

Neuromotor and cognitive outcomes of preterm infants at three months of corrected age in a northeastern region of Brazil: A longitudinal feasibility study

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Neuromotor and cognitive outcomes of preterm infants at three months of corrected age in a northeastern region of Brazil: A longitudinal feasibility study

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Abstract

Background: Investigating the development of preterm infants is crucial for identifying the need for early intervention during a critical period of optimal neurological development. This study hypothesized that the development of premature infants living in economically vulnerable regions may be impaired in the first months of life.

Objective: To monitor the development of preterm infants residing in the northeastern region of Brazil, from admission to intensive care until three months of corrected age.

Methods: Following previous studies that support the need to investigate the development of premature infants living in economically vulnerable regions, twenty preterm infants born at less than 32 weeks of gestational age were included, with a total of 67 assessments performed. These comprised 21 Motor Optimality Score evaluations, 22 Test of Infant Motor Performance assessments, 8 Bayley III-Cognitive Subscale assessments, 8 Bayley III-Motor Subscale assessments, and 10 evaluations of mother-infant interaction using the Recorded Interaction Task.

Results: Infants exhibited low scores on the Motor Optimality Score both during hospitalization and at three months of corrected age, decreased motor performance, and motor and/or cognitive abilities below average at three months. All dyads demonstrated good interaction quality.

Conclusions: The development of preterm infants appears to be negatively affected between hospital discharge and three months of corrected age.

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Original Manuscript

Neuromotor and Cognitive Outcomes of Preterm Infants at Three Months of Corrected Age in a Northeastern Region of Brazil: A longitudinal feasibility study

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ABSTRACT

Introduction: Investigating the development of preterm infants is crucial for identifying the need for early intervention during a critical period of optimal neurological development. This study hypothesized that the development of premature infants living in economically vulnerable regions may be impaired in the first months of life.

Aim: To monitor the development of preterm infants residing in the northeastern region of Brazil, from admission to intensive care until three months of corrected age.

Methods: Following previous studies that support the need to investigate the development of premature infants living in economically vulnerable regions, twenty preterm infants born at less than 32 weeks of gestational age were included, with a total of 67 assessments performed. These comprised 21 Motor Optimality Score evaluations, 22 Test of Infant Motor Performance assessments, 8 Bayley III-Cognitive Subscale assessments, 8 Bayley III-Motor Subscale assessments, and 10 evaluations of mother-infant interaction using the Recorded Interaction Task.

Results: Infants exhibited low scores on the Motor Optimality Score both during hospitalization and at three months of corrected age, decreased motor performance, and motor and/or cognitive abilities below average at three months. All dyads demonstrated good interaction quality.

Conclusion: The development of preterm infants appears to be negatively affected between hospital discharge and three months of corrected age.

Keywords: prematurity; motor development; cognitive development; early intervention; physical therapy

INTRODUCTION

The World Health Organization defines a preterm infant (PTI) as any live-born neonate delivered before 37 weeks of gestation¹. However, studies have shown that the lower the gestational age at birth, the poorer the neurodevelopmental outcomes are compared to term-born infants. PTI are at a greater risk for experiencing delays in developmental areas, including motor skills, cognitive

abilities, language development, and behavioral or emotional disorders that may persist from childhood into adulthood²⁻⁵. In this context, early intervention plays a crucial role in promoting the development of PTI. In Brazil, these interventions start after signs of developmental delays are observed and consist of strategies and programs aimed at infants at risk for neurodevelopmental disorders, to minimize delays and foster healthier developmental trajectories^{6,7}.

