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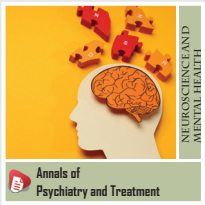

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Research Article

Assessment of Cognitive and Psychomotor Development in Infants in Kaffrine (Senegal): The Contribution of the BSID IV Test and the Influence of Nutritional and Family Factors

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Abstract

Introduction: The early years of life, a critical period known as the 'first 1,000 days', shape an individual's future intellectual, emotional and social abilities. In Senegal, few studies have explored the combined influence of nutritional and socio-familial factors on cognitive development. We report here the first use of the Bayley Scales of Infant Development (BSID) for the assessment of neurocognitive development in infants in Senegal.

Methods: We conducted a prospective study in Kaffrine (Senegal), a region characterised by a high prevalence of malnutrition. The infants included in the study were assessed using the BSID-IV to measure cognitive and motor performance. The family environment was assessed using the HOME questionnaire and feeding practices using the IYCF questionnaire. Associations between developmental scores, nutritional factors and socio-familial factors were analysed using bivariate tests.

Results: The study involved 27 infants aged between 11 and 13 months (sex ratio = 1.25:1). The results show that the duration and exclusivity of breastfeeding were significantly associated with higher cognitive scores ($p < 0.05$). Children from households with a stable family structure and an environment rich in interaction did not appear to perform better.

Conclusion: This study demonstrates the crucial importance of nutritional factors on cognition and psychomotor skills. These findings highlight the need to strengthen public health interventions aimed at improving both child nutrition and the quality of the family environment, particularly in highly vulnerable regions such as Kaffrine.

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Abbreviations

HOME: Home Observation for Measurement of the Environment; IYCF: Infant and Young Child Feeding; BSID-IV: Bayley Scale of Infant Development IV

Introduction

A child's cognitive and psychomotor development is the result of dynamic interactions between genetic factors, intrauterine conditions and the postnatal environment. The early years of life, particularly the critical period of the 'first 1,000 days' [1], represent a window of vulnerability and opportunity during which essential stages of brain maturation, synaptogenesis and myelination take place. Harmonious development during this period determines academic success, social skills, mental health and socio-economic prospects in adulthood [2,3].

Nutrition is a key determinant of this process. The quality and quantity of nutrient intake directly influence brain growth and the development of cognitive functions [4]. However, malnutrition, which remains common in low- and middle-income countries, significantly impairs psychomotor and cognitive development. In sub-Saharan Africa, nearly 90 million children under the age of five are affected by this issue [5]. In Senegal, acute malnutrition affects around 8% of children in this age group, with significant regional disparities. The Kaffrine region, one of the poorest in the country, remains particularly vulnerable, according to national nutrition and demographic surveys. In 2022, the highest prevalence rate of chronic malnutrition among children aged 0–59 months in Senegal was recorded there. It was 26%, compared with 18.3% nationally.

Beyond nutritional determinants, the socio-familial environment also has a decisive influence on a child's development. The quality of emotional interactions, cognitive stimulation, the stability of the family environment and the availability of play materials are all factors that shape developmental outcomes [6]. However, most existing studies have examined the influence of feeding practices and that of the family environment separately, without sufficiently exploring their interactions.

In this context, it appears essential to document the links between nutrition, the family environment and child development in Senegal. This study, conducted in the Kaffrine region, aimed to assess the combined impact of these factors on the cognitive and psychomotor development of infants. It also introduces a major methodological innovation: the use, for the first time in Senegal, of the Bayley Scale of Infant Development (BSID), an international benchmark tool for neurodevelopmental assessment in early childhood.

Materials and methods

Study design and population

This is a prospective cohort study conducted in the Kaffrine department between 1 June 2021 and 30 September 2024. As part of the global project 'Action against malnutrition and stunting' in three countries (Senegal, India, Indonesia), 500 pregnant women were included. They were distributed across the various municipalities of Kaffrine in proportion to the size of the population. Representativeness was thus ensured. They were monitored regularly throughout their pregnancy. The babies were monitored until the age of 2. One in ten of them underwent a cognitive assessment using the cognition subscale of the Bayley IV, yielding a sample of 27 infants.

