# A Systematic Review Exploring the impact of Human Milk on Neurocognitive domains of development

# A Comprehensive Analysis

Impact of Human Milk on Neurocognitive Development

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#### Abstract—

Background: Human milk has been linked to enhanced brain development, yet evidence of comprehensive research regarding the effects of Human Milk on Neurocognitive outcomes is lacking. This paper aims to fill that gap by systematically examining the influence of Breast milk on Neurocognitive functioning. Objective: To provide a comprehensive analysis of the impact of human milk on neurocognitive development, to inform pediatric care practices, parental counselling and recommendations to enhance research credibility in the area. Methodology: This systematic review was conducted in line with PRISMA guidelines. Electronic searches were performed in PubMed, Scopus, MEDLINE, MDPI, SCI, and CLIB for studies published between 2021 and 2025 using predefined keywords. Eligible designs included randomised controlled trials, cohort and cross-sectional studies, longitudinal analyses, secondary data reviews, and peer-reviewed narrative reviews. Only English-language human studies were included; animal studies and conference abstracts were excluded. Two reviewers independently screened and assessed the studies for inclusion. Results: Twenty studies met the criteria. Across various methodologies, human milk intake has consistently shown a positive association with neurocognitive outcomes. Reported benefits included better Early Childhood Development scores, higher IQ scores, improved white matter integrity, greater hippocampal grey matter volume, higher power spectral density, and favourable overall brain structural measures. Conclusion: While current evidence supports Breastfeeding as a positive influence on neurodevelopment, further high-quality, longitudinal studies are needed to disentangle biological effects from sociodemographic factors and to clarify the long-term impact into adolescence and adulthood.

Keywords—Breast milk, Human milk, Cognitive function, Intellect, Development

# 1. Introduction

- Human Breast milk is recognised for its substantial benefits in promoting early health, supporting Neurocognitive development, enhancing immunity, lowering the risk of non-communicable diseases, and alleviating maternal postpartum depression. Drawing from recent scientific literature, this study highlights the beneficial effects of Breast milk on children's overall Neurocognitive wellness. The fats found in Human Milk play a crucial role in supporting growth, regulating inflammation, aiding immune responses, and contributing to the advancement of vision, cognitive abilities, and motor skills in infants. [1] Importantly, Docosahexaenoic acid (DHA) and Arachidonic acid, both components of Breast milk, are vital for optimal brain development during times of accelerated neural growth. Furthermore, myo-inositol present in Breast milk has been shown to boost the quantity and size of synapses, thereby strengthening communication between neurons in the brain. [2]
- While these results are encouraging, there remains a lack of comprehensive research regarding the effects of Human Milk on Neurocognitive outcomes. This paper aims to fill that gap by systematically examining the particular influence of Breast milk on Neurocognitive functioning.

# 2. MATERIALS & METHODS

PROSPERO 2025 CRD420251137726. Available from https://www.crd.york.ac.uk/PROSPERO/view/CRD420251137726.

# 2.1 Review Objective

To provide a comprehensive analysis of the impact of human milk on neurocognitive development, informing pediatric care practices, parental counselling, and recommendations to enhance research credibility in the area.

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# 2.2 Search Strategy and Data Collection

This review was carried out following the PRISMA (Transparent Reporting of Systematic Reviews and Meta-Analyses) guidelines.<sup>[3]</sup> The analysis explores links between consumption of Human Milk and Neurocognitive development, drawing together studies published from 2021 onwards to evaluate potential cognitive advantages associated with Breast milk. Researchers conducted a systematic search across electronic databases such as PubMed, Scopus, MEDLINE, MDPI, SCI, and CLIB-The Cochrane Library, employing keywords like "Breast milk," "Human Milk," "Cognitive function," "Intellect," and "Development". After screening, 20 manuscripts were selected for in-depth analysis.

# 2.3 Study Selection

The selection process involved screening titles, abstracts, and full-text articles by independent researchers. Each article underwent a comprehensive review to assess its alignment with the study objectives. Studies were included if they addressed topics related to Breast milk and its impact on Neurocognitive enhancement, memory, cognitive function, developmental milestones, IQ, or cognition, and were published in English. No temporal limitations were applied during the search. Following the application of exclusion criteria, 20 articles were ultimately incorporated into the systematic review, as detailed in Table 1. The PRISMA flowchart for the process is presented in Figure 1.

