Review Article

The Impact of Breastfeeding on Auditory, Speech, and Language Development: A Narrative Review

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Running title: The Importance of Breastfeeding on The Auditory System

Abstract

Introduction: The type of feeding has different effects, and the effects of breastfeeding on the auditory system, speech and language has also been confirmed. The aim of this study is to provide a comprehensive review of various studies conducted on the effects of different feeding types on the auditory system, speech and language.

Materials and Methods: A narrative review was conducted using PubMed, Scopus, Medline, Web of Science, Google Scholar, ScienceDirect, and the Cochrane Library to identify English-language studies on the effects of feeding type on auditory, speech, and language development. A total of 57 studies published between 1981 and 2025 were identified and selected based on predefined inclusion criteria, and the findings were synthesized to evaluate developmental outcomes

Results: Breastfeeding has different effects on various aspects of hearing, speech, language, and cognition in children compared to formula feeding. Breastfeeding, as a protective factor against middle ear. Breastfeeding is associated with better speech and language development, including

verbal intelligence, better receptive and expressive language, improved language skills, and the natural development of oral-motor skills necessary for speech production.
Conclusion: As the optimal source of nutrition for infants, breast milk not only meets physical and motor needs but also contributes to optimal functioning of the peripheral and central auditory systems. It plays a significant role in enhancing communication skills, speech and language development, and related abilities.This review is limited by its narrative design and the heterogeneity of existing studies; future research should employ standardized, longitudinal methodologies to clarify causal mechanisms.
Keywords: Auditory system; Breastfeeding; Bottle feeding; Formula feeding; Speech, Language

Introduction

Breast milk is a dynamic and bioactive fluid uniquely designed for optimal nutrition and growth of the human infant (1, 2). Colostrum, the initial milk produced after birth, is rich in immunological components such as secretory immunoglobulin A (IgA), lactoferrin, leukocytes, and growth factors such as epidermal growth factor(3). Breast milk contains macronutrients, including proteins (e.g., casein, α-lactalbumin, lactoferrin, and immunoglobulins) (4, 5), fats (providing 50% of the milk's total energy), and carbohydrates (mainly lactose, which provides 40% of the energy) (6). It also includes micronutrients such as vitamins (A, B1, B2, B6, B12, D, and iodine, which depend on the mother's diet) (2), as well as minerals, digestive enzymes, hormones, immune cells (e.g., macrophages), and bioactive molecules such as oligosaccharides that promote infant health and survival(1, 2).

This biological fluid contains bioactive factors with antiseptic properties that protect against infections (1, 2, 7). Additionally, the fatty acids in breast milk play a key role in regulating growth, inflammatory responses, immune function, vision, and cognitive and motor development (1). Lactoferrin, a sialic acid-rich, iron-binding milk glycoprotein, plays a role in modulating immune system function and facilitating iron absorption, as well as having antibacterial and anti-inflammatory effects(8) Lactoferrin protects the developing brain from neuronal damage, promotes neural connections and neurotrophin production, and reduces oxidative stress. Breast milk oligosaccharides have also been linked to infant neurodevelopment; total levels as well as specific types of fucosylated (when containing fucose) and sialylated (when containing sialic acid) HMOs have been positively associated with cognitive, language, and motor domains at 18 to 24 months of age. Specific HMOs can influence the functional maturation of the developing brain in myelination. Lactoferrin in breast milk is significantly higher than in cow's milk, and the frequency of feeding is also important in infant cognitive development(8)

Lactoferrin protects the developing brain from neuronal injury and enhances brain connectivity and neurotrophin production.(9) Bovine milk fat globule membrane supplementation is significantly associated with improved cognitive development.(10) Clinical data from the last decade support the importance of MFGM and docosahexaenoic acid for improved neurodevelopmental outcomes.(11) A recent randomized trial protocol aims to test whether MFGM enriched formula improves cognitive development compared with standard formula.(12) Postnatal high docosahexaenoic acid diets altered auditory brainstem responses in juvenile rats.(13) Neurotrophins such as BDNF and NT-3 are essential for the development and maintenance of auditory pathways; NT-3 is specifically required for the formation and preservation of cochlear hair-cell ribbon synapses.(14) Moreover, the maturation and fidelity of auditory-nerve activity depends on adequate BDNF signaling, which supports precise sound-evoked neural responses.(15)

