

Breastfeeding and Childhood IQ: The Mediating Role of Gray Matter Volume

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Objective: A substantial body of literature has established the positive effect of breastfeeding on child developmental outcomes. There is increasing consensus that breastfed children have higher IQs after accounting for key variables, including maternal education, IQ, and socioeconomic status. Cross-sectional investigations of the effects of breastfeeding on structural brain development suggest that breastfed infants have larger whole brain, cortical, and white matter volumes. To date, few studies have related these measures of brain structure to IQ in breastfed versus nonbreastfed children in a longitudinal sample.

Method: Data were derived from the Preschool Depression Study (PDS), a prospective longitudinal study in which children and caregivers were assessed annually for 8 waves over 11 years. A subset completed neuroimaging between the ages of 9.5 and 14.11 years. A total of 148 individuals had breastfeeding data at baseline and complete data on all variables of interest, including IQ

and structural neuroimaging. General linear models and process mediation models were used.

Results: Breastfed children had significantly higher IQ scores and larger whole brain, total gray matter, total cortical gray matter, and subcortical gray matter volumes compared with the nonbreastfed group in models that covaried for key variables. Subcortical gray matter volume significantly mediated the association between breastfeeding and children's IQ scores.

Conclusion: The study findings suggest that the effects of breastfeeding on child IQ are mediated through subcortical gray matter volume. This effect and putative mechanism is of public health significance and further supports the importance of breastfeeding in mental health promotion.

Key words: breastfeeding, IQ, brain development

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A substantial body of literature has established the positive effect of breastfeeding on a variety of child health and developmental outcomes.¹ Although numerous studies have detected a positive relationship between breastfeeding and childhood IQ, many are confounded by the fact that in most wealthy societies, more educated women and those with higher incomes choose to breastfeed, making it unclear whether these correlates are driving the effects. However, the results of randomized controlled trials,^{2,3} cross-population studies that eliminate social patterns of breastfeeding,⁴ longitudinal cohort studies in several countries,^{5,6} and meta-analyses⁷ all offer support for positive associations between breastfeeding and child IQ when accounting for these critical confounds. At the same time, however, other work using sibling comparisons and designs that account for within-family effects fails to support this relationship.⁸ Taken together, this body of work suggests that the impact of breastfeeding on child IQ is complex and likely involves contributions from genetics (e.g., maternal-to-child IQ), nutritional components of breast milk, the maternal-child relationship (e.g., maternal nurturance, close physical contact), and psychosocial factors (e.g., poverty, stimulation). Despite these conflicts and complexities in the behavioral literature, there is increasing consensus that breastfed children on average have higher IQs even after accounting for maternal education and IQ, socioeconomic status, and other key factors. This is of key

public health importance, as childhood IQ is associated with adaptive outcomes including health (both mental and physical) and longevity later in life.⁹

Following these findings, investigations of the effects of breastfeeding on structural brain development have been of increasing interest as a possible mechanism for the positive effects of breastfeeding on cognitive development. Such studies begin to elucidate how breastfeeding affects IQ by addressing whether the structure of key brain regions involved in cognitive ability are enhanced by breastfeeding. Cross-sectional studies have shown that breastfed infants have enhanced early white matter development, as well as larger whole brain and cortical volume and thickness.^{8,10-13} Furthermore, smaller ventricular volumes and larger head circumferences were evident in the first 2 months of life in breastfed versus bottle-fed infants.¹⁴ However, despite the demonstrated effects of breastfeeding on cognitive outcomes and data showing enhanced brain development, to date few studies have related these measures of brain structure to IQ in breastfed versus nonbreastfed children in the same study sample longitudinally, a study design that is necessary to begin to elucidate the mechanism by which breastfeeding affects IQ. Given findings suggesting an important relationship between gray matter volume and IQ in healthy developing children,¹⁵⁻¹⁷ the role of gray matter in this hypothesized relationship was of particular interest. Based on prior findings linking white matter tracts to IQ and

studies demonstrating an effect of breastfeeding on IQ and white matter volume,¹⁸ we also explored white matter volume. Thus, we tested whole brain and subcortical brain volume as separate mediating mechanisms through which breastfeeding influences IQ.

The goal of the current study was to address this gap in the literature by testing the hypothesis that the relationship between breastfeeding and IQ would be mediated by the effect of breastfeeding on structural brain development and, in turn, the effect of brain on IQ. To do so, we used data from an 11-year longitudinal study that was originally designed to investigate early childhood depression but that also included maternal report of breastfeeding obtained when children were between the ages of 3.0 and 5.11 years, as well as neuroimaging, IQ, and behavioral assessments at school age and early adolescence (ages 9–15 years). Importantly, key potential confounds such as income to needs (a measure of socioeconomic status [SES] in relation to the federal poverty level), maternal education, and other psychosocial variables were also measured. As breastfeeding is a modifiable health behavior across cultures, which could have a powerful impact on child IQ and other critical developmental outcomes, a greater understanding of the relationships between breastfeeding, brain development, and IQ is of great importance to health promotion and mental health and developmental disorder prevention. Importantly, enhancing child IQ could diminish the need for special educational services and mitigate the associated social impairment and psychiatric comorbidities that arise with cognitive delay.