The primary objectives of this global program are to investigate, map, and mitigate the overlapping biological, dietary, and socio-environmental drivers of maternal undernutrition and early childhood growth faltering (stunting) during the critical "first 1,000 days" window.

Inclusion criteria

The study included all infants aged 11 to 13 months whose mothers were already participating in the research project and who had undergone a cognitive assessment using the cognition subscale of the Bayley Scale IV.

Exclusion criteria

Children with incomplete data were excluded from the study.

Data collection

Local teams of investigators, specifically pre-school teachers selected for the cognition and education team, underwent rigorous standardised training to administer the various assessment tools. To ensure high inter-rater reliability and scoring consistency across the team, this training phase was immediately followed by a practical pre-test evaluation and strict on-site field supervision throughout the data collection period.

A detailed neurodevelopmental assessment was carried out on infants aged 11 to 13 months using the international benchmark tool, the Bayley Scales of Infant and Toddler Development, Fourth Edition (BSID-IV). While the complete BSID-IV instrument evaluates multiple areas of early development across three primary domains (the cognitive, language, and motor scales), only the cognitive subscale was administered and included in the current statistical analyses. This specific subscale comprises a total of 73 items; in accordance with the standardised testing guidelines for the 11- to 13-month age group, the evaluation commenced at item 19 for all infants in the study cohort.

A monthly assessment of breastfeeding practices (breastfeeding or not, age at which complementary feeding began, foods used for complementary feeding) was carried out using the Infant and Young Child Feeding (IYCF) questionnaire during the first six months of life.

An assessment of the socio-familial environment was carried out using the HOME (Home Observation Measurement of the Environment) questionnaire. All questions are binary (Yes or No). A 'Yes' response indicates that the family is awarded 1

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point for exhibiting the behaviour considered positive. A 'No' response indicates that no points (0) are awarded. The number of 'Yes' responses is totalled to obtain a score. The maximum score is 48 points.

For the specific item evaluating whether the interior play environment was "free from hazards," compliance ("Yes") was strictly defined based on standardised HOME inventory criteria. A household met this safety threshold if the immediate floor space and low surfaces accessible to a crawling or newly walking infant were entirely clear of visible physical dangers. This included the total absence of exposed electrical wiring, small choking objects, sharp edges or unsecured furniture, and accessible household chemicals/medicines. The safe placement of active cooking stoves or heaters was monitored as a separate, complementary variable within this safety framework.

Statistical analysis

Data analysis was performed using IBM SPSS Statistics version 26. Quantitative variables were analysed descriptively by calculating the mean and standard deviation, while qualitative variables were expressed using absolute and relative frequencies (percentages). Bivariate analyses were performed using chi-square tests for categorical associations, and independent samples t-tests (and ANOVA) were utilised to compare mean developmental scores across groups. Because chronological age within the 11 to 13-month window was significantly associated with raw cognitive scores, linear regression models were utilised to assess the independent impacts of nutritional practices and family environment scores while statistically controlling for infant age as a continuous covariate. An association was considered statistically significant when the p-value was less than 0.05.

Ethical considerations

This study was conducted in strict compliance with international ethical standards for research involving human subjects. Formal informed consent was voluntarily obtained from the mothers of all participating infants after the core objectives, risks, and benefits of the project were thoroughly explained by the maternity ward staff. The National Ethics Committee of Senegal officially granted administrative authorisation and general ethical approval for this research under reference number SEN19/78, dated December 31, 2019.

Results

Socio-demographic data

A total of 27 infants aged between 11 and 13 months and 15 days underwent cognitive assessment using the Bayley Scale 4. Females accounted for 56% of the sample, with a sex ratio of 1.25:1. Thirteen of these children lived in rural areas, representing 48%. Housewives constituted the largest group among caregivers, followed by shopkeepers (Table 1).