Early interventions may include sensorimotor physical therapy and behavioral approaches that focus on modifying the clinical or home environment to improve outcomes. The aim is to reduce potential deficits, enhance long-term development, and optimize parent-infant interactions⁶⁻⁷. Research has shown that early intervention can improve specific outcomes for PTI and their families, including motor, cognitive, overall development, feeding, growth, and parent-child relationships⁶⁻⁷. However, in Brazil's Northeastern region, limited healthcare resources, a lack of trained personnel, and the concentration of certified early intervention services in large urban centers often result in delayed intervention⁸. In addition, there is still resistance among professionals and services to migrating from the Biomedical Model, focused on the diagnosis and treatment of diseases, to the Biopsychosocial Model to implement preventive measures for well-established risk conditions⁹, such as prematurity. Therefore, referrals to specialized services generally occur only after clear signs of developmental delay are observed^{1,10-12}. These referrals often occur after the window for screening early neuropsychomotor milestones has passed, leading to a missed opportunity for stimulation during a critical period of accelerated neurological development^{10,11}. Furthermore, Brazil lacks a single coordinating body for these programs¹³, and the public health networks, which should provide interdisciplinary and continuous care, often fail due to organizational issues. This results in limited access and inefficient services, especially in areas far from metropolitan centers¹⁴.

Given this scenario, the present study hypothesized that the development of PTI living in economically vulnerable regions may be impaired in the first months of life. Therefore, this study aimed to monitor the development of PTI residing in Northeastern Brazil, from admission to intensive care to three months of corrected age (CA).

METHOD

A systematic and rigorous process was undertaken to support the need for this study. Three prior studies were conducted:

Analysis of the ratio between preterm births and early stimulation procedures performed by the Unified Health System in the Northeastern region. This study demonstrated a ratio of less than 0.6, indicating that fewer than 16% of preterm infants born between 2018 and 2022 received early stimulation services during their first year of life.

Analysis of maternal satisfaction with participation in neonatal care during hospitalization and adherence to medical and physical therapy appointments, at a referral maternity hospital in Northeastern Brazil. This study showed that although most mothers reported high satisfaction with their involvement in their babies' care, they did not return for outpatient follow-up within the first month after hospital discharge, suggesting the impact of the sample's sociodemographic characteristics on access to health services.

*Analysis of family members' perceptions of preterm infants regarding prematurity, neurodevelopment, and intervention, at a referral maternity hospital in Northeastern Brazil*¹⁵. This study revealed limited understanding among family members regarding prematurity and the potential impact on infants' neurodevelopment, as well as the importance of early intervention, suggesting a short-term approach to healthcare.

Based on these studies, it is therefore relevant to investigate the development of preterm infants in the first months of life. This longitudinal feasibility study was conducted at a school maternity hospital *blind to reviewers*, in Northeastern Brazil.

Study Setting

The maternity is a referral center for high-risk pregnancies in the state and follows the guidelines of the Kangaroo Method¹⁶. The care is structured into three stages. The first begins during the prenatal period, with follow-up of high-risk pregnancies, and extends into neonatal care in the Neonatal Intensive Care Unit (NICU), where parents are encouraged to adopt skin-to-skin contact as soon as clinically possible. The second stage occurs in the Kangaroo Neonatal Intermediate Care Unit (KaNICU), when the neonate is clinically stable and no longer requires ventilatory support. During this phase, the mother-infant dyad is admitted together, with intensive promotion of skin-to-skin contact and direct breastfeeding. The third stage occurs after hospital discharge and consists of outpatient follow-up until the infant reaches a weight of 2,500 grams. After this stage, the infant is referred for continued follow-up at a primary healthcare unit nearest their home municipality.

Some PTI are expected to receive services from physical therapy professionals, as well as complementary services such as speech therapy, psychology, and occupational therapy during hospitalization. During the first stage, physical therapy primarily focuses on the cardiorespiratory and sensory systems. Sessions are offered one to two times per day, seven days a week. In the second stage, physical therapy expands its focus to include neuromotor system regulation techniques, while continuing care for the sensory system. Sessions are offered at least once per day, five days a week. In the third stage, the outpatient clinic offers physical therapy services two days per week, part-time, with infants scheduled for at least one session per month.

Participants

The sample was selected by convenience, and recruitment lasted for six months. Of the 45 neonates born at or before 32 weeks of gestational age, 20 were enrolled in the study, and 10 remained under follow-up until three months of corrected age (Figure 1).