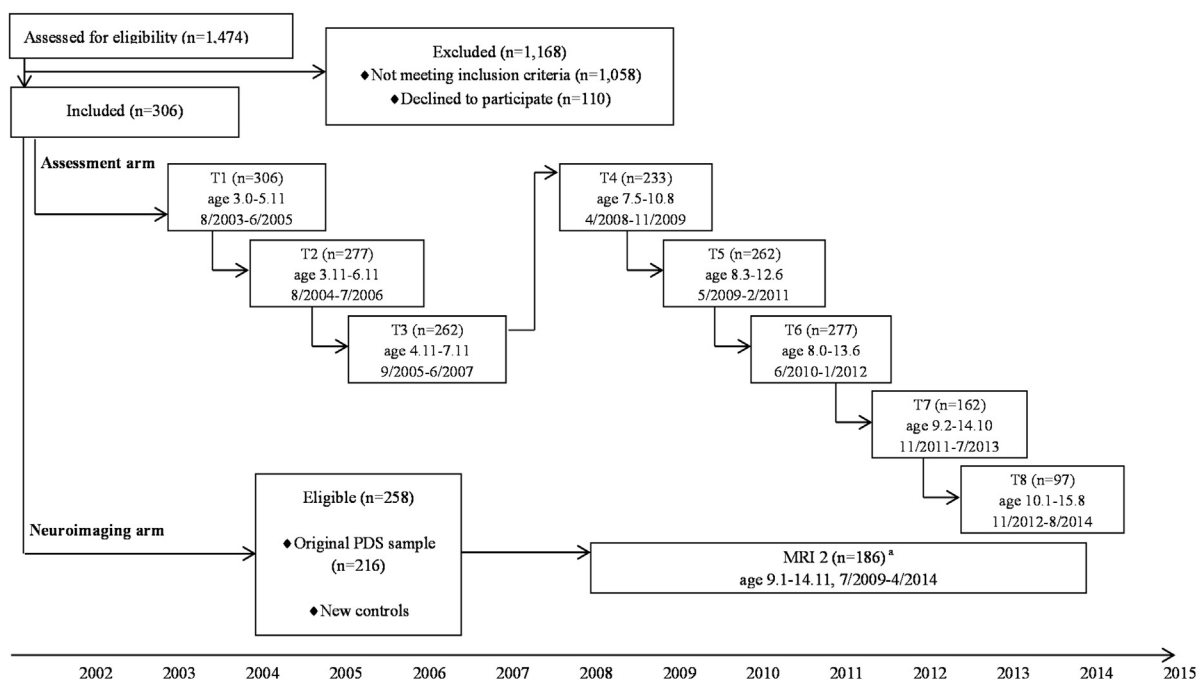
METHOD

Overview of Study Design and Participants

At baseline ($n = 306$), children 3.0 to 5.11 years old and their primary caregivers were recruited from daycare, preschool, and primary care sites in the St. Louis area for a study of preschool depression. The sample was ascertained based on child characteristics, and a screening checklist¹⁹ was used to oversample children with early-onset behavioral and emotional symptoms (specifically depression) as well as healthy controls. Children and their caregivers were assessed annually for 8 assessment waves over 11 years. A subset (those with any history of major depressive disorder [MDD] and healthy controls) completed 3 sessions of neuroimaging. From the original sample, 148 individuals had data on breastfeeding obtained at baseline from maternal report and had complete data on all variables of interest in the current analyses, including IQ and structural neuroimaging at scan 2 (Figure 1). Following minimal cut-offs used in the breastfeeding literature, participants with breastfeeding duration of less than 30 days were not included in the analyses. Three individuals with IQ scores of less than 75 were excluded from analyses due to being below the normative range and the possibility that a unique brain developmental process may be operative with IQs below the normative range. IQ scores ranged from 75 to 133 for participants included in the analyses. Parental written consent and verbal child assent (in children 4 years and older) were obtained before study participation. The institutional review board at Washington University approved all procedures in accordance with the Health Insurance Portability and Accountability Act (HIPAA) and institutional ethical guidelines.

A total of 211 child participants (a subset of the 306 study participants ascertained at baseline and described above) were invited to complete 3 sessions of neuroimaging between 2008 and 2014. As the first step, we conducted multilevel models of subcortical gray volume across the 3 scan waves to test for an effect of breastfeeding

FIGURE 1 Flow of the Preschool Depression Study (PDS). Note: MRI = magnetic resonance imaging. *Of 211 potential scan 2 participants, 21 had unusable scan data, 2 did not have IQ data, 3 had an IQ score < 75, 5 did not have breastfeeding data, 7 had breastfeeding duration of less than 1 month, 18 refused participation, and 7 had braces; therefore, scan 2 data were included in the analyses for 148 participants.



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