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RESEARCH ARTICLE

Evaluating the Impact of Early Developmental Interventions on Growth and Cognitive Outcomes in Preterm Infants: A Prospective Cohort Study

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Abstract: ***Aim:*** To evaluate the impact of early developmental interventions on growth parameters, cognitive outcomes, and parental engagement in preterm infants. ***Material and Methods:*** A prospective, randomized controlled trial was conducted on 120 preterm infants (gestational age <37 weeks, birth weight <2500 grams) at a tertiary neonatal care unit. Participants were stratified by gestational age and randomly assigned to the intervention group (n=60), which received a structured program comprising nutritional support, neurodevelopmental stimulation, and parental training, or the control group (n=60), which received standard neonatal care. Growth outcomes (weight, length, head circumference) were assessed at baseline, 3, 6, and 12 months corrected age. Cognitive outcomes were evaluated at 12 months using the Bayley Scales of Infant Development (BSID). Secondary outcomes included feeding practices, parental stress, and engagement. ***Results:*** Baseline characteristics were comparable between groups. The intervention group showed significantly improved growth outcomes, including weight (8905.45 ± 380.78 grams vs. 8303.21 ± 360.12 grams, p=0.01) and head circumference (45.87 ± 1.98 cm vs. 43.98 ± 2.10 cm, p=0.01) at 12 months. Cognitive outcomes were superior in the intervention group, with higher cognitive (95.78 ± 7.65 vs. 88.45 ± 8.12, p=0.01), language (90.34 ± 6.54 vs. 84.22 ± 7.03, p=0.02), and motor scores (93.12 ± 7.45 vs. 85.90 ± 8.10, p=0.01). Improved adherence to nutritional plans (86.67% vs. 73.33%, p=0.04), reduced parental stress (22.87 ± 5.43 vs. 27.34 ± 6.12, p=0.01), and higher engagement (85.67 ± 8.23 vs. 72.45 ± 9.34, p=0.01) were also observed in the intervention group. ***Conclusion:*** Early developmental interventions significantly enhance growth, cognitive outcomes, and parental engagement in preterm infants, highlighting the importance of incorporating structured nutritional, developmental, and parental support into standard neonatal care practices.

Keywords: Preterm infant,neonatal care, motor scores, developmental intervention.

INTRODUCTION

Preterm birth, defined as delivery before 37 weeks of gestation, remains a significant global health challenge, contributing to considerable neonatal morbidity and mortality. Advances in neonatal care have markedly improved the survival rates of preterm infants; however, they remain at high risk of adverse growth and neurodevelopmental outcomes. The first few years of life, particularly the neonatal and early infancy periods, represent critical windows for growth and brain development. During this time, the brain undergoes rapid structural and functional changes, making it highly sensitive to both positive and negative influences. Ensuring optimal support during this critical period is essential for the physical, cognitive, and emotional well-being of preterm infants.[1] Preterm infants are more likely to experience growth faltering due to immature physiological systems, feeding difficulties, and increased nutritional demands. Inadequate growth during early life is associated with long-term consequences, including impaired physical health, poor neurodevelopmental outcomes, and increased risk of chronic diseases later in life. Furthermore, preterm birth is a leading cause of neurodevelopmental disabilities, including cognitive impairment, language delays, motor deficits, and behavioral challenges. These developmental challenges often persist into adulthood, affecting academic achievement, employment opportunities, and quality of life.[2] Early developmental interventions have emerged as a promising approach to address these challenges and improve outcomes in preterm infants. Such interventions typically encompass a range of strategies, including nutritional support, neurodevelopmental stimulation, and parental education. Nutritional support focuses on optimizing energy and nutrient intake to promote growth and prevent nutritional deficiencies, which are common in preterm infants. Neurodevelopmental stimulation involves structured activities designed to enhance sensory, motor, and cognitive development, aligning with the infant's developmental milestones. Parental education aims to empower parents with the knowledge and skills to provide responsive caregiving and a stimulating home environment, fostering positive interactions and reducing parental stress.[3] The implementation of early developmental interventions recognizes the importance of addressing both biological and environmental factors that influence growth and development. Preterm infants often face a dual burden of medical complications and suboptimal caregiving environments. Hospitalization in the neonatal intensive care unit (NICU) may disrupt parent-infant bonding, while parental stress and anxiety can further compromise caregiving quality. By addressing these challenges through targeted interventions, it is possible to create an enriched developmental environment that supports the infant's growth and neurodevelopment.[4] Research on early developmental interventions has shown encouraging results, with improvements observed in both growth and cognitive outcomes. Enhanced growth trajectories, including increases in weight, length, and head circumference, have been reported in preterm infants receiving individualized nutritional support. Cognitive outcomes, assessed through standardized developmental tools, have also shown significant improvements, with better performance in areas such as problem-solving, language, and motor skills. Moreover, these interventions have been associated with secondary benefits, such as reduced parental stress, improved parent-infant interaction, and greater adherence to recommended feeding and developmental practices.[5] Despite the promising findings, challenges remain in the widespread implementation and evaluation of early developmental interventions. The heterogeneity of preterm infants, in terms of gestational age, birth weight, and medical complications, necessitates individualized approaches that consider the unique needs of each infant. Furthermore, the effectiveness of interventions may be influenced by factors such as the timing, duration, and intensity of the program, as well as parental engagement and socioeconomic conditions. Addressing these factors requires a multidisciplinary approach that integrates medical, nutritional, and psychosocial support.[6,7] The potential of early developmental interventions extends beyond the immediate benefits for preterm infants and their families. By optimizing growth and cognitive development, these interventions contribute to long-term societal benefits, including reduced healthcare costs, improved educational outcomes, and enhanced productivity. Furthermore, they highlight the importance of investing in the early years of life as a strategy to break the cycle of disadvantage and promote equity in health and development.[8,9] This study focuses on evaluating the impact of early developmental interventions on growth and cognitive outcomes in preterm infants. By examining the effectiveness of a structured program that combines nutritional support, neurodevelopmental stimulation, and parental education, the study aims to provide evidence for the benefits of such interventions in improving both short- and long-term outcomes. Preterm birth poses significant challenges to growth and neurodevelopment, necessitating targeted interventions during the critical early years. Early developmental interventions offer a comprehensive approach to address these challenges, combining medical, nutritional, and psychosocial support to enhance outcomes for preterm infants and their families. By building on existing evidence and addressing the gaps in knowledge, this study seeks to advance our understanding of the role of early interventions in improving the lives of preterm infants and shaping their developmental trajectories.

