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The role of early developmental intervention to influence neurobehavioral outcomes of children born preterm

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ABSTRACT

Children who are born preterm are at risk of adverse long-term neurobehavioral outcomes, including cognitive, motor, and behavioral impairments. Early developmental interventions that commence within the first year after preterm birth have a preventative focus, with the aim to positively influence the developmental trajectory. While there is a great deal of heterogeneity in the research trials to date, there is evidence that early developmental interventions have a moderate effect on cognitive and behavioral outcomes up to preschool age, with some evidence for improved motor outcomes. This review discusses key components of early developmental interventions including commencing the intervention as early as possible, ideally in the neonatal intensive care unit, and promoting developmental skills overtime with an appropriate enriched environment. The importance of involving and supporting parents in early intervention is also highlighted, particularly given the influence of the parent–infant relationship on developmental outcomes and higher rates of mental health problems in parents after preterm birth.

Introduction

Children who are born preterm (<37 weeks' gestational age) are at increased risk for a range of neurobehavioral impairments compared to their peers born at term.[1] Rates of major neurobehavioral impairments such as cerebral palsy, autism, attention hyperactivity disorder (ADHD), blindness, and deafness are higher in children born preterm, occurring in up to 15% of preterm children.[1–3] The rates of milder neurobehavioral impairments in areas including language,[4] attention,[5] social–emotional development,[3] executive function,[6] and developmental coordination disorder (DCD)[2] also occur at

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much higher rates in children born preterm, with over half of these children having one or more neurobehavioral impairments.[7] The range of neurobehavioral impairments for children born preterm is diverse, but they all may have significant effect on quality of life and academic performance.[8] Further, preterm children have up to a 4–6-fold increase in psychiatric disorders including anxiety and depression.[9,10] Long-term, neurobehavioral impairments in adults born preterm including lower intelligence and academic achievement are associated with lower wages and decreased wealth.[11]

The risk of neurobehavioral impairments not only increases with decreasing gestational age, but is also related to perinatal (e.g., brain injury and infection) and environment influences (e.g., lower socio-economic status and parenting). Although the effects of neurological and medical factors play an important role, overtime environmental and social factors become increasingly important.[12] Despite many advances in obstetric and neonatal care that have improved neurobehavioral outcomes for preterm children over the past few decades,[13] the rates of impairments remains too high, and early developmental interventions are needed not only during the neonatal intensive care period but also during the first years of life to optimize outcomes.

It is commonly assumed that providing early interventions will benefit all children at high risk of neurobehavioral impairments, but the evidence for this is variable.[14,15] Although the definition of early intervention is inconsistent in research and clinical practice, it has broadly been defined as "multidisciplinary services provided to children from birth to 5 years of age to promote child health and well-being, enhance emerging competencies, minimized developmental delays, remediate existing or emerging disabilities, prevent functional deterioration and promote adaptive parenting and overall family function."[16] For the purpose of this review, we have restricted early developmental interventions to the first year after birth, as the theoretical and biological constructs of starting intervention in the first year during key periods of brain and musculoskeletal development, and the nature of the parent–infant relationship are different compared with later in childhood. In this review, we will summarize the state of the evidence for early developmental interventions for preterm infants across the range of neurobehavioral impairments including cognitive, motor, and behavioral domains and the theoretical frameworks for these programs. We will also discuss the important role parents have in early developmental intervention programs.

Critical periods of brain development and early intervention

There is increasing evidence both from animal and human models that the early environment (including parenting behavior) and experiences shape brain development.[17,18] For example, childhood maltreatment (such as abuse or neglect) has been associated with smaller brain volumes in children,[19] while higher levels of early maternal supportive behavior has been associated with larger hippocampal volumes.[20] Infants born very preterm are exposed to the extra-uterine environment during an important period of brain development in the late 2nd trimester or early 3rd trimester. The last trimester of pregnancy is associated with a rapid period of brain development, with white matter increasing 5-fold and gray matter increasing 4-fold.[21] Infants born early are susceptible to alterations in brain development not only due to the disruption of genetically programmed patterns of brain genesis, but also due to experiences such as neurological insults including intraventricular hemorrhage and periventricular leucomalacia, biological influences such as infection and bronchopulmonry dysplasia, and environmental influences such as altered auditory and visual stimuli, along with physical separation from their parents.[22–24]

Although the developing brain is vulnerable, this rapid plasticity in the brain means that there is also potential for early experiences and the environment to positively influence brain development. For example, in feline models of early intervention for motor impairments, it has been shown that better functional outcomes are obtained when intervention occurs early while the cortico-spinal tract is developing rather than later when the cortico-spinal tract is complete.[14] By training early, there is reactive synaptic plasticity resulting in brain structure reorganization and hence improved outcomes. The same principles underlie early developmental interventions for preterm infants, so that by training early the aim is to improve brain connections during key periods of brain development, rather than waiting for an impairment to occur once altered brain connections have developed. Importantly, training must not be passive but rather it needs to be active so that the infant is learning (i.e., development, alteration, and/or selection of neural circuits) through their experiences.

The role of parents and the child's early environment in early intervention

Within an ecological framework, parents and the home environment have the strongest, most proximal, and enduring influence on child development,[25] even after taking other environmental factors such as socio-economic status (SES) and parental education into account.[26] There is also evidence that even for preterm children with great exposure to medical risk factors such as neurological abnormality, a stimulating home environment and sensitive parent–infant relationship are associated with better neurodevelopmental outcomes.[27–29] More negative and intrusive early parenting is associated with poorer developmental outcomes for very preterm children across childhood.[27,30] Conversely, warm and sensitive parenting and a positive family environment can have a protective effect on the development of preterm children, even after accounting for the influence of medical risk factors such as brain injury.[27,28,31] Thus the parent–infant relationship and the parenting environment of the infant is considered to be one of the primary mechanisms through which many early intervention programs have a positive effect on preterm children, and is a focus of many programs [e.g., mother–infant transaction program (MITP)].[32,33] Indeed, our Cochrane review on early intervention programs for preterm infants concluded that early intervention programs that focused on the parent–child relationship were more