Exclusive breastfeeding for the first six months of life not only provides optimal nutrition (5) but also reduces the risk of later metabolic diseases such as obesity and type 2 diabetes (16). Numerous growth factors in breast milk support intestinal maturation and repair, nervous system development, and anemia prevention.(2) Studies have shown that higher breast milk intake is associated with higher IQ, better mathematical ability, and stronger working memory at age 7. Brain imaging also confirms that breastfeeding is associated with increased gray matter volume in deep brain regions, such as the thalamus and hippocampus, which act as primary relay stations. (17) Furthermore, breastfeeding strengthens emotional mother-infant interactions (1), and breastfeeding mothers typically spend more time nurturing their infants (18), which further supports neurological and cognitive development(17).

Formula milk is an industrial substitute for breast milk designed to mimic its nutritional composition. It is fortified with ingredients such as iron, nucleotides, and blended fat compounds to meet infants' nutritional needs. Formula milk is available in three forms: powdered, concentrated liquid, and ready-to-use, and must contain appropriate amounts of water, carbohydrates, proteins, fats, vitamins, and minerals. Infant formulas are divided into three main categories: 1) cow's milk-based formulas typically contain intact cow's milk proteins (whey and casein), lactose as the carbohydrate source, and a blend of vegetable oils for fat, together with added vitamins and minerals, 2) Soy-based formulas do not contain cow's milk proteins and lactose.(19) Their protein source is soy protein isolate supplemented with methionine, carnitine and taurine; fat is mainly provided by vegetable oils and docosahexaenoic acid (DHA) and arachidonic acid (ARA) are added to all soy formulas; and 3) specialized formulas such as extensively hydrolyzed (eHF) are composed of short peptides and free amino acids obtained by enzymatic hydrolysis. These types of formulas are the first choice in children diagnosed with cow's milk allergy, and amino acid formulas (AAF) provide protein in the form of free amino acids without any peptides.(1, 20, 21) However, compared to breast milk, cow's milk contains higher levels of fat, protein, and minerals and lacks the immune cells and bioactive factors present in breast milk, though it is suitable for most healthy, full-term infants (1).

Given the negative impacts of hearing, speech, and language disorders on social interactions,(22) learning, and quality of life (23), early identification and diagnosis of these disorders are of critical importance(24, 25). Since the development of hearing, speech, and language systems begins in infancy, examining influential factors during this period, such as the type of infant feeding (breast milk or formula milk), can play a significant role in preventing or reducing potential disorders. Therefore, this article provides a review of studies on the impact of breastfeeding on the auditory system, speech, and language. Although the beneficial nutritional and immunological effects of breast milk are well established, studies investigating its effect on the development of hearing, speech, and language have been sparse, disjointed, and for the most part focussed on general developmental outcomes rather than on specific neurobiological substrates. To our knowledge, no review has considered data regarding the potential impact on - and pathways linked to - auditory maturation and early speech-language outcomes of key bioactive components of breastmilk (e.g., lactoferrin, human milk oligosaccharides, long-chain polyunsaturated fatty acids, and milk fat globule membrane). Hence, this narrative review is going to close this gap by integrating research in nutritional neuroscience, auditory physiology, and developmental language from the last four decades.