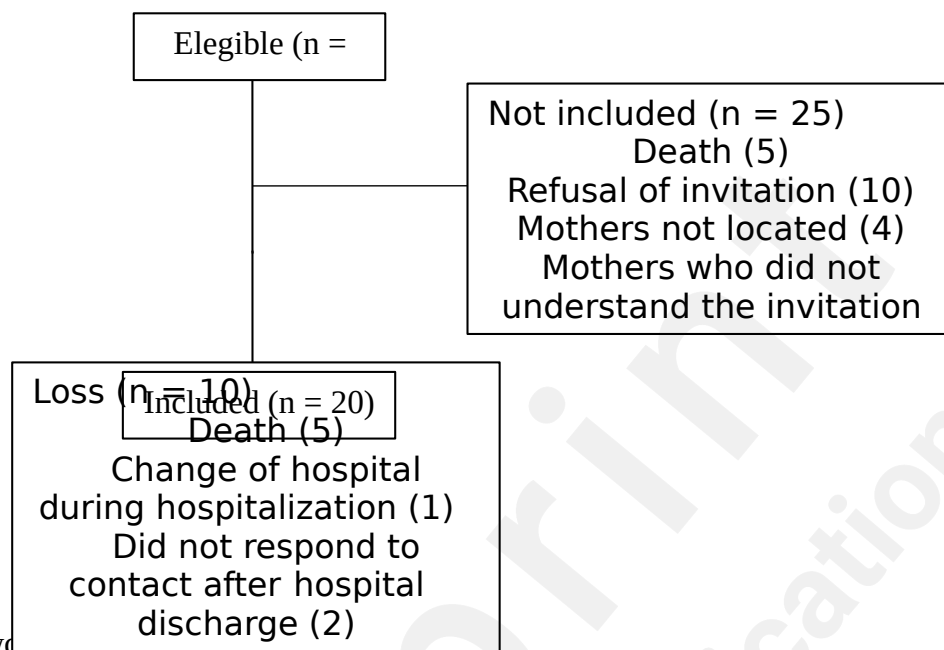
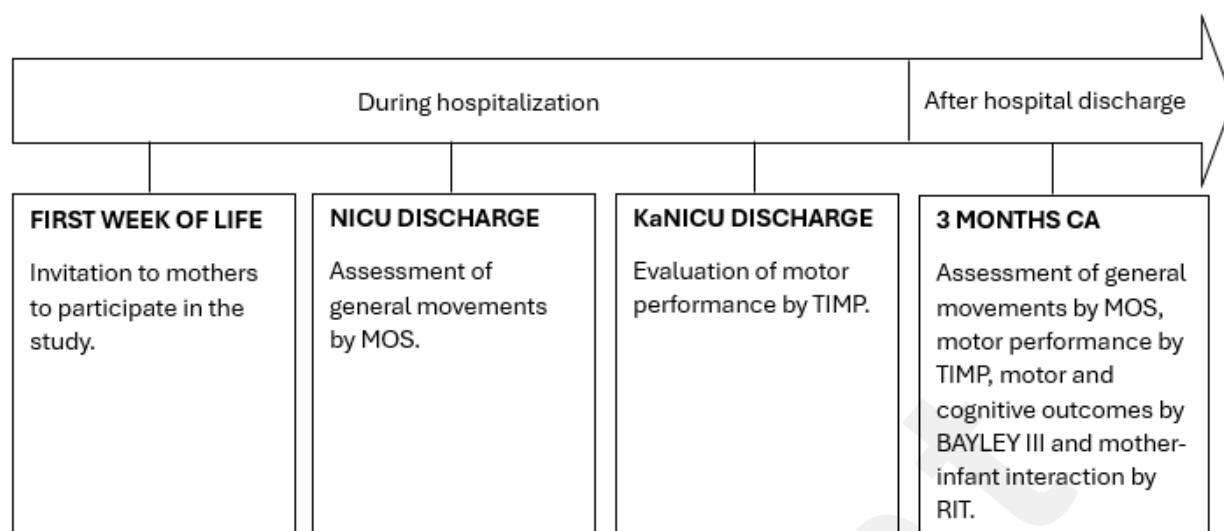


Figure 1. Flowchart of participant selection process.