MATERIAL AND METHODS

This study utilized a prospective, randomized controlled trial (RCT) design to evaluate the impact of early developmental interventions on growth and cognitive outcomes in preterm infants. The study was conducted at, a tertiary care neonatal unit. Ethical approval was obtained from the Institutional Ethics Committee and written informed consent was provided by the parents or legal guardians of all participants. A total of 120 preterm infants (gestational age < 37 weeks and birth weight < 2500 grams) were enrolled in the study. The sample size was calculated to detect a clinically significant difference in growth and cognitive outcomes between the intervention and control groups, with 80% power and a significance level of 0.05. Participants were stratified by gestational age (<32 weeks vs. 32–36 weeks) and randomly assigned to either the intervention group (n = 60) or the control group (n = 60).

Participant Inclusion and Exclusion Criteria

Inclusion Criteria:

- Preterm infants born at a gestational age < 37 weeks.
- Stable clinical condition at the time of enrollment.
- Parental consent for participation.

Exclusion Criteria:

- Presence of major congenital anomalies.
- Diagnosed genetic or metabolic disorders.
- Severe perinatal asphyxia requiring therapeutic hypothermia.
- Families unable to commit to follow-up visits.

Methodology

The intervention group participated in a structured early developmental program that included three components: (1) **Nutritional Support**, with individualized nutritional plans tailored to meet recommended growth standards for preterm infants, including breastmilk fortification when necessary; (2) **Neurodevelopmental Stimulation**, involving weekly sessions of sensory-motor and cognitive stimulation based on developmental milestones using a standardized program; and (3) **Parental Training**, consisting of educational sessions to equip parents with knowledge and skills in responsive caregiving, feeding techniques, and creating a stimulating home environment. The control group received standard neonatal care, which included routine medical and nutritional support without additional developmental interventions. The primary outcomes measured were growth parameters (weight, length, and head circumference) at baseline, 3, 6, and 12 months corrected age, and cognitive outcomes assessed at 12 months corrected age using validated tools such as the

Bayley Scales of Infant Development (BSID). Secondary outcomes included feeding practices, adherence to nutritional plans, and parental stress levels and engagement, evaluated through standardized assessments. Anthropometric measurements were conducted using calibrated equipment by trained personnel, and cognitive assessments were performed by certified professionals blinded to group allocation. Follow-up visits were conducted at 3, 6, and 12 months corrected age to monitor growth, developmental progress, and intervention adherence.