Materials and Methods

A narrative review was conducted utilizing Medline (PubMed), Google Scholar, Science Direct, and the Cochrane Library, with no time limitations. The search terms included: “breastfeeding AND auditory system,” “breastfeeding AND speech,” “breastfeeding AND language,” “formula feeding AND auditory,” “formula feeding AND speech,” “formula feeding AND language,” “bottle feeding AND auditory system,” “bottle feeding AND speech,” “bottle feeding AND language,” “auditory system,” “speech,” and “language.” Beyond the database searches, we examined the references of chosen articles to confirm that all pertinent studies were included. All articles identified through this method were evaluated, and a subset was selected based on these criteria: articles with available abstracts or full texts, articles pertaining to the auditory, speech, and language systems, and articles written in English.
Initially, we selected 94 relevant papers.
From this collection, we purposefully sampled 57 papers that were most pertinent to the topic of the effects of type of feeding on the auditory system, speech and language, ensuring they met our inclusion criteria (Figure 1). This thorough search and selection process enabled us to compile a strong body of literature, enhancing our understanding of how breastfeeding impacts the health of auditory, speech and language systems.

Results and Discussion
Breast milk contains essential fatty acids, antioxidants, and growth factors that generally support brain development (1). Therefore, it is expected to impact various parts of the auditory and speech-language systems. Below, we separately examine the effects of breast feeding on the auditory and speech-language systems.

Effects of Breastfeeding on the Auditory system
Effect of breastfeeding on peripheral auditory system
Breastfeeding may contribute to better hearing by improving the condition of the middle ear and reducing the risk of middle ear infections(26). A study by Garcia et al. (2012) showed breastfed infants had a higher chance of normal outcomes in ENT assessments and tympanometry tests (27) As a result breastfeeding is breastfed seemed to be a protective factor for the middle ear changes, probably by lessening infections and bettering the function of the Eustachian tube(28).
Bowatte et al. (2015) (29) provided evidence that breastfeeding, particularly exclusive breastfeeding for up to six months, can protect children up to two years of age against acute otitis media (AOM), reducing the risk by up to 43%. The mechanisms behind these benefits are multifaceted. From an auditory perspective, breast milk contains immunogenic components such as IgA, which protects against middle ear infections (30). Additionally, the body position during breastfeeding may improve Eustachian tube function, reducing the risk of fluid accumulation in the middle ear(28).
Research indicates that breastfeeding can improve outcomes in auditory tests, such as Transient Evoked Otoacoustic Emissions (TEOAEs), in infants and children(27, 28). For instance, a study on healthy infants born vaginally with a gestational age >37 weeks and body weight >2.5 kg found that the failure rate in TEOAE tests within the first 48 hours of life was lower in breastfed infants compared to formula-fed infants(28).

Effect of breastfeeding on central auditory system
A study on 100 apparently healthy infants aged 4–6 months showed that Auditory Brainstem Response (ABR) results indicated statistically significant delays in the absolute latency of waves

III and V in formula-fed infants compared to breastfed infants. This may be due to earlier auditory brainstem maturation in breastfed infants, as breast milk contains a complete set of unsaturated fatty acids, including DHA and ARA, which promote brain and auditory brainstem maturation. Additionally, there was a statistically significant increase in mean interpeak latencies of waves I-III, III-V, and I-V in both ears of formula-fed infants compared to breastfed infants. This could be due to a delay in the transmission of auditory signals in the lower brainstem, possibly due to a delay in brainstem maturation in formula-fed infants compared to breast-fed infants(31).

A study by Alatorre-Cruz et al. (2023) investigated infants fed with breast milk (BF), cow's milk-based formula (MF), and soy-based formula (SF) at 3, 6, 9, 12, and 24 months using the Mismatch Negativity stimulus. Behavioral differences in auditory perception were observed at 24 months. In a phonological discrimination task, Event-Related Potentials (ERPs) analysis showed that the SF group exhibited an electrophysiological pattern associated with difficulties in phonological stimulus awareness. The SF group also showed greater right-hemisphere involvement in phonological processing at 12 months. The researchers concluded that prolonged and repeated use of soy formula may result in language development that is different from that observed in the BF or MF groups. The composition of soy formula may affect the development of the left frontal lobe, a nodal area of the brain involved in phonological stimulus awareness(32).