Data Collection

The PTI mothers were invited to participate in the study during the first week of their infants' lives. The PTI were followed remotely, and their development was assessed in person at three points: upon discharge from the NICU, upon discharge from the KaNICU, and at three months of CA. At this corrected age, mother and child were also evaluated. Figure 2 presents a timeline outlining the instruments and corresponding assessment points. A physical therapist conducted all evaluations, and 75% of the assessments were coded by a physical therapist blinded to the newborn's clinical condition. These evaluations were recorded, and the videos were reviewed offline by a professional trained in using the assessment scales.



Notes: NICU = Neonatal Intensive Care Unit; KaNICU = Kangaroo Neonatal Intermediate Care Unit; CA = Corrected Age; MOS = Motor Optimality Score; TIMP = Test of Infant Motor Performance; BAYLEY III = Bayley Scales of Infant and Toddler Development Third Edition; RIT = Recorded Interaction Task

Figure 2. Timeline outlining the instruments and corresponding assessment points

Instruments for Developmental Assessment

Motor Optimality Score – MOS: Developed by Prechtl, this scale reliably identifies infants at risk for neuromotor impairments. It assesses the quantity and quality of spontaneous motor patterns from birth to approximately the 20th post-term week^{17,18}. A five-minute video was used to record the infants' spontaneous movements at NICU discharge and at three months of CA. At three months CA, scores below 20 indicate a high risk for cerebral palsy.

Test of Infant Motor Performance – TIMP: This validated tool is used to assess neuromotor performance in infants between 34 weeks of gestation and four months of CA. It demonstrates strong psychometric properties and high intra- and inter-rater reliability¹⁹. Assessments were conducted at hospital discharge and three months of CA. Motor performance was classified as average, low-average, below average, or far below average for age.

Bayley Scales of Infant and Toddler Development, Third Edition – BAYLEY III: Considered the gold standard for evaluating infant development, this instrument has been validated and adapted for the Brazilian population²⁰. Motor and cognitive scales were applied at three months of CA and classified as average, below average (low average and borderline), or above average (high average and well above average) for age.

Instrument for Caregiver-Infant Interaction Assessment

Recorded Interaction Task – RIT: This tool assesses caregiver-infant interaction during routine tasks, focusing on maternal and infant behaviors²¹. A video recorded the caregiver-infant bond during a diaper-changing activity at three months of corrected age. Scores below 35 suggest weakened caregiver-infant interaction and warrant further investigation.

Data Analysis

A database was created using the Statistical Package for the Social Sciences (version 20.0) to perform the statistical analysis. Descriptive analysis was conducted using means, standard deviations, and ranges for numerical variables, and frequencies and percentages for categorical variables.

Ethics Approval and Consent to Participate

This study was conducted in compliance with the principles of the Helsinki Declaration, and was approved by the *blind to reviewers* (CAEE number *blind to reviewers*). All participants signed the Free and Informed Consent Form, based on Resolution No. 466 of December 12, 2012, of the National Health Council.

RESULTS

During the study period, a total of 67 assessments were conducted: 21 MOS, 22 TIMP, 8 BAYLEY-Cognitive, 8 BAYLEY-Motor, and 10 RIT. Of the 20 PTI included in the study, 8 completed all evaluations. Table 1 presents the characteristics of the 20 PTI included in the study.

Table 1. Characteristics of the 20 PTI included in the study

Infants Characteristics	M ± SD (Min – Max) n=20
Gestational age at birth (weeks)	29.3 ± 1.7 (25.3 – 31.6)
Birth weight (grams)	1258 ± 319.1 (810 – 1850)
Apgar score at 1 minute	6.2 ± 2.0 (3.0 – 8.0)
Apgar score at 5 minutes	8.0 ± 1.0 (5.0 – 9.0)
Sex	F (%) n=20
Female	11 (55%)
Male	9 (45%)
Physical Therapy after discharge	F (%) n=10
Yes	0 (0%)
Not	10 (100%)

Notes: M = mean; SD = standard deviation; Max = maximum value; Min = minimum value; F = frequency; % = percentage; Apgar = neonatal vitality score, with scores below 4 indicating low neonatal vitality.

