REVIEW ARTICLE

1. School of Medicine, Universidad Ricardo Palma. Lima, Peru.
a. Medical student. ORCID: https://orcid.org/0009-0009-7836-6241

Correspondence::
María del Pilar Zavala Guillen
zavalaguillenmariadelpilar@gmail.com

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Relationship between maternal malnutrition and neurodevelopmental delays in infants

Relación entre la malnutrición materna y el retraso en el neurodesarrollo en lactantes

María del Pilar Zavala Guillen[1,a]

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ABSTRACT

Infant neurodevelopment is especially vulnerable to nutritional deficiencies during gestation, a stage in which the brain depends entirely on maternal nourishment for its structuring and maturation. The objective was to identify the relationship between maternal malnutrition and neurodevelopmental delay in infants. A systematic review was conducted by searching for scientific articles related to the topic. The research question used was: What is the relationship between maternal malnutrition and neurodevelopmental delay in infants? Population: Infants, Exposure: Maternal malnutrition, Outcome: Neurodevelopmental delay. The search sources were PubMed, Scopus, SciELO, and Google Scholar. Articles published between 2020 and 2025 were selected. Of the 178 articles found, 149 were excluded for not meeting our inclusion criteria. 29 contained information on the topic, of which 19 were used as a theoretical and conceptual framework, and 10 were used for the systematic review. Maternal nutrition during pregnancy is a key determinant of neurodevelopment, with adequate dietary quality associated with better outcomes and malnutrition with a higher risk of developmental delay.

Keywords: Infant, Maternal Nutritional Physiological Phenomena, Neurodevelopmental Disorders (source: MeSH)

RESUMEN

El neurodesarrollo infantil es especialmente vulnerable a las deficiencias nutricionales durante la gestación, etapa en la que el cerebro depende completamente del aporte materno para su estructuración y maduración. El objetivo fue identificar la relación entre la malnutrición materna y el retraso en el neurodesarrollo en lactantes. Se realizó una revisión sistemática mediante la búsqueda de artículos científicos relacionados al tema. Se utilizó la pregunta PEO:¿Cuál es la relación entre la malnutrición materna y el retraso en el neurodesarrollo de lactantes? Población: Lactante, Exposición: Malnutrición materna, Outcome (resultado): Retraso en el neurodesarrollo. Las fuentes de búsqueda fueron PubMed, Scopus, Scielo y Google Scholar. Se seleccionaron artículos publicados desde 2020 hasta 2025. De 178 artículos encontrados se descartaron 149 artículos por no cumplir con nuestros criterios de inclusión, 29 contuvieron información sobre el tema, de los cuales 19 fueron utilizados como base teórico-conceptual y 10 fueron utilizados para la revisión sistemática. La nutrición materna durante la gestación es un determinante clave del neurodesarrollo, asociándose una adecuada calidad dietaria con mejores resultados y la malnutrición con un mayor riesgo de retraso.

Palabras clave: Lactante, Fenómenos fisiológicos maternos nutricionales, trastornos del neurodesarrollo (fuente: DeCS)

Introduction

According to the World Health Organization (WHO), the term "malnutrition" refers to deficiencies, excesses, or imbalances in caloric or nutrient intake[1]. In the context of pregnancy, this nutritional imbalance implies an inadequate intake to meet the metabolic demands of the pregnant woman and ensure proper fetal development[2].

Neurodevelopment, meanwhile, is a complex biological process through which the central nervous system (CNS) progressively structures and matures, enabling the acquisition of cognitive, motor, sensory, emotional, and social functions[3, 4, 5]. This dynamic process is determined by the interaction of biological, environmental, and social factors[6].

Maternal nutrition plays a decisive role in the formation and maturation of the fetal CNS, as the nutrients ingested by the mother constitute the primary substrates for essential processes such as neuronal proliferation, cell differentiation, synaptogenesis, and myelination. Furthermore, it has been shown that maternal malnutrition is closely linked to structural and functional alterations in the developing brain, affecting regions such as the cerebral cortex, hippocampus, and cerebellum[7].

