knowledge	r=0.55 (0.003)	
	8	Time in NICU (days)	r=-0.61 (0.001)	R^2=0.58. f^2=1.38### F=5.51. p=0.002 Time in NICU: β=-0.67. p=0.015
		Gestational age (weeks)	r=0.44 (0.014)	
		Birth weight (g)	r=0.44 (0.014)	
		Toys: fine motor skills	r=0.44 (0.015)	
		Parental knowledge	r=0.51 (0.008)	
	12	Time in NICU (days)	r=-0.37 (0.041)	R^2=0.55. f^2=1.22### F=4.53. p=0.008 Time in NICU: β=-0.43. p=0.035 Months of breastfeeding: β=0.41. p=0.020
		Family income (R$)	r=0.49 (0.007)	
		Months of breastfeeding	r=0.44 (0.015)	
		Toys: fine motor skills	r=0.40 (0.027)	
		Parental knowledge	r=0.48 (0.013)	
Language score	4	Parental knowledge	r=0.52 (0.007)	-----
	8	Toys: fine motor skills	r=0.42 (0.020)	R^2=0.20. f^2=0.25## F=3.38. p=0.049 Non-significant predictors
		Toys: broad motor skills	r=0.41 (0.025)	
	12	Family income (R$)	r=0.58 (0.002)	R^2=0.38. f^2=0.61### F=5.16. p=0.006 Family income: β=0.42. p=0.028
		Toys: fine motor skills	r=0.50 (0.005)	
		Toys: broad motor skills	r=0.46 (0.010)	
Motor score	4	Parental knowledge	r=0.39 (0.049)	-----
	8	Toys: fine motor skills	r=0.44 (0.016)	R^2=0.30. f^2=0.43### F=4.99. p=0.016 Non-significant predictors
		Parental knowledge	r=0.46 (0.017)	
	12	Gestational age (weeks)	r=0.36 (0.045)	R^2=0.62. f^2=1.63### F=3.71. p=0.014 Time in NICU: β=-0.80. p=0.012
		Time in NICU (days)	r=-0.57 (0.001)	
		Family income (R$)	r=0.45 (0.015)	
		Variety of stimuli	r=0.41 (0.022)	
		Toys: fine motor skills	r=0.48 (0.007)	
		Toys: broad motor skills	r=0.41 (0.021)	
		Parental knowledge	r=0.54 (0.005)	

BSID-III: Bayley Scale of Infant Development - Third Edition; R: Pearson's correlation; R2: coefficient of determination of regression analysis; the regression effect size was estimated using Cohen f^2; value less than 0.15 was considered small#, between 0.15 and 0.34, moderate##, and equal to or greater than 0.35, large###; β: beta coefficient; F: result of analysis of variance for the regression model.

neural development and, consequently, cognitive and motor skills.[18] Our results emphasize that the environment of a NICU is a risk factor for the subsequent behavior of preterm children,[13,25] corroborating previous studies.[19,20]

Prematurity and low birth weight have been identified as two of the risk factors most strongly associated with developmental delays in the first year of life due to different clinical outcomes. When these health complications are added to the deprivation of essential stimuli as a result of the ICU stay, as observed in the present study, negative repercussions reach a global dimension and affect different spheres of development, which explains the results of this research. Considering that child development begins in the intrauterine life and involves several aspects such as neurological maturation and physical growth, the greater the number of negative biological complications established at the beginning of the process, the greater the susceptibility of he infant and the greater the difficulties they will have to overcome. Thus, as these infants return home, more stimulation of fine and gross motor skills, materials and spaces for playing and musical games will be necessary to help them compensate the restricted opportunities in the NICU.

In this investigation, variables related to the household setting—family income, variety of stimuli, availability of fine and gross motor toys, parenting practices and knowledge, and breastfeeding—were associated and had their relevant roles for cognitive, motor and language development alternated in the first year of life. Family income, variety of stimuli, and months of breastfeeding were the strongest predictors of neurodevelopment.

When it comes to family income, preterm children from more economically deprived families had lower cognitive, language and motor performance scores, similarly to what previous studies have shown.[19] Poverty and its resulting problems are among the main risk factors for well-being and the development of children of different ages.[5,6] Less access to toys and less stimuli at home are among the problems resulting from lower incomes,[3,4,6,8] as observed in our study.

The variety of stimuli in interactions with family members, body play,[6] the organization of physical structures in the environment and its surroundings that facilitate the child's exploratory movements and playing on the floor,[20] and the availability of toys[6,20] are crucial in the development process to enhance experiences and resulting benefits. A rich environment optimizes developmental potential.[4] The environment is even more relevant for at-risk children, including preterm children. Their developmental outcome is strongly influenced by the quality and diversity of experiences and stimulating interactions with family members.[3,4]

This study makes progress when it comes to previous ones by showing partial relationships between parental knowledge and cognitive, motor and language development of preterm children. The results suggest that prolonged hospital stays and severe adverse clinical outcomes, which may have negative future repercussions, seem to be compensated by parental knowledge to some extent, for undesired effects on development. These parents, even in the face of the adversities of prematurity and socioeconomic vulnerability, organized and adapted their environment to enrich exploration opportunities, positively influencing their children's development, which would explain the partial relationships in this study.