Table 2 presents the descriptive data from the developmental and caregiver-infant interaction assessments.

Table 2. Descriptive data

Assessments	During Hospitalization		3 months of CA
	NICU Discharge	Hospital Discharge	
MOS (n)	(n = 11)*	Ø	(n=10)
M ± SD (min – max)	24.45 ± 7.6 (9 – 34)		21,90 ± 6,2 (10 – 28)
F(%) score < 25	5 (45.5%)		6(60)
TIMP (n) – F (%)	Ø	(n = 12)	(n=10)
Average		12 (100%)	2(20)

During Hospitalization			
Assessments	low-average		4(40)
	below average		3(30)
	well below average		1(10)
3 months of CA			
BAYLEYm (n) – F (%)	Ø	Ø	(n=8)
average			4(50)
low average			4(50)
borderline			
BAYLEYc (n) – F (%)	Ø	Ø	(n=8)
average			4(50)
low average			2(25)
borderline			2(25)
RIT	(n)	Ø	(n=10)
M ± SD (min – max)			57,9 ± 12,3 (38 – 76)

Notes: CA = corrected age; NICU = Neonatal Intensive Care Unit; M = mean; SD = standard deviation; Max = maximum value; Min = minimum value; F = frequency; % = percentage; MOS = Motor Optimality Score; TIMP = Test of Infant Motor Performance; BAYLEYm = Bayley Scales of Infant and Toddler Development III – Motor subscale; BAYLEYc = Bayley Scales of Infant and Toddler Development III – Cognitive subscale; RIT = Recorded Interaction Task; * One preterm infant did not undergo MOS assessment at NICU discharge due to sedative medication use; Ø = assessment not performed at this age.

Developmental Assessments During Hospitalization

In the MOS evaluation, PTI presented scores ranging from 9 to 34, with 45.5% scoring below 25. In the TIMP assessment, all PTI (n = 12) scored within the average range for their corrected age.

Developmental Assessments at 3 Months CA

In the MOS assessment, 60% of PTI scored below 20, indicating a potential neurological deficit and the need for early intervention. In the TIMP evaluation, 80% of the infants showed a decline in motor performance compared to their scores at hospital discharge. Half of the PTI assessed with the BAYLEY III demonstrated motor and cognitive development below the average for their corrected age.

Caregiver-Infant Interaction Assessment at 3 Months CA

All caregiver-infant dyads assessed with the RIT (n = 10) scored above 35, indicating adequate caregiver-infant interaction²².

Individual Developmental Trajectories

Table 3 presents the individual developmental trajectories of the participants who completed all assessments through the end of the study.

Table 3. Individual developmental trajectories

During Hospitalization			3 months of CA			
ID	MOS	TIMP	TIMP	MOS	BAYLEYm	BAYLEYc
1	20 [#]	Average	Low-average	21 [#]	Average	Average
2	34	Average	Far below average	26	Average	Low average
3	31	Average	Below average	10 [#]	Low average	Borderline
4	18 [#]	Average	Average	25	Average	Average
5	*	Average	Low-average	28	Low average	Borderline
6	26	Average	Below average	12 [#]	Low average	Average
7	23 [#]	Average	Low-average	28	Low average	Average
8	19 [#]	Average	Below average	22 [#]	Average	Low average

Notes: ID = identification of participants who completed the study; MOS = Motor Optimality Score; TIMP = Test of Infant Motor Performance; BAYLEYm = Bayley Scales of Infant and Toddler Development III – Motor subscale; BAYLEYc = Bayley Scales of Infant and Toddler Development III – Cognitive subscale; * = not performed due to use of sedative medication; # = score suggestive of neurological deficit and need for intervention.