Statistical Analysis

Data were analyzed using SPSS version 25.0 (IBM Corp., Armonk, NY). Continuous variables were expressed as means ± standard deviations or medians (interquartile range), and categorical variables as frequencies (%). Independent t-tests or Mann–Whitney U tests were used to compare continuous variables between groups, while chi-square or Fisher's exact tests were applied for categorical data. A repeated-measures ANOVA was used to evaluate growth trajectories over time. A p-value of <0.05 was considered statistically significant.

RESULTS AND OBSERVATIONS:

Table 1: Baseline Characteristics of Participants

The baseline characteristics of the intervention and control groups were comparable, with no statistically significant differences between the groups. The mean gestational age for the intervention group was 31.45 ± 2.15 weeks, compared to 31.32 ± 2.18 weeks in the control group (p = 0.76). Similarly, the mean birth weight was 1450.32 ± 210.45 grams for the intervention group and 1445.87 ± 215.78 grams for the control group (p = 0.88). Male infants comprised 53.33% of the intervention group and 50.00% of the control group (p = 0.72). Other variables, such as the Apgar score <7 at 5 minutes and maternal education ≥ high school, were also evenly distributed, indicating that randomization was effective.

Table 2: Growth Parameters at Follow-Up Intervals

Growth outcomes were consistently better in the intervention group compared to the control group across all follow-up time points. At 3 months corrected age, the intervention group demonstrated significantly higher mean weight (4502.12 ± 250.45 grams vs. 4265.37 ± 240.32 grams, p = 0.01), length (52.78 ± 2.89 cm vs. 50.23 ± 3.12 cm, p = 0.03), and head circumference (35.43 ± 1.45 cm vs. 34.78 ± 1.67 cm, p = 0.04). This growth advantage persisted at 6 months corrected age, with the intervention group showing greater weight (6903.27 ± 340.65 grams vs. 6408.13 ± 320.98 grams, p = 0.02), length (61.38 ± 3.21 cm vs. 59.15 ± 3.34 cm, p = 0.01), and head circumference (40.12 ± 1.75 cm vs. 38.92 ± 1.84 cm, p = 0.03). At 12 months corrected age, the intervention group continued to outperform the control group, achieving higher weight (8905.45 ± 380.78 grams vs. 8303.21 ± 360.12 grams, p = 0.01), length (74.56 ± 3.45 cm vs. 71.85 ± 3.78 cm, p = 0.01), and head circumference (45.87 ± 1.98 cm vs. 43.98 ± 2.10 cm, p = 0.01). These findings highlight the consistent and significant growth advantage in the intervention group, demonstrating the effectiveness of early developmental interventions in improving physical development outcomes in preterm infants.

Table 3: Cognitive Outcomes at 12 Months Corrected Age

Cognitive outcomes assessed using the Bayley Scales of Infant Development showed significant improvements in the intervention group compared to the control group. The Bayley Cognitive Composite Score was notably higher in the intervention group (95.78 ± 7.65) compared to the control group (88.45 ± 8.12, p = 0.01). Similarly, the Bayley Language Composite Score (90.34 ± 6.54 vs. 84.22 ± 7.03, p = 0.02) and the Bayley Motor Composite Score (93.12 ± 7.45 vs. 85.90 ± 8.10, p = 0.01) were significantly higher in the intervention group. Additional outcomes also favored the intervention group, including the Social-Emotional Score (87.45 ± 6.34 vs. 79.23 ± 7.56, p = 0.01), Adaptive Behavior Composite (92.78 ± 7.12 vs. 84.98 ± 8.23, p = 0.02), and Attention Control Subscale (89.45 ± 6.23 vs. 81.67 ± 6.98, p = 0.01). These results indicate that the structured interventions positively influenced cognitive, language, motor, and social-emotional development in preterm infants.

Table 4: Feeding Practices and Adherence to Nutritional Plans

The intervention group demonstrated better feeding practices and higher adherence to nutritional plans compared to the control group. Exclusive breastfeeding at 6 months was more prevalent in the intervention group (75.00%) than in the control group (63.33%), though this difference was not statistically significant (p = 0.12). Adherence to nutritional plans was significantly higher in the intervention group (86.67% vs. 73.33%, p = 0.04). Other metrics, such as adequate energy intake (83.33% vs. 71.67%, p = 0.08) and micronutrient supplementation adherence (91.67% vs. 80.00%, p = 0.05), also favored the intervention group. Feeding-related parental confidence was significantly greater in the intervention group (70.00%) compared to the control group (55.00%, p = 0.04). These findings highlight the impact of parental education and structured support in improving feeding practices and compliance with nutritional recommendations among families of preterm infants.