Globally, maternal malnutrition remains a public health problem, particularly in low- and middle-income countries. It predominantly affects regions in sub-Saharan Africa, South Asia, and Latin America, where it has also been linked to poverty, lack of access to health services, and gaps in nutrition education[8, 9, 10]. It is estimated that more than forty million women of childbearing age have a low body mass index, and that approximately one in three suffers from iron-deficiency anemia during pregnancy[8]. Carrera C, et al. describe maternal malnutrition as a problem frequently observed in public sector hospitals and health facilities[11].

In the Peruvian context, although there is evidence regarding the prevalence of and strategies for preventing and intervening in maternal-fetal malnutrition, its direct impact on neurodevelopment has been little studied[12, 13]. Uceda et al. note that Peru's status as a middle-income country, combined with low maternal educational levels and poverty, could exacerbate the negative effects on fetal health [14]. Likewise, the limited production of recent local evidence hinders the formulation of clinical guidelines, public health policies, and early intervention programs based on national data, which could be associated with the persistence of neurodevelopmental delays in children.

Therefore, the present study aims to identify the relationship between maternal malnutrition and neurodevelopmental delays in infants.

Search methodology

In this systematic review, we included articles in English and Spanish published between 2020 and 2025 from the search engines PubMed, Scopus, Scielo, and Google Scholar.

The clinical question used was: What is the relationship between maternal malnutrition and neurodevelopmental delay in infants?

PEO query: Population: Infant, Exposure: Maternal malnutrition, Outcome: Neurodevelopmental delay.

The keywords were as follows: Infant, Maternal Nutritional Physiological Phenomena, and Neurodevelopmental Disorders (DeCS), which were used in SciELO and Google Scholar; and Infant, Maternal Nutritional Physiological Phenomena, and Neurodevelopmental Disorders (MeSH), which were used in PubMed. This study addresses health priorities such as "Malnutrition and anemia due to deficiencies in the mother-child dyad during pregnancy and up to 36 months of age," according to the National Institute of Health (INS) Health Research Priorities 2024–2030, and is also included among the main lines of health research at Ricardo Palma University for 2021–2025 as "Maternal, Perinatal, and Neonatal Health."

- Inclusion Criteria
  - Articles in Spanish or English published in the last 5 years that include, through combinations of keywords, in the title or abstract: Infant, Maternal Nutritional Physiological Phenomena, Neurodevelopmental Disorders (DeCS) terms: Searched in Scielo and Google Scholar. Infant, Maternal Nutritional Physiological Phenomena, Neurodevelopmental Disorders (MeSH) terms: Used for PubMed and Scopus.
  - Studies with a population consisting of infants.
  - Studies with a population exhibiting neurodevelopmental delay
- Exclusion criteria
  - Studies with a population consisting of adolescents
  - Studies unrelated to our topic.

Development of the topic

Of the 178 articles identified, 149 were excluded for failing to meet our criteria regarding keyword combinations in the title or abstract, leaving 29 articles for our systematic review. Of the 29 selected, 10 articles contained research findings, and 19 were considered for theoretical and conceptual aspects.

Ten studies were included in this analysis. Table 1 presents the main characteristics of the 10 studies selected for the systematic review, covering the publication period from 2020 to 2025.

Table 2 presents the significance, strengths, and weaknesses of the 10 selected studies, covering the period from 2020 to 2025.

The studies included in the review showed the following:

Quin R, et al., China (2025) conducted a descriptive, prospective cohort study of births in Jiangsu, in which 3,750 mother-infant pairs were followed to assess the relationship between the mother's dietary iron intake during pregnancy and the infant's neurocognitive development at 12 months of age. No significant association was found with total iron intake (diet + supplements); however, heme iron intake did show a beneficial association, reducing the risk of "suboptimal cognitive development" in the infant by 35%. In conclusion, maternal heme iron intake may contribute to better cognitive development in infants[15].