#### 2.3.1 Inclusion criteria

Included studies met the following criteria:

- Participants aged 0–19 years, regardless of gestational age or birth weight.
- The intervention employed was Human breast milk.
- Studies comprising Soy milk, Infant formula, and Fortified milk used as a comparator.
- Breastfed infants generally demonstrate modest but consistent outcomes in measures of cognitive performance, language development, and academic achievement compared to those fed with formula, soy milk, and fortified milk.
- The time frame for assessing the effect spanned from 2 months to 16 years of age.

# 2.3.2 Exclusion criteria

Excluded studies met the following criteria:

- Studies including all ages where data for those aged 0-19 years are not separately reported.
- Mixed feeding (breast milk with other milk) and milk other than Human milk as the study intervention.
- Multiple milk types assessed in the same participants.
- All studies involving routes of drug administration other than oral delivery were excluded.
- Excludes studies focused only on behavior, temperament, or isolated motor skills due to limited relevance to long-term neurodevelopment or cognition.

#### 2.3.3 Data Extraction

Data extraction was conducted in accordance with a standardised protocol to maintain consistency and accuracy across all included studies. Key information gathered encompassed the criteria for selecting pertinent research articles, study designs, evaluation instruments, parameters employed in the assessment of neurocognitive function, timing of assessments, and methodologies used for outcome evaluation.

Records excluded **IDENTIFICATION** Duplicate articles excluded (n=30) Records identified (n=109) Records excluded **SCREENING** Total articles screened (n=79) Total articles excluded based on inclusion criteria (n=23) Records excluded Full text articles assessed for Falling beyond range (n=12) eligibility (n=56) **ELIGIBILITY** Keyword selection (n=9) Not in English language (n=3) Studies included in bibliometric **INCLUDED** analysis (n=20)

Identification of studies via Pub Med, Scopus, SCI, MEDLINE, MDPI and CLIB Database

Figure 1: PRISMA flow diagram of the literature screening process

# 3. DISCUSSION

A total of 109 records were retrieved through searches of the PubMed, Scopus, MEDLINE, CLIB, MDPI and SCI databases. Following duplicate removal, 79 articles remained for further screening. The titles and abstracts of these 79 records were examined to assess relevance to the research topic. During this initial evaluation, 23 records were excluded because they did not meet the predefined inclusion criteria related to Neurocognitive function. The full texts of the remaining 56 articles were then assessed for eligibility. Of these, 36 records were excluded for the following reasons: 12 had publication dates outside the target range, 9 lacked the required keywords, 3 were not published in English, and 12 had unavailable full texts. Ultimately, 20 studies satisfied all eligibility criteria and were included in the analysis.

Table 1: Studies selected for the Systematic review

Sr.	Title	Sampl	Study	Inclusion criteria	<b>Assessment Point</b>	Result	Reference
no		e size	design		(age in years)		
1	Association between breastfeeding during infancy and white matter microstructure	n=85	nal Cohort Study	Full-term birth (>37 weeks' gestation), Birthweight >2500 grams, Living in the Calgary area Ability to speak English as a primary language	At 2.34 & at 6.97 years of age	Infants who are exclusively breastfed demonstrate enhanced development of global and regional white matter microstructure compared to those receiving infant formula.	Kar et al, 2021, Canada <sup>[4]</sup>
	in early childhood						
2	Breastfeeding, Physical	not mentio	Observatio nal	Data from the ongoing Prospective Western Region	At 3 years of age	There was a 0.4-SD mprovement in overall child	Wallenborn et al,