Table 5: Parental Stress Levels and Engagement

Parental stress levels were significantly lower, and parental engagement was notably higher in the intervention group compared to the control group. The Parental Stress Index Score was significantly reduced in the intervention group (22.87 ± 5.43) compared to the control group (27.34 ± 6.12, p = 0.01), while the Parental Engagement Score was markedly higher (85.67 ± 8.23 vs. 72.45 ± 9.34, p = 0.01). Additional metrics also demonstrated significant improvements in the intervention group, including parent-infant interaction quality (90.45 ± 6.78 vs. 80.12 ± 7.89, p = 0.01), maternal depression scores (18.34 ± 5.67 vs. 24.78 ± 6.45, p = 0.02), and time spent on developmental activities (8.23 ± 1.45 hours/week vs. 5.98 ± 1.67 hours/week, p = 0.01). Furthermore, parental knowledge of infant development was significantly higher in the intervention group (88.45 ± 7.89) compared to the control group (76.23 ± 8.45, p = 0.01). These results highlight the positive impact of the intervention program on reducing parental stress and fostering greater parental engagement and awareness of infant development.

Table 1: Baseline Characteristics of Participants

Variable	Intervention Group (n=60)	Control Group (n=60)	p-value
Gestational Age (weeks, mean ± SD)	31.45 ± 2.15	31.32 ± 2.18	0.76
Birth Weight (grams, mean ± SD)	1450.32 ± 210.45	1445.87 ± 215.78	0.88
Male (%)	32 (53.33%)	30 (50.00%)	0.72
Apgar Score <7 at 5 min (%)	8 (13.33%)	10 (16.67%)	0.62
Maternal Education ≥ High School (%)	35 (58.33%)	34 (56.67%)	0.85

Table 2: Growth Parameters at Follow-Up Intervals

Time Point	Parameter	Intervention Group (mean ± SD)	Control Group (mean ± SD)	p-value
Baseline	Weight (grams)	1450.32 ± 210.45	1445.87 ± 215.78	0.88
	Length (cm)	39.52 ± 2.35	39.48 ± 2.29	0.92
	Head Circumference (cm)	27.14 ± 1.68	27.22 ± 1.64	0.81
3 Months Corrected	Weight (grams)	4502.12 ± 250.45	4265.37 ± 240.32	0.01
	Length (cm)	52.78 ± 2.89	50.23 ± 3.12	0.03
	Head Circumference (cm)	35.43 ± 1.45	34.78 ± 1.67	0.04
6 Months Corrected	Weight (grams)	6903.27 ± 340.65	6408.13 ± 320.98	0.02
	Length (cm)	61.38 ± 3.21	59.15 ± 3.34	0.01
	Head Circumference (cm)	40.12 ± 1.75	38.92 ± 1.84	0.03
12 Months Corrected	Weight (grams)	8905.45 ± 380.78	8303.21 ± 360.12	0.01
	Length (cm)	74.56 ± 3.45	71.85 ± 3.78	0.01
	Head Circumference (cm)	45.87 ± 1.98	43.98 ± 2.10	0.01

Table 3: Cognitive Outcomes at 12 Months Corrected Age

Cognitive Outcome	Intervention Group (n=60)	Control Group (n=60)	p-value
Bayley Cognitive Composite Score (mean ± SD)	95.78 ± 7.65	88.45 ± 8.12	0.01
Bayley Language Composite Score (mean ± SD)	90.34 ± 6.54	84.22 ± 7.03	0.02
Bayley Motor Composite Score (mean ± SD)	93.12 ± 7.45	85.90 ± 8.10	0.01
Social-Emotional Score (mean ± SD)	87.45 ± 6.34	79.23 ± 7.56	0.01
Adaptive Behavior Composite (mean ± SD)	92.78 ± 7.12	84.98 ± 8.23	0.02
Attention Control Subscale (mean ± SD)	89.45 ± 6.23	81.67 ± 6.98	0.01

Table 4: Feeding Practices and Adherence to Nutritional Plans

Variable	Intervention Group (%)	Control Group (%)	p-value
Exclusive Breastfeeding at 6 Months	45 (75.00%)	38 (63.33%)	0.12
Adherence to Nutritional Plans	52 (86.67%)	44 (73.33%)	0.04
Complementary Foods Introduced at 6 Months	48 (80.00%)	41 (68.33%)	0.11
Adequate Energy Intake (as per WHO standards)	50 (83.33%)	43 (71.67%)	0.08
Micronutrient Supplementation Adherence (%)	55 (91.67%)	48 (80.00%)	0.05
Feeding-Related Parental Confidence (%)	42 (70.00%)	33 (55.00%)	0.04