In a study by Maria Angela Guzzardi et al (2020), it was found that exclusive breastfeeding for at least the first six months was strongly associated with higher auditory and language scores in five-year-old girls. This effect was gender-specific, being significant in girls but not in boys. Exclusive breastfeeding for the first three months was sufficient to predict higher auditory-linguistic development in girls. Additionally, infants exclusively breastfed gained less weight between three and six months compared to non-exclusively breastfed infants, and greater weight gain during this period was associated with poorer auditory and language development at five years(33). In the study by Pivik et al., infants' brain responses and central auditory processing to speech sounds were examined using ERP. The results showed that breast-fed infants had a higher ability to discriminate syllables, whereas there was no significant difference between infants fed cow's milk formula or soy formula. The results suggest that although breast milk has a clear advantage in speech sound processing compared to formula, there was no difference between cow's milk and soy formulas in terms of supporting brain development and function.(34)

Although the addition of cow's milk fat globule membrane (bMFGM) or bMFGM components to infant formula may aid in language development for cognitive maturation in early life. MFGM is a combination of many components that are involved in myelination, signaling, and thus circuit formation, including sphingomyelin, gangliosides, sialic acid, and cholesterol.It was found that infants who received bovine MFGM added to their formula showed shorter P1 latency in the auditory ERP test compared to those who received standard formula. These results can be interpreted as a higher degree of myelination and improved connectivity of the brain region, which in turn leads to increased efficiency in perceiving a specific and distinct stimulus (35). Although there are a few pieces of research that do not support the above conclusion. For example, the study by Garon-Carrier et al. indicates that exclusive breastfeeding or the duration of breastfeeding has little to no effect on cognitive abilities in the early stages of life. The only notable change being a very small enhancement in the short-term memory of a few children.(36)Similarly, Der et al. showed that once maternal intelligence and other major confounders are properly accounted for, breastfeeding hardly has any impact on children's intelligence.(37) In addition, a regional systematic review from sub-Saharan Africa (Mohammed et al.) reported that after socioeconomic

confounding was controlled for, there was no relationship between breastfeeding and cognitive or educational outcomes (38).

Effects of Breastfeeding on the Speech and Language System

Genetic and environmental factors are key determinants of a child's language development(39). Among environmental factors, breastfeeding's impact on language development has been studied in several studies, and the relationship between breastfeeding duration(40) and exclusive breastfeeding with child language development has been confirmed(41-43). Closer interactions during breastfeeding may strengthen the mother-child bond(1, 18) and stimulate cognitive and communicative development(17).

Language development during the first two years of life is associated with brain growth and the maturation of neural circuits connecting Broca's and Wernicke's areas (the fronto-temporo-parietal language system) (44). Language skills in children up to four years can be influenced by the type of feeding in the first 18 months and, to a lesser extent, by socioeconomic status (45). A study by Deborah L. Dee et al. (2007) found that breastfeeding, especially exclusive breastfeeding, is associated with improvements in language and motor skills in early childhood (43).

Studies have shown that breastfed infants perform better in terms of language development, stimulus processing, and IQ during the first year of life compared to formula-fed infants (46). Various studies have also reported that breastfed infants aged five to seven years have greater white and gray matter volume in the right and left parietal lobes and the left temporal lobe, and increased activity in the right frontal and left temporal lobes (47-49).

Goel et al. (2025) emphasize that the duration and exclusivity of breastfeeding are critical, with breastfeeding linked to achieving language milestones, such as sentence formation and comprehension, in children aged 3–5 years (41). Belfort et al. (2013) found that longer exclusive breastfeeding leads to better receptive language at age three and higher verbal and nonverbal IQ at age seven (50). Exclusive and prolonged breastfeeding is associated with higher IQ and better cognitive development. Belfort's study demonstrated that longer durations of breastfeeding, especially exclusive breastfeeding, correlate with higher IQ levels in school-aged children, particularly verbal IQ (5). Thus, breast milk is recognized as the best nutritional source for infants, containing nutrients and non-nutritive bioactive factors not found in formula milk (17).