The data show that although all participants were discharged from the hospital with motor performance within the average range for age, as assessed by the TIMP, only two participants (ID 1 and 4) scored within the average range for both motor and cognitive development on the BAYLEY III at 3 months CA. However, one of them (ID 1) had a score suggestive of neurological deficit on the MOS and a low TIMP score. Two participants (IDs 3 and 6), although having MOS scores higher than 25 during hospitalization, exhibited scores indicative of neurological impairment at three months CA. Furthermore, seven (87.5%) participants with scores indicating neurological deficits at a corrected age of 3 months also scored below average on one or both BAYLEY III subscales (motor and/or cognitive).

DISCUSSION

Prematurity is a complex health condition that negatively impacts the development of PTI, who exhibit poorer neurodevelopment and are more likely to present delays in global developmental indicators when compared to full-term infants². Our data indicate that the motor and cognitive development of PTI, living in the Northeast region of Brazil, can be impaired in neurological and/or neurofunctional assessments, at three months of corrected age (CA).

Investigating the development of PTI is essential to identify the need for early intervention during the optimal neurological window. Therefore, the objective of this study was to monitor the development of PTI residing in Northeastern Brazil, from their stay in intensive care to three months of CA.

At NICU discharge all the PTI showed low scores, once the maximum tool range for this age group is 42 points. However, just 50% of them scored <25, that indicates risk for neuromotor impairment¹⁸. This may be related to the neurological immaturity of very preterm infants (born

before 32 weeks' gestational age)¹ and the stressful environment of intensive care hospitalization²². These two factors, inherent to prematurity, may have negatively influenced the neurological development trajectory of these infants during their stay in the NICU²³.

At discharge after KaNICU, all PTI demonstrated average motor performance for their age. This data may be attributed to the care provided in KaNICU, where the Kangaroo Method offers a biopsychosocial approach that promotes continuous skin-to-skin contact between mother and baby in the kangaroo position¹. Studies have shown that skin-to-skin contact provides numerous benefits for PTI, especially positive effects on growth and neurodevelopmental outcomes²⁴. A study by Pavlyshyn and Sarapul (2023) investigated the influence of skin-to-skin contact on pain and stress in hospitalized PTI. It was found that initially elevated levels of pain and stress hormones returned to normal after regular skin-to-skin contact, resulting in a significant reduction in dopamine and a simultaneous increase in beta-endorphin, serotonin, and oxytocin, thereby improving the infant's overall well-being²⁵. This fact is particularly relevant considering the intensive care environment is inherently stressful for PTI from their first week of life²². Other benefits of early and regular skin-to-skin contact for neurodevelopment include improved neurophysiological maturity, better sleep patterns, and increased EEG complexity²⁶⁻²⁹. Thus, neonatal care in KaNICU may be associated with favorable motor outcomes at discharge by promoting better physiological regulation and supporting development. Additionally, as expected, infants hospitalized in this unit had access to physical therapy services, which are critical in monitoring development, minimizing complications, and promoting neurosensory, motor, and behavioral development³⁰.

However, at 3 months CA, 80% of PTI showed reduced motor performance, 50% had scores suggesting neurological impairment, and 50% assessed using the BAYLEY-III were below average for their age. In the individual trajectories analyzed, even infants who scored within the average for the neurofunctional assessments showed low scores in the MOS. These findings raise concerns about the permanence of the biomedical model, centered on diagnosis, for referral to early intervention.

A cohort study that analyzed MOS scores at 3 and 4 months CA in 169 very preterm infants and their sensory-motor and cognitive outcomes at 2 years of age found that MOS ≤ 23 predicted motor and neurosensory impairments, with a strong association with cerebral palsy, motor delays, and cognitive deficits³¹. Considering this, and reviewing the PTI developmental scores at 3 months CA, we observed that all infants scored below average in at least one assessment. Even those with MOS < 23 who performed within the average range on another tool (TIMP, BAYLEYm, and/or BAYLEYc) are still at risk, as literature suggests a strong association with cerebral palsy, and motor and cognitive delays. These data, in this small sample, highlight the negative impact of the

stimulation gap from hospital discharge until 3 months CA.