Assessment of the family environment

Six infants aged between 11 and 13 months, who were tested using the Bayley 4, were given the Home Observation Measurement of the Environment (HOME) questionnaire. The sample was divided into three categories based on the number of points obtained: low scores (0 to 16 points), intermediate scores (17 to 32 points) and high scores (33 to 48 points). The scores obtained in our study ranged from 26 to 44, with a mean score of 35 ± 6.782. The median score was also 35.

Table 1: Average HOME scores by sociodemographic characteristics.

Variable	Sample size	Average score	Significance of the correlation
Age			
11 months 12 months	2 3	32 38	p=0,118
13 months	1	32	
Gender			
Female	4	36	p=0,332
Male	2	33	
Area of residence			
Rural	3	31,3	p=0,108
Urban	3	38,7	
Caregiver's occupation			
Housewife Unemployed	3 2	31,3 42	p=0,215
Government service	1	32	

The mother was the primary caregiver for all the children. The father was present during half of the observations. Three of the primary caregivers were housewives, two were unemployed, and one worked in a government department.

Half of the children lived in rural areas, and the majority (67%) were girls. The mean score was 31.33 ± 6.110 in rural areas and 38.67 ± 6.110 in urban areas. This difference was not statistically significant (p=0.108).

Boys had an average score of 33 ± 9.899 compared with 36 ± 6.325 for girls (p=0.332).

- Emotional and verbal responsiveness: We observed that the caregivers generally had good communicative interactions with the infants. Vocalisations were spontaneous, and their voices were audible and clear. The caregivers displayed affectionate behaviour towards the children. All the mothers tended to smile and laugh with the infant. They engaged in positive physical interactions (hugs, caresses, etc.)

- Use of restrictions and punishment: The majority of carers resorted to negative verbal or physical interactions in response to the child's behaviour. Half reported using physical punishment in the previous week.

- Promotion of child development: Caregivers promote development by maintaining their focus on the infant and encouraging their progress. Two mothers considered that their behaviour had no impact on that of their child.

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- Organisation of the physical and temporal environment: Most children (67%) were looked after by another child under the age of 12 when the primary carer was absent. The homes were mostly clean, tidy, well-lit and well-ventilated. Play areas inside the home were free from hazards in 67% of households, but the cooker or stove was not often kept in a place that was safe for the child. All children were regularly taken to a health centre to be weighed or vaccinated.

- Provision of appropriate play materials: Generally speaking, the children did not have toys suitable for their age, nor toys that encouraged gross motor skills. Caregivers also did not engage the children in interesting activities throughout the duration of the visits.

- Opportunities for varied daily stimulation: Households did not have any stimulating materials (magazines, newspapers or books). Overall, the children shared at least one meal a day with both parents. They all received visits from relatives or friends at least once a month.

- Child hygiene: All the children were clean and odour-free, with clean hair and clothes.

The results of the simple linear regression test show that the correlation between HOME and BSID IV scores is very weak.

Feeding practices during the first 6 months

The IYCF questionnaire was completed every month during the first 6 months of life. All the children surveyed were breastfed. The foods most frequently introduced during the first 6 months were water and infant formula. (Table 2) Of the 26 children who received the questionnaire, only 8 were exclusively breastfed during the first six months, representing 30.8%. Eighteen children were introduced to complementary foods before the age of six months, such as plain water, infant formula, etc.

For the majority of children, the introduction of solid foods began in the first month of life. Four of the 12 boys who received the questionnaire were exclusively breastfed for six months, representing 33%. Among girls, 28.6% were exclusively breastfed. Only 17% of infants in rural areas were exclusively breastfed, compared with 42.9% in urban areas.

Table 2: Foods used for complementary feeding before 6 months.