Ouyang J, et al., China (2024) conducted an observational, analytical cohort study in which 1,423 families were recruited to determine the relationship between maternal dietary patterns and children's neurocognitive development at 36 months of age. It was found that children whose mothers followed a diet rich in protein and micronutrients during pregnancy showed better neurodevelopmental outcomes. In conclusion, consuming a balanced diet during pregnancy (especially adequate micronutrients and protein) as well as adequate iron intake may promote neurodevelopment in offspring[16].

Table 1. Titles, authors, and study designs of research studies related to the systematic review.

Authors	Tittle	Year	Country	Population	Design
Quin R, Pang L, Hu H, Jiang Y, Hong L, Ye K, Liu C, Xu X, Liu X, Zhou K, Jiang T, Du J, Hu L, Zhibin H, Shi Z, Lin Y	Associations of maternal dietary iron intake during pregnancy with infant neurodevelopment: evidence from prospective cohort study	2025	China	3750 patients	Descriptive, prospective, cohort
Ouyang J, Cai W, Wu Penggui, tong J, Gao G, Yan S, Tao F, Huang K	Association between Dietary Patterns during Pregnancy and Children's Neurodevelopment: A Birth Cohort Study	2024	China	1423 patients	Observational, analytical, cohort
Dai F, Wang P, Li Q, Zhang L, Yu L, Wu L, Tao R, Zhu P	Mediterranean diet during pregnancy and infant neurodevelopment: A prospective birth cohort study	2023	China	1471 patients	Analytical, prospective, cohort
Kou X, Becerra N, Canals J, Bulló M, Arija V	Association between Prenatal Dietary Toxicants and Infant Neurodevelopment: The Role of Fish	2024	Spain	460 patients	Cohort, prospective
Huamán E, Marmolejo D, Huamán M	Seguridad alimentaria nutricional y neurodesarrollo en niños menores de 3 años del Valle del Canipaco del Perú	2022	Peru	148 patients	Observational, analytical, cross-sectional
Na X, Glasier C, Aline A, Xiawei O	Maternal Diet Quality during Pregnancy Is Associated with Neonatal Brain White Matter Development	2023	USA	44 patients	Observational, cohort, longitudinal
Lauzon B, Marques C, Kadawathagedara M, Bernard J, Tafflet M, Lioret S, Aline M.	Maternal diet during pregnancy and child neurodevelopment up to age 3.5 years: the nationwide Étude Longitudinale Francaise depuis l´Enface (ELFE) birth cohort	2022	France	9992 patients	Prospective, longitudinal cohort
Motoki N, Inaba Y, Shibazaki T, Misawa Y, Ohira S, Kanai M, Kurita H, Teruomi T, Nomiyama T.	Insufficient maternal gestational weight gain and infant neurodevelopment at 12 months of age: the Japan Environment and Children's Study	2022	Japan	30 694 patients	Cohort, prospective
Canul A, Mendoza A, Solís J, Borboa H, Martinez S, Hernández C, Gil G, Osorio E, Torres M, Duárez B, Gonzales I, Rodriguez C, Rodriguez A, Reyes E, Camacho I, Hernández S, Perichart O, Estrada G	Maternal Overweight and Obesity Alter Neurodevelopmental Trajectories During the First Year of Life: Findings from the OBESO Cohort	2025	Mexico	97 patients	Cohort, prospective
Cruz J, Díaz A, Canals J, Arija V	Maternal VItamin B12 Status during Pregnancy and Early Infant Neurodevelopment: The ECLIPSES Study	2023	Spain	434 patients	Cohort, prospective

Table 2. Significance, strengths, and weaknesses of the research studies related to the systematic review.