Formula feeding can also affect speech. Bottle feeding, especially with prolonged use of a pacifier, has been associated with an increased risk of speech disorders in preschool children. In contrast, breastfeeding supports the normal development of oral motor skills, which are essential for speech production(51). Mahurin-Smith and Ambrose (2013) reported a possible protective effect of breastfeeding against speech disorders and a reduced risk of persistent stuttering. Their study found that duration of breastfeeding was associated with persistent stuttering, and that increasing duration of breastfeeding reduced the likelihood of a child continuing to stutter (40).

Formula feeding, particularly with nutrient-enriched formulas, yields varied results. Nieto-Ruiz et al. (2020) showed that formulas containing DHA and ARA improve language skills in healthy children aged 3–5 years compared to standard formulas, with Oral Language Task of Navarra-Revised scores similar to those of breastfed children (45). Higher DHA levels are associated with greater cortical gray matter volume (52), which supports various language tasks (53). Studies report better language and communication skills in infants fed DHA-enriched formulas (54, 55).Although a large randomized controlled trial conducted by Makrides et al. revealed that increasing DHA intake to levels similar to human milk did not improve overall cognitive development. The authors concluded that higher DHA exposure does not lead to general neurodevelopmental advantages in this population.(56)

While the majority of the studies included in this review tend to indicate a positive correlation between breastfeeding and auditory or language skills, there are methodological discrepancies among them that contribute to inconsistent evidence. For instance, multiple studies have described a more rapid maturation of the auditory brainstem or enhanced ERP based phonological discrimination in breastfed babies, while other studies, mainly in the comparison between formulas based on cow's milk and soy, report negligible or no differences in central auditory processing. In a similar vein, the evidence for long-term language development is mixed, with some groups exhibiting strong dose-dependent effects of exclusive breastfeeding, while others emphasize the pre-eminent effect of SES/environmental factors. These differences may be due to variations in study design, definitions of feeding, characteristics of the samples, and the degree to which confounding factors such as maternal education, nutritional supplementation of formulas were accounted for. Thus, despite an overall trend favoring breastfeeding, the evidence is mixed and suggests that more stringent, standardized and mechanistically focused approaches are needed to elucidate the mechanisms by which early feeding influences the development of auditory and speech-language.

Summary of studies on the effect of feeding on the auditory system,speech and language has been shown in table1.

Table 1. summary of studies on the effect of feeding on the auditory system,speech and language.

Number	Author	Year	Study Design	Type of feeding	Population sample size and age range	Main findings
1	Deborah L.Dee et al(43)	2007	Cross-sectional observational study	Breastfeeding	N=22399 children (10-71 months)	Breastfeeding prevents delays in the development of children's language and motor skills.
2	Dr. Doa'a Ramili et al.(57)	2011	Retrospective case-control observational study	breastfeeding	N=100 children (<12 years)	duration of breastfeeding is not directly related to severe to profound hearing impairment.
3	Michele Vargas Garcia et al.(27)	2012	Observational comparative study	Breastfeeding and Bottle feeding	N=60 Infants (0-4 months)	Breastfed infants were more likely to have normal tympanometry and normal ear evaluations than bottle-feed or mixed-feed infants.
4	Jose Miguel Sequi-Canet et al.(28)	2020	Retrospective observati	Breastfeeding and Bottle feeding	N=12866 Newborns (up to 2 days)	Breastfeeding results in better OAE outcomes compared to bottle feeding.