Food used for weaning	Number of children concerned	Proportions
Plain water	12	66,7%
Infant formula	4	22,2%
Yoghurt	2	11,1%
SRO	1	5,6%
Egg	1	5,6%
Powdered/tinned milk	1	5,6%
Branded baby food (Bledina, etc.)	1	5,6%
Pumpkin, carrot, potato	1	5,6%
Juice	1	5,6%
Vitamines or medicine drops	1	5,6%
Clear broth	1	5,6%

Cognitive assessment

Raw scores on the BSID-IV cognitive subscale ranged from 54 to 81, with an overall sample mean score of 65.17 ± 10.420 (median = 62).

As expected with raw developmental metrics, chronological age was significantly associated with baseline cognitive performance ($p = 0.045$). Older infants demonstrated higher raw scores, with a mean of 75.2 ± 6.989 for infants aged 13 months to 13 months and 15 days, compared to 66.2 ± 9.474 for those aged 12 months, and 62.5 ± 8.963 for the youngest cohort aged 11 months. No statistically significant differences in mean raw cognitive scores were observed based on gender ($p = 0.113$) or geographical area (rural versus urban, $p = 0.175$).

Infants whose caregiver was a salesperson had the highest mean cognitive score, namely 83.3 ± 14.012. In contrast, infants whose mothers were not in employment had the lowest mean cognitive score (64.61 ± 9.230)

Bivariate analysis

Impact of the family environment

After adjusting for infant chronological age within the linear regression model, the correlation between the total HOME score and the BSID-IV cognitive performance remained very weak and statistically non-significant ($R = 0.054$).

Impact of breastfeeding practices

In contrast, early nutritional habits demonstrated a robust relationship with cognitive outcomes that persisted after controlling for age. The mean raw score on the BSID-IV was higher among children who had been exclusively breastfed during their first six months of life compared to those who were not (69.75 ± 14.665 versus 66.22 ± 9.693). Furthermore, a direct, statistically significant correlation was confirmed between delaying the introduction of complementary foods until the recommended age of 6 months and achieving higher subsequent cognitive scores (p less than 0.01).

Discussion

Our study aimed to assess the cognitive and psychomotor development of infants in the Kaffrine region of Senegal by analysing the combined influence of nutritional and socio-familial factors. It is notable for its pioneering use of the BSID-IV in this context. Our findings confirm the vital role of nutrition in early cognitive development. The duration and exclusivity of breastfeeding, as well as the introduction of complementary foods at the recommended age of six months, are significantly associated with better cognitive performance. All the mothers surveyed practised breastfeeding. This is in line with trends in the Senegalese population. However, the proportion of children exclusively breastfed during the first six months was relatively low (30.8%) in our study. One possible reason for this low rate in our study, given the context of Kaffrine characterised by low school enrolment, is likely to be misconceptions surrounding infant feeding (particularly regarding the practice of giving

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water to newborns and infants). Other plausible factors include the provision of advice on exclusive breastfeeding during antenatal consultations and the amount of time the mother spends with the baby, as demonstrated by the study by Gueye et al [7] in the municipality of Kaolack. Thus, the low coverage of healthcare staff in the region makes access to information difficult. In 2013, in the Kaffrine region, the ratio of women of reproductive age (WRA) per state-employed midwife was 3,895 per midwife, compared with the WHO standard of 300 WRA per state-employed midwife [8].

Contrary to our initial assumptions and numerous studies, the quality of the family environment, as measured by the HOME score, did not emerge as a significant predictor of cognitive scores. Several hypotheses may explain this unexpected result. Firstly, the small sample size (n=6) for this analysis limits the statistical power and the generalizability of this finding. Secondly, it is possible that in a context of severe nutritional deprivation, the impact of dietary deficiencies is so significant that it overshadows the beneficial effects of a stimulating family environment. We recommend a study with a larger sample size to better assess the correlation between these variables.

Conclusion

This study demonstrates the decisive influence of nutritional practices, particularly exclusive breastfeeding, on the cognitive development of infants in the Kaffrine region. Although the family environment did not show a significant impact in our limited sample, these results highlight the urgent need to strengthen early nutritional interventions in vulnerable areas. Larger studies incorporating a longitudinal approach are needed to better understand the complex interaction between nutritional and environmental factors on child development.

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