Tittle of the study	Importance of the study	Strengths	Weaknesses
Associations of maternal dietary iron intake during pregnancy with infant neurodevelopment: evidence from prospective cohort study	Determine the relationship between the mother's dietary iron intake (heme and non-heme) in each trimester of pregnancy and the baby's neurocognitive development at 12 months of age.	The study has a large sample size, and a detailed assessment of the mothers' diets was conducted in each trimester of pregnancy.	Using the food frequency questionnaire (FFQ) risk of measurement error (over- or under-reporting)
Association between Dietary Patterns during Pregnancy and Children's Neurodevelopment: A Birth Cohort Study	Determine the relationship between maternal dietary patterns (the most prominent being protein and micronutrients) and the neurocognitive development of children at 36 months of age.	The study analyzed dietary patterns rather than a single nutrient, and the dietary assessment was conducted every quarter.	The study uses the Ages & Stages Questionnaire (ASQ-3), which is completed by parents, risk of perception bias.
Mediterranean diet during pregnancy and infant neurodevelopment: A prospective birth cohort study	Determines the relationship between the maternal Mediterranean diet during pregnancy and early neurodevelopment in 12-month-old infants, identifying a biological mechanism (C-peptide).	The study measured metabolites in cord blood, including C-peptide, cholesterol (HDL, LDL), and triglycerides, to explore mechanisms linking maternal diet and child development.	The study only evaluates the Mediterranean diet, and was only conducted between weeks 16-23. Furthermore, the FFQ and ASQ-3 were used, with the risk of measurement and perception errors.
Association between Prenatal Dietary Toxicants and Infant Neurodevelopment: The Role of Fish	To determine the relationship between prenatal exposure to dietary contaminants from fish and early childhood neurodevelopment. Demonstrating that excessive intake is linked to poorer outcomes in language development.	Estimated dietary contaminants for fish (arsenic, methylmercury, DL-PCBs, and non-DL-PCBs) were evaluated, and an early neurodevelopmental study was conducted (at 40 days after birth).	The estimation of dietary contaminants was not direct (maternal blood or tissues) and varies depending on the country. Due to the observational nature of the study, there is potential for residual confounding.
Seguridad alimentaria nutricional y neurodesarrollo en niños menores de 3 años del Valle del Canipaco del Perú	Determine the association between nutritional food insecurity and the neurodevelopment of children under three years of age, contributing to evidence in the Latin American population.	Multiple nutritional factors were analyzed (food insecurity, child nutritional status, maternal supplementation, among others), which provided a more integrated overview. Furthermore, the study was conducted in a community that has been little researched in Peru.	The study does not directly evaluate maternal nutrition in relation to development, but it does include "maternal supplementation" as a variable. Furthermore, it does not specify how neurodevelopment was evaluated.
Maternal Diet Quality during Pregnancy Is Associated with Neonatal Brain White Matter Development	To determine the association between the quality of the maternal diet during pregnancy and the development of cerebral white matter (using neuroimaging (white matter anisotropy fraction) in newborns.	Diffusion magnetic resonance imaging was used to evaluate the brain microstructure of the newborn, and dietary assessment was performed every three months.	The study has a small sample size and does not directly evaluate functional, cognitive, or behavioral domains.
Maternal diet during pregnancy and child neurodevelopment up to age 3.5 years: the nationwide Étude Longitudinale Francaise depuis l´Enface (ELFE) birth cohort	Determine the relationship between the overall quality of the maternal diet (based on the ELFE study) during pregnancy and the neurobehavioral development of children up to 3-5 years of age.	The study has a large sample size because it is a national cohort study, and it analyzes diet in general (rather than focusing on a single nutrient).	The use of the food frequency questionnaire (FFQ) carries a risk of measurement error (over- or under-reporting), and the parent-reported assessment of neurodevelopment carries a risk of perception bias.
Insufficient maternal gestational weight gain and infant neurodevelopment at 12 months of age: the Japan Environment and Children's Study	Determine the association between insufficient gestational weight gain (GWG) in the mother and the baby's neurodevelopment.	The study has a large sample size.	The study uses the Ages & Stages Questionnaire (ASQ-3), which is completed by parents, risk of perception bias.
Maternal Overweight and Obesity Alter Neurodevelopmental Trajectories During the First Year of Life: Findings from the OBESO Cohort	Determine the association between maternal pre-pregnancy weight status and the neuropsychomotor development of infants at 6 and 12 months of age.	The study conducted a longitudinal assessment, evaluating neurodevelopment at two time points (6 and 12 months).	The study has a small sample size, and pre-pregnancy maternal weight was self-reported, with a risk of measurement bias.
Maternal VItamin B12 Status during Pregnancy and Early Infant Neurodevelopment: The ECLIPSES Study	Determine the association between maternal vitamin B12 status at the beginning and end of pregnancy and early neurological development in infants at 40 days of age.	The study evaluated vitamin B12 concentrations in the first and third trimesters of pregnancy, and an early neurodevelopmental study was also conducted (at 40 days after birth).	Generalizability to other populations is limited.