Our results are in line with previous studies conducted in Brazil and in other countries, which report that parents with greater knowledge about child development, which ususally results from higher levels of education, perceive themselves as more responsible for their children's development, so they model behaviors, interact more frequently in conversation and guidance, and provide children with greater social opportunities. These actions combined promote effective development.[21,22]

The results related to duration of breastfeeding — one of the predictors of cognitive development at 12 months — are in line with those of previous results.[22,23] Two biological mechanisms seem to influence this process. First, the daily approximation of skin-to-skin contact between mother and child stimulates the production of prolactin and oxytocin, which can indirectly affect development;[24] secondly, the quality of breast milk is superior.[23] The positive effects of breastfeeding on cognitive development are more evident in children with greater delays and in populations with greater economic disparities, reducing several health risks among these children;[23] therefore, promoting breastfeeding from the NICU should be a goal for the development of premature.

Factors associated with cognitive development transitioned from environmental to biological risk factors over time. Initially, at 4 months of age, opportunities for stimulation within the home explained, with a large effect size, the variation in cognitive development. Brain growth and development are influenced by children's sensory enrichment experiences; this opportunity for stimuli can even change its structure and functionality.[18] The more compromised the child, the greater the intervention of the context to compensate for delays, since, at 8 months of age, the adverse consequences of prematurity with clinical complications that led the child to stay in the NICU[20] are inversely and robustly associated with cognitive development. Premature children are born with immature brains, which did not reach the ideal size and adequate neuronal development,[21] so they are more vulnerable to brain injuries because of immaturity and of processes such as infections and inflammation,[18] which directly impact cognition. In addition, during hospitalization, they are deprived of sensory stimuli essential for the maturation of the systems. With increasing age, the child's demands for interaction with the environment increase, and the resources available to them will be required in more complex tasks; their clinical restrictions can limit the experiences of exploration in the environment, negatively affecting their cognitive development. It is noteworthy, therefore, that the family and the opportunities of the environment become fundamental so that the care offered to the child in the first year of life is enriched and has an impact on cognitive benefits.[3]

As for language, family income was a determining factor for its development, although partial associations with parental knowledge and the availability of fine and gross motor toys at 4 and 8 months of age have been observed. In previous studies with preterm children,[14,19] socioeconomic factors were also more strongly associated with language scores than adverse clinical outcomes of prematurity, similarly to the results of our study. Language development is closely related to exposure opportunities and social interaction, parental education and care provided by caregivers. All these factors are directly related to higher family income, and our study confirms these results with the partial associations and the main prediction analysis.

We also emphasize that most studies that relate language development to prematurity risk factors report more evident difficulties from 24 months of age onwards.[18] We understand that, with younger children, it may be more difficult to observe these relationships by the difficulty in assessing more sophisticated language skills; however, an effort is needed to detect language difficulties earlier, as the window of opportunity for language learning—the period when it is easier to learn language skills at higher levels—peaks around 11 months of age thanks to the greater number of new synapses for language acquisition.

Regarding motor development, parental knowledge and the availability of toys were essential at the beginning of development, but these factors were only seen in partial relationships. With advancing age, for the initial risks, stay in the NICU was the only predictor to remain in the model, negatively explaining motor development and presenting a high effect size. Broad motor skills in higher postures — which require antigravity control[3] — begin to be required at the end of the first year of life. Premature children with adverse clinical outcomes that restrict their mobility have slower motor development, with different rates of progression and lower quality in postural control and antigravity movements,[25] including independent walking.[26]

We also verified strong correlations between the three evaluated domains — cognitive, motor and language —, corroborating previous studies.[19] Child development, especially in the first year of life, occurs interdependently: one domain influences and is influenced by another. Regarding delays, we found an increase in percentages at 12 months of age for the cognitive and motor domains. A plausible explanation can be understood by the difficulties in early diagnosing more subtle delays. Previous studies have already shown that preterm babies, when severe brain injuries are absent, tend to show delays throughout the first year of life, often with late diagnoses due to the subtlety of the difficulties presented.[18]

This investigation brings progress to the current body of studies by highlighting the importance of parenting practices in promoting cognitive development of preterm infants in their first year of life. It is noteworthy that the sample size of this research is small, although adequate for the methodological procedures applied and based on previous studies. We suggest further investigating these associations in large-scale studies with control for biological factors present in children's first year of life (diseases, hospitalizations, surgeries) — a limitation of the present study. It was not possible to verify whether the answers provided by the parents in the AHEMD-IS represented the reality of each household, which can also be considered a limitation of this investigation; previous studies[10-12,14,15] follow the same protocol, assuming that parents are reliable in assessing the environment in which they live.

In conclusion, considering the motor trajectories of the preterm infant, as well as the uniqueness of each case of prematurity, investigating risk factors in the first year of life is essential to provide the necessary information for intervention strategies that can compensate for delays. Thus, interaction with the main caregiver was able to minimize the effects of biological vulnerability and boosted these processes. In addition, the study shows that although the lenght of stay in the ICU does not seem to have a negative influence on the first months of life (period with preponderance of reflexes), it does impact negatively the acquisition of gross motor skills at 12 months of age. Early motor intervention can help these children and prevent these difficulties. Educational programs for parents are necessary in order to prevent the long-term effects of previously established risks and, therefore, are a recommendation for future studies.

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Conflict of interests

The authors declare there is no conflict of interests.

Authors' contributions

Study design: Hass JV, Valentini NC, Procianoy RS, Silveira RC. *Data collection:* Hass JV, Panceri C. *Data analysis:* Hass JV, Panceri C, Valentini NC. *Manuscript writing:* Hass JV, Valentini NC. *Manuscript revision:* Hass JV, Panceri C, Valentini NC, Procianoy RS, Silveira RC. *Study supervision:* Valentini NC, Procianoy RS.

Declaration

The database that originated the article is available with the corresponding author.

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