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	Growth, and	ned	Prospectiv	Birth cohort.		development ( $\beta = .38$ ,	2021, Sao
	Cognitive		e Birth			confidence limit: 0.23–0.53),	Paulo, Brazil,
	Development		Cohort			a 0.6-SD increase in height-	South
	Bevelopment		Colloit			for-age z score ( $\beta = .55$ ,	America <sup>[5]</sup>
							America
						confidence limit: 0.31–0.79),	
						and a 67% reduction in	
						stunting odds (odds ratio =	
						_	
						0.33, 95% CI: 0.20–0.54).	
3	Human milk	not	Review	Preterm infants (e.g., very	not mentioned	The identification of stem	Chiurazzi et
	and brain	mentio	Study	preterm infants born		cells, the incorporation of	al, 2021,
			Study	-		-	
	development	ned	100	between weeks 23-27), term		protein molecules, and the	Switzerland <sup>[6]</sup>
	in infants		1	infants, or a mix of both	***	introduction of novel	
			A	V		microRNA molecules in	
			A 3			human milk all underscore	
			B S				
			I = V			the essential role of human	
			2 37			milk in early life nutrition.	
		i i	y y			The discovery of stem cells.	
4.	Fooding	n= 285	Observatio	The Moms2Moms cohort	At 6 years of age	Each additional month of	Keim et al,
4.	Feeding	11= 283	0.0		At 6 years of age		, , , , , , , , , , , , , , , , , , ,
	Infants at the		nal	(Ohio, US) reported infant		exclusive breastfeeding was	2021,
	Breast or		Prospectiv	feeding practices.	J.	linked to a lower risk of	Ohio, US <sup>[7]</sup>
	Feeding	V	e Cohort		2.50	executive function (working	
	_		Y.				
	Expressed		Study			memory) deficit, with an	
	Human Milk:		V A			adjusted relative risk of 0.78	
	Long-Term		T			(95% CI 0.63-0.96).	
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	_					Part	
	Executive		111111111111111111111111111111111111111				
	Function, and		4			100	
	Eating						
	Behavior						
	Outcomes at			5~4			
	Age 6 Years						
5	Influence of	n= 149	Secondary	7–11-year-olds who	not mentioned	Extended periods of	Higgins et al,
	exclusive	11 11/	Data	participated in one of five	not inclinioned	-	2022,
						exclusive breastfeeding were	
	breastfeeding		Analysis	studies that assessed neural		correlated with increased	USA <sup>[8]</sup>
	on		Report	responses to food cues.		grey matter volumes in both	
	hippocampal		_			hippocampal regions	
						improcumpui regions	
	structure,			V	N/		
	satiety			V			
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<u> </u>	status.		NT	7 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		***	D
6	Human Breast	not	Narrative	Included publications	not mentioned	Human breast milk plays an	Dimitroglou,
	Milk: The Key	specifi	review	exploring the roles of		essential role in conferring	et al,
	Role in the	ed		Human Breast milk in the		passive immunity, fostering	
	Maturation of			development of VPIs (very		optimal gastrointestinal	2022, Athens,
						2 0	
	Immune,			pre-term infants aging <32		development, and	Greece [9]
	Gastrointestin			weeks of gestation).		facilitating neurological	
	al and Central					maturation, all of which	
						contribute to the overall	
	Nervous						
	Systems: A					health and resilience of the	
	Narrative					infant.	
	Review						
	IXC VICW						
7	Influence of	n= 536	Observatio	Infants < 6 months of age	At 2 & 6 months of	BF infants had higher global	Gilbreath et
	exclusive		nal Cohort	who were fed with Breast	age	beta and gamma power at	al, 2023,
					"5"	both 2 and 6 months. This	USA <sup>[10]</sup>
	breastfeeding		Study	milk, Soy formula, and EEG			USA
	on			recordings		variation was also noted in	
	hippocampal					source space, suggesting	
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English language.		mother-infant			English language.		risk of infections, obesity,	[18]
dyad allergies, and chronic							-	
diseases. For mothers, it		<i>y</i>					_	
supports faster postpartum								
recovery, aids weight loss,							_	
reduces risks of breast and							reduces risks of breast and	
ovarian cancers and heart							ovarian cancers and heart	
disease, and strengthens							disease, and strengthens	
emotional bonding.							_	
Together, these benefits	1						_	
							_	
foster a positive mother-			I	I	İ		_	
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	1.5		201	01	T 1/1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	0.11	infant relationship	0 0
	16		n=381	Observatio	Initial recruitment at 9 & 10	Collection of	The duration of	González et
associations Prospectiv Follow up after 2 years, 11- duration data at a positive association with Angeles,	16	breastfeeding	0	nal	years of age	Breastfeeding	The duration of breastfeeding demonstrated	al, 2025, Los