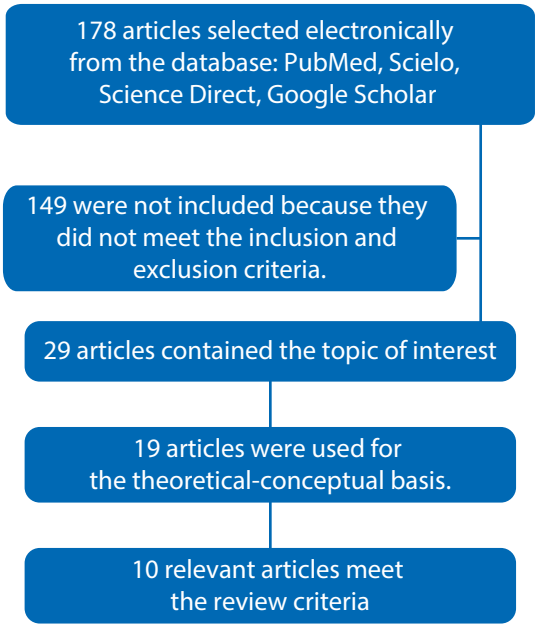

Figure 1. Study identification and selection process.

Dai F, et al., China (2023) conducted a prospective cohort study of births at three centers in Hefei (Anhui Women and Child Health Care Hospital). A total of 1,471 mother-child pairs were analyzed to examine the impact of the Mediterranean diet during pregnancy on child neurodevelopment. It was found that mothers with high adherence to the Mediterranean diet were associated with better results on the neurodevelopmental test (communication, fine motor skills, and personal-social skills). It was concluded that greater adherence to the Mediterranean diet during pregnancy was associated with a lower risk of neurodevelopmental delays in infants at one year of age[17].

Kou X, et al., Spain (2024) conducted a prospective cohort study in a subgroup of participants from the ECLIPSE study. The study included 460 mother-child pairs with the aim of analyzing the relationship between prenatal exposure to dietary contaminants from fish and early childhood neurodevelopment. It was found that higher prenatal exposure to contaminants derived from fish was associated with poorer outcomes in the language domain. In conclusion, although fish is an important source of nutrients, it can expose women to contaminants during pregnancy, affecting infants' language development[18].

Huamán M, et al., Peru (2022) conducted a cross-sectional observational study in the Canipaco Valley (Huancayo). A total of 109 children under the age of 3 were evaluated to determine the association between nutritional security and neurodevelopment in children under three years of age from families in the Canipaco Valley. They found that 20.2% of the children were at risk for neurological development issues and 68.38% exhibited delayed neurological development; furthermore, inadequate iron supplementation during pregnancy was significantly associated with neurodevelopment. They concluded that children with greater nutritional food insecurity are at higher risk of neurodevelopmental delay[19].

Na X, et al., United States (2023) conducted an observational, longitudinal cohort study of patients at the Arkansas Center for Child Nutrition. They studied 44 pairs of mothers and their newborns to determine the association between the quality of the maternal diet during pregnancy and the development of cerebral white matter in newborns. In the study, there were no significant correlations between the Healthy Eating Index-2015 (HEI-2015) score in the second or third trimester and fractional anisotropy; however, a significant correlation was found between the sodium subscore of the HEI-2015 during the first trimester and FA values. It was concluded that early maternal dietary quality during pregnancy (particularly regarding sodium) could positively influence the microstructure of the newborn's cerebral white matter[20].