			onal study			
5	Ana Nieto-Ruiz et al (45)	2020	Prospective, randomized, double-blind study	Breastfeeding and Formula feeding	N=122 children (4 years)	Children fed standard formula are at higher risk of suffering language development disorders compared to breastfed children.
6	Maria Angela Guzzardi et al.(33)	2020	Prospective cohort study	Breastfeeding and Formula feeding	N=90 Girls (5 years)	Exclusive breastfeeding is relative to higher hearing and language outcomes in five-year-old girls.
7	Eman M. Sayed et al.(31)	2021	Case-control design	Breastfeeding and Formula feeding	N=100 Infants (4-6 months)	According to ABR results, the nervous system of breastfed infants matures better and earlier in the first six months of life compared to formula-fed infants.
8	GC. Alatorre-Cruz et al (32)	2023	Longitudinal, observational cohort study	Breast milk Cow-milk-based formula and soy-based formula	N=364 Infants (3-24 months)	Long-term and repeated use of soy formula may cause different language development compared to infants fed with breast milk or cow-milk-based formula. The composition of soy formula may affect the development of the left frontal lobe, a nodal region of the brain involved in the awareness of phonological stimuli.
9	Yan Wang et al.(30)	2024	Correlational(case-control) observational study	Breastfeeding and Formula feeding	N=162 children (≤6 years)	Breastfeeding reduces the risk of OME infections.
10	Malika Goel et al (41)	2025	Retrospective cohort analysis	Breastfeeding	N=22866 children (3-5 years)	Breastfeeding up to 6 months, even if not exclusive, shows a positive association with the development of language variables.