It is important to note that after reaching 2500 grams, PTI in the Kangaroo Method are referred to primary healthcare services near their hometowns and should be directed to early intervention programs when needed¹⁶. However, this referral often occurs after the screening window for early neuropsychomotor milestones (3–4 months CA), thus creating a gap in stimulation during a critical period of accelerated neurological development^{10,11}. Additionally, Brazil lacks a centralized service responsible for coordinating these programs¹³. As a result, healthcare networks that are supposed to provide continuous care often fail to do so due to organizational issues within the public health system, particularly in areas far from metropolitan centers¹⁴. Consequently, PTI in lower- and middle-income regions face challenges in accessing specialized developmental follow-up, revealing a stimulation gap and a monitoring gap.

A recent review examined the effects of such post-discharge programs on motor and cognitive outcomes and reported improved developmental outcomes compared to those who did not receive intervention³². A notable point in this review is that most studies began during hospitalization and involved family-infant interaction³². A case series evaluating a transition intervention from NICU to home correlated improvements in the micro- and macrostructure of cerebral white matter with cognitive and motor problem-solving abilities over time, showing positive developmental outcomes from interventions that prevent stimulation gaps³³. Although the study by Lyne et al. (2024) did not specifically address family involvement in early intervention programs, a meta-analysis by Ferreira et al. (2020) investigated the effects of family-centered early interventions in socially at-risk PTI and included five studies that began in the hospital and continued at home³⁴. Despite the diversity in methodologies, all studies demonstrated some positive effect on cognitive and motor development in PTI³⁵. Our study also found good mother-infant interaction during routine diaper-changing activities. This data supports our hypothesis that strong dyadic interaction could contribute to positive motor and cognitive outcomes if PTI were included in early intervention programs starting during hospitalization and continuing at home, immediately after discharge.

Although this is a feasibility study, to our knowledge, it is the first to investigate the early developmental trajectory of preterm infants in low- and middle-income Brazilian regions, such as the Northeastern, offering innovative and thought-provoking data. Our findings corroborate the need for continued research and support the hypothesis that the development of preterm infants living in socioeconomically vulnerable regions may be negatively affected. Future studies with greater statistical power are necessary. Given Brazil's socioeconomic diversity, further research on early PTI development in various regions is recommended to better understand its developmental impact. As a

clinical contribution, this study may initiate a discussion on leveraging the humanized, biopsychosocial care model in KaNICU to implement home-based, continued developmental interventions. As a contribution to public health policy, this study may also prompt discussion about systematic developmental monitoring of PTI through structured assessments at various stages of care. Consequently, this could improve access, organization, and referral to early intervention programs, especially in areas distant from major metropolitan centers.

CONCLUSION

The development of premature infants was impaired between hospital discharge and three months of corrected age. Further studies with larger sample sizes are needed before generalizing these findings.

CONFLICT OF INTEREST

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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AUTHOR'S CONTRIBUTION:

Nathália de Figueiredo Silva designed the study, collected and analyzed data, and wrote the manuscript.

Carolina Daniel de Lima-Alvarez oversaw the overall coordination of the research, reviewed the study design, and revised the manuscript.

Stacey C. Dusing oversaw the overall coordination of the research, reviewed the study design, and revised the manuscript.

Silvana Alves Pereira oversaw the overall coordination of the research, reviewed the study design, and revised the manuscript.

All researchers approved the final version of the manuscript.

LIST OF ABBREVIATIONS

PTI = preterm infant

CA = corrected age

NICU = Neonatal Intensive Care Unit

KaNICU = Kangaroo Neonatal Intermediate Care Unit

MOS = Motor Optimality Score

TIMP = Test of Infant Motor Performance

BAYLEY III = Bayley Scales of Infant and Toddler Development, Third Edition

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