	1	1	1			ue 10 October 2025   ISSN: 2	
	with brain		e	12 years of age	specific intervals, 0,	cortical thickness in 31	USA <sup>[19]</sup>
	structure and		ongitudina		1–6, 7–12, and >12	regions, surface area in 45	
	cognition		l cohort		months.	regions, and fluid cognition	
	from late					(all p values $< 0.05$ ).	
	childhood to					Additionally, greater cortical	
	early					myelin was observed in four	
	adolescence					· ·	
	adolescence					regions and increased at	
						follow-up in 12 regions (all	
						p values $< 0.05$ ). The	
						relationship between	
						breastfeeding and fluid	
				and the second second		cognition was mediated by	
			A Comment			surface area ( $\beta = 0.008$ ,	
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17	Descritording		Observatio	Dontininanta vyana shildran	not mentioned	In this cohout study	Goldshtein et
17	Breastfeeding	n=	All and the second seco	Participants were children	not mentioned	. In this cohort study,	
		570532	nal	born between January 2014		exclusive or extended	al,
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	Development	n	ve cohort	least 35 weeks' gestation		with lower odds of	[20]
			study	without severe morbidity		developmental delays as	
				and with at least 1 follow-up	4	well as language or social	
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10	F1 '	- 260	C	Infantal All TYPAN	A+ 121 - C	Dealer of the second	English 1
18	Exclusive	n=269	Cross-	Infants born with FTNVD	At 12 months of age	Exclusive breastfeeding	Ford et al,
	breastfeeding		sectional	Moderation analyses using		(EBF) was significantly	2025,
	modifies the		study	the Mann-Whitney test	10 10	associated with higher	Brazil <sup>[21]</sup>
	association		4	examined the effect of EBF		cognitive ( $p < 0.01$ ),	
	between			at 6 months (effect modifier)		language ( $p < 0.02$ ), and	
	maternal			on the relationship between		Bayley Global Scores (BGS)	
	education and			Bayley-III cognitive,		(p < 0.001). EBF altered the	
	child			language, and motor scores,		impact of low maternal	
						_	
	development:			as well as Bayley Global		education (defined as less	
	a cross-			Score (BGS) (outcomes),		than 10 years and 10–12	
	sectional			and maternal education	10	years of education) on both	
	study nested			(independent variable).		cognitive scores and BGS.	
	in a cohort					In mothers with more than	
						10 years of education, EBF	
						was linked to a large effect	
				V	W	size on the Bayley Global	
					37		
						Score $(r = 0.51)$ and a	
						medium effect size in the	
						cognitive domain ( $r = 0.38$ ).	
19	Breastfeeding	n=	Systematic	Systematic literature	not mentioned	There was no clear threshold	Patnode et
	and Health	ESRs	Review	searches in MEDLINE,		of Breastfeeding duration	al,2025,
	Outcomes for	existin	,	Embase, and CINAHL for		that appeared to be most	Portland,
	Infants and	Î .				beneficial for any outcome	, , , , , , , , , , , , , , , , , , ,
		g		English-language articles		beneficial for any outcome	Oregon,
	Children: A	system		published from 2006 to			USA <sup>[22]</sup>
	Systematic	atic		August 14, 2024.			
	Review	review					
		) =29					
		Primar					
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		studies					
20	5	=145	D :	CIL 1 1 1		D (C 1) 1 1 1 2	D 11 1
20	U	n= 190	Review	Clinical studies, systematic	not mentioned	Breastfeeding has significant	Purkiewicz et
	The	articles	study	reviews, and meta-analyses		positive effects on both child	al,
	Multifaceted			were included.		development and maternal	2025, Poland,
1	Impact on					well-being, impacting	Europe <sup>[23]</sup>
			•	1	i .		i

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Child					various aspects from	
Development					neurological development	
and Maternal					and immune function to	
Well-Being					emotional and physical	
					health	

# 3.2 Global Distribution of Studies

The included studies encompassed research from a global perspective, with the United States contributing the largest proportion of publications. Of the 20 studies reviewed, eight (40%) originated from the U.S., followed by three from Brazil (15%), two each from Poland and Switzerland (10% each), and one each from Canada, Greece, Australia, China, and Israel (5% each).

The predominance of U.S.-led research underscores significant investigation into the neuroprotective effects of breast milk within that country. Brazil emerged as the second most active contributor, indicating growing research engagement. Switzerland and Poland also made notable contributions, while countries such as Israel, China, Greece, Canada, and Australia were represented by single studies.

Overall, the geographic distribution demonstrates concentrated research activities in the United States and Brazil, with fewer studies emerging from other regions. This disparity underscores the need for increased research efforts in underrepresented areas to enhance the evidence base and ensure broader global relevance. Currently, the landscape remains weighted toward higher output from the United States and Brazil.