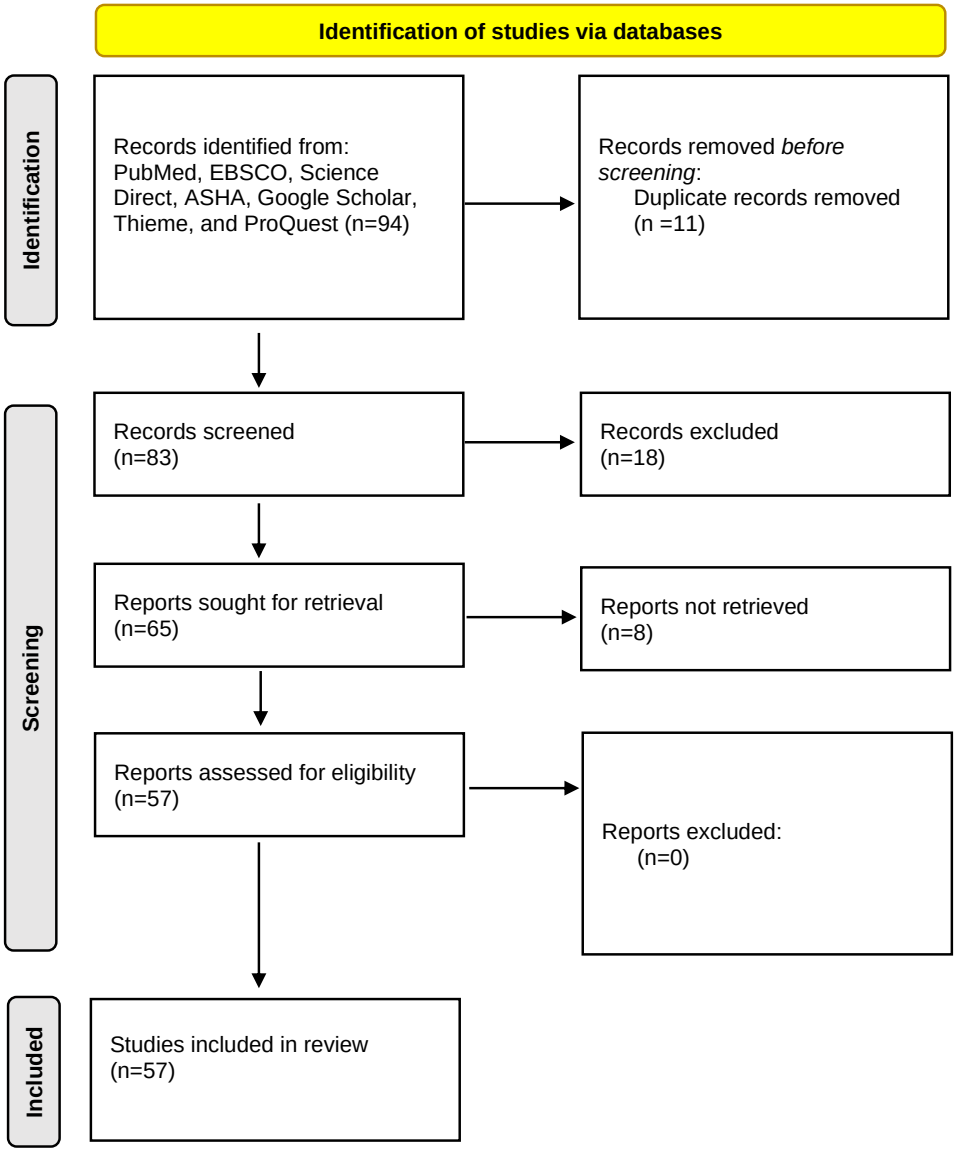

Figure 1. The flow diagram

Conclusion

Whereas some research has implied that breast-feeding and formula feeding might have similar effects, numerous scientific findings make the case that breast-feeding is more beneficial than formula feeding. However, the influence of breast-feeding versus formula feeding on language development in children is a matter of complexity and is determined by factors like genes, the environment, and the social and economic status of the family.

It is first of all important to understand that breastfeeding leads to better outcomes in certain aspects of hearing and cognitive development than formula feeding. In particular, the differences involve a lower rate of middle ear infections, some improvements in auditory test performance, and relations with higher IQ and general cognitive abilities, especially in the language and auditory

areas. Moreover, a few results have led to the proposal of gender-related differences, which still have to be investigated further.
On the whole, evidence exists that supports the beneficial role of breast milk in hearing and brain development. However, the researchers concede that more studies are required to confirm and elaborate on these effects.

Limitations and Future Directions
The review presented here is mostly narrative and relies on interpretative descriptions rather than on quantitative synthesis. As a result, the statistical power of the conclusions drawn is limited. The studies included in the review might have various biases, for example, selection bias and inadequate control of socioeconomic or genetic factors, thus leading to uncertainty in the reported associations. Besides, there is considerable methodological heterogeneity in the studies which limits the possibility of quantitatively combining the findings.
Subsequent research should use uniform, longitudinal, and multicenter designs with strict control of confounding variables to unveil the developmental effects of breastfeeding more accurately. The researchers should also probe into the biological basis of the beneficial delivery of breast milk components—such as bioactive compounds, DHA/ARA, immune factors, and neuromodulatory substances—to give more evidence for causation.
Moreover, upcoming research should be striving to use objective auditory measures (e.g., ABR, OAE, ERP) along with behavioral language assessments to get a fuller evaluation. Ensuring that there are studies done in different populations and looking at the moderating factors such as maternal health, feeding practices, and early auditory experiences will also deepen the generalizability of the results. On a policy level, it is still essential to reinforce global programs that facilitate exclusive breastfeeding and make maternal education and lactation resources.

Authors' Contributions
Conceptualization: Nasrin Gohari, Bita Ghorbani Aghdam. Data curation: Nasrin Gohari, Bita Ghorbani Aghdam. Formal analysis: Nasrin Gohari. Investigation: Nasrin Gohari, Bita Ghorbani Aghdam Methodology: Nasrin Gohari, Bita Ghorbani Aghdam. Project administration: Nasrin Gohari, Bita Ghorbani Aghdam. Supervision: Nasrin Gohari, Bita Ghorbani Aghdam. Validation: Nasrin Gohari, Bita Ghorbani Aghdam, Mahdi Khoshfetrat. Visualization: Nasrin Gohari. Writing—original draft: Nasrin Gohari, Bita Ghorbani Aghdam. Writ-ing—review & editing: Nasrin Gohari, Bita Ghorbani Aghdam, Mahdi Khoshfetrat. Approval of final manuscript: Nasrin Gohari, Bita Ghorbani Aghdam, Mahdi Khoshfetrat.

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