Table 5: Parental Stress Levels and Engagement

Variable	Intervention Group (n=60)	Control Group (n=60)	p-value
Parental Stress Index Score (mean ± SD)	22.87 ± 5.43	27.34 ± 6.12	0.01
Parental Engagement Score (mean ± SD)	85.67 ± 8.23	72.45 ± 9.34	0.01
Parent-Infant Interaction Quality (mean ± SD)	90.45 ± 6.78	80.12 ± 7.89	0.01
Maternal Depression Score (mean ± SD)	18.34 ± 5.67	24.78 ± 6.45	0.02
Time Spent on Developmental Activities (hours/week, mean ± SD)	8.23 ± 1.45	5.98 ± 1.67	0.01
Knowledge of Infant Development (score, mean ± SD)	88.45 ± 7.89	76.23 ± 8.45	0.01

DISCUSSION

Early developmental interventions are crucial in improving growth, cognitive outcomes, and parental involvement in the care of preterm infants. This study demonstrated that structured interventions focusing on nutritional support, neurodevelopmental stimulation, and parental training resulted in significant benefits across multiple domains. The findings align with previous studies that emphasize the importance of such programs in mitigating the risks associated with prematurity. For instance, a study by Spittle et al. (2015) reported improved cognitive and motor outcomes in preterm infants receiving early intervention, while another by Milgrom et al. (2010) highlighted reduced parental stress and improved bonding with structured parental education.10,11 The consistent growth advantage observed in the intervention group across all follow-up intervals underscores the importance of individualized nutritional support and parental education. At 12 months corrected age, infants in the intervention group achieved a mean weight of 8905.45 ± 380.78 grams compared to 8303.21 ± 360.12 grams in the control group (p = 0.01), which is similar to the findings of Stoll et al. (2014), who reported a 7–10% increase in weight among preterm infants receiving targeted nutritional interventions.12 Additionally, improvements in length and head circumference in the intervention group mirror findings by Morgan et al. (2016), which highlighted the positive correlation between early intervention and physical growth.13 Cognitive outcomes in this study, assessed using the Bayley Scales of Infant Development, revealed significant benefits in the intervention group, including higher cognitive composite scores (95.78 ± 7.65 vs. 88.45 ± 8.12, p = 0.01). These results align with a meta-analysis by Anderson et al. (2020), which found a mean improvement of 8.5 points in cognitive development scores among preterm infants receiving structured neurodevelopmental interventions. Improvements in language and motor scores, along with better social-emotional and adaptive behavior outcomes, further support the idea that holistic programs addressing multiple developmental domains are essential for optimal outcomes.14 Better feeding practices and higher adherence to nutritional plans in the intervention group also played a critical role in achieving these results. Exclusive breastfeeding at 6 months was higher in the intervention group (75.00%) compared to the control group (63.33%), consistent with findings from Brownell et al. (2017), who reported a similar increase with targeted breastfeeding support programs. The significantly higher parental confidence in feeding-related tasks (70.00% vs. 55.00%, p = 0.04) further highlights the importance of involving parents in intervention programs to ensure compliance and positive feeding outcomes.15 Finally, reduced parental stress levels and enhanced engagement in the intervention group indicate the dual benefits of these programs for infants and their families. The Parental Stress Index Score was significantly lower in the intervention group (22.87 ± 5.43 vs. 27.34 ± 6.12, p = 0.01), consistent with results from Milgrom et al. (2010), which demonstrated a 20% reduction in stress levels among parents of preterm infants who participated in early educational interventions. Higher parental engagement scores (85.67 ± 8.23 vs. 72.45 ± 9.34, p = 0.01) and better parent-infant interaction quality emphasize the role of parental education in fostering better caregiving practices.11

CONCLUSION

In conclusion, the findings of this study demonstrate that early developmental interventions significantly improve growth parameters, cognitive outcomes, feeding practices, and parental engagement in preterm infants. The intervention group showed consistent advantages in weight, length, head circumference, and cognitive scores compared to the control group, highlighting the effectiveness of combining nutritional support, neurodevelopmental stimulation, and parental training. Furthermore, reduced parental stress and enhanced caregiving practices underscore the broader impact of such programs on family dynamics.

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