#### 3.3 Evaluation metrics

The studies reviewing Breast milk and its influence on Neurocognitive development have applied multiple psychological test batteries, such as the Mann-Whitney Test, Bayley Global Scores, Area Deprivation Index (ADI), Early Childhood Development Questionnaire, Child Psychological Development Scale, medical imaging techniques like MRI scans, and electronic graphing tools including EEG, Spectro-microscopy, and gene ontology, as evaluation metrics for assessing neurocognitive abilities in human models. The neuropsychological domains assessed encompassed language milestones, socio-emotional maturity, fine motor skills, visual motor abilities, behavior, executive function, and eating behaviors. Additional advanced domains evaluated included hippocampal structure, fluid cognition, fractional anisotropy, total cortical surface area, total brain measures, and milk proteomics.

# 3.4 Summary of main findings

This systematic review and comprehensive analysis examined the impact of Breast milk on Neurocognitive domains of development. The review encompassed studies from the past five years, including 7 narrative reviews, 6 observational studies, 3 secondary analysis reports, 1 systematic review, and 3 cross-sectional studies.

We observed consistent evidence suggesting Breastfeeding, particularly exclusive and prolonged Breastfeeding, is positively associated with improved Neurocognitive outcomes in children. These findings reinforce existing recommendations for Breastfeeding in infants, highlighting its beneficial impact on higher brain functioning and decreasing the likelihood of developmental delay. While the magnitude of benefit may vary depending on genetic, socioeconomic, and environmental factors, most studies indicate that children who receive Breast milk tend to show better performance in measures of intelligence, fine motor milestones, language development, and academic achievement compared to those who are formula-fed. Additionally, the superiority of Breast milk in lowering adiposity indices, as well as increased cortical and subcortical gray matter volume and greater cortical surface area during peri-adolescence, underscores its crucial role in achieving optimal Neurocognitive outcomes during adolescence. The variability in demographic characteristics, testing times, and the diversity of assessments employed further complicated the analysis of this outcome. However, residual confounding factors (such as maternal education and home environment) cannot be completely excluded, and further high-quality longitudinal research is warranted to establish causal pathways.

# 3.5 Implications for practice

This systematic review provides robust support for current Breastfeeding recommendations, emphasizing its positive effects on cognitive abilities and reduced risk of neurodevelopmental disorders. Notably, our analysis demonstrates a clear association between Neurocognitive health and Human milk, a relationship that is increasingly concerning in the context of rising neurobehavioral disabilities. Recognizing breastfeeding as a modifiable determinant, it becomes imperative to enhance parental awareness of its neurodevelopmental benefits and to implement evidence-based strategies that increase breastfeeding prevalence, thereby mitigating associated risks

As Breastfeeding represents a modifiable factor, it is essential to educate parents on its neurodevelopmental benefits and to actively promote strategies that encourage increased Breastfeeding rates, which may serve to mitigate the associated risks.

# 4. CONCLUSION

The available evidence from a systematic review indicates that Human Milk plays a beneficial role in supporting Neurocognitive development in infants, particularly during the critical early years of life. Breastfed infants generally demonstrate modest but consistent advantages in measures of cognitive performance, language development, and academic achievement compared to those fed with formula. These benefits appear to be mediated not only by bioactive nutrients such as long-chain polyunsaturated fatty acids, oligosaccharides, and growth factors, but also by the psychosocial and environmental context of Breastfeeding. However, the magnitude of effect varies across studies due to differences in methodology, confounding variables (such as maternal education and socioeconomic status), and length of follow-up. While current evidence supports Breastfeeding as a positive influence on neurodevelopment, further high-quality, longitudinal studies are needed to disentangle biological effects from sociodemographic factors and to clarify the long-term impact into adolescence and adulthood.

# 5. RECOMMENDATIONS

Implement randomized controlled trials where ethically possible (e.g., donor milk vs. formula in preterm infants) to establish causality rather than association. Examine how exclusivity, duration, and timing of Breastfeeding relate to Neurocognitive outcomes. Use experimental and animal models to clarify the biological pathways through which Human Milk impacts the brain. Furthermore, determining the minimum duration of Breastfeeding needed for measurable benefits may authenticate future research. Carefully account for socioeconomic status, parental IQ, maternal education, and home environment, which strongly influence cognitive outcomes. Use consistent, validated Neurocognitive assessment methods to improve comparability across studies. Finally, conducting large-scale, long-term follow-up studies to track cognitive outcomes from infancy through adolescence and into adulthood would enhance the credibility of the research.

# 6. AUTHOR CONTRIBUTIONS

Conceptualisation S. A. A.; Methodology S. A. A.; Data curation and review, S. A. A., V. P.; Writing—original draft preparation, S. A. A.; Supervision, HP.S. All authors have read and agreed to the published version of the manuscript.

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