Laouzon B, et al., France (2022) conducted a prospective, longitudinal cohort study called ELFE (Échantillon Longitudinal Français depuis l'Enfance). A total of 992 children were evaluated to determine the relationship between the overall quality of the mother's diet during pregnancy and the children's neurobehavioral development up to 3–5 years of age. It was found that higher quality of the maternal diet during pregnancy was associated with better scores on early childhood neurobehavioral development. It was concluded that promoting a diet of higher overall quality during pregnancy could support neurobehavioral development in offspring[21].

Motoki, N, et al., Japan (2022) conducted a prospective cohort study through the Japan Environment and Children's Study (JECS). They studied 30,694 mothers and their respective children under 12 months of age to determine whether insufficient gestational weight gain (GWG) in the

mother is associated with an increased risk of neurodevelopmental delay in the infant. 60.4% of the mothers had weight gain below the guidelines, and it was found that mothers with GWG below the recommendations had a significantly higher risk of delays in communication, gross motor skills, fine motor skills, problem-solving, and personal-social skills. It was concluded that insufficient gestational weight gain may have an adverse effect on the infant's early neuropsychomotor development[22].

Canul, A., et al., Mexico (2025) conducted a prospective cohort study titled OBESO (Epigenetic and Biochemical Origins of Overweight and Obesity) at the National Institute of Perinatology in Mexico City. They analyzed 97 mother-child pairs to examine the association between maternal pre-pregnancy weight status and the neuropsychomotor development of infants at 6 and 12 months of age. They found that infants of mothers who were overweight or obese prior to pregnancy had lower scores in the language and socio-emotional domains. In conclusion, maternal overweight and obesity may have adverse effects on early childhood neurodevelopmental trajectories[23].

Cruz, J, et al., Spain (2023) conducted a prospective cohort study as part of the ECLIPSE study in a Mediterranean region of northern Spain. A total of 434 mother-infant pairs were studied to analyze the relationship between maternal vitamin B12 status at the beginning and end of pregnancy and the infants' early neurological development at 40 days of life. It was found that when comparing the group with the lowest vitamin B12 levels (1st tertile) to another group with levels between 312–408 pg/mL (2nd tertile) in the first trimester, the latter group showed a positive association with higher scores in gross motor skills, language, and cognition. It was concluded that ensuring sufficient levels of vitamin B12 early in pregnancy could promote the baby's development (especially in motor skills, language, and cognition)[24].

Discussion

Neurodevelopment is a complex process that begins in the first weeks of gestation and continues through the first years of life[25]. Abnormalities in this process, manifested as neurodevelopmental delay, constitute a significant cause of disability in childhood and are associated with limitations in academic performance, independence, and social interactions[26]. In this context, maternal malnutrition is recognized as a major risk factor, given that pregnancy represents a critical window during which adequate nutrient availability is essential to prevent permanent alterations in brain development [25]. Therefore, this systematic review examines the available evidence on the relationship between maternal malnutrition and neurodevelopmental delay.

The studies included in this review reinforce the importance of adequate maternal micronutrient status in fetal neurobiological programming[16, 17, 18, 19]. In accordance with international recommendations, the United Nations Children's Fund states that pregnant women should consume 2.6 µg of vitamin B12 daily due to its role in DNA synthesis and the maintenance of the nervous system, processes essential during neuronal proliferation and fetal myelination[27]. This recommendation is supported by the findings of Cruz J, et al., who observed that higher maternal levels of vitamin B12 (312–408 pg/mL) are associated with better outcomes in gross motor skills, language, and cognition, suggesting an impact beyond the prevention of clinical deficiencies, with possible direct implications for early neurocognitive performance[24].

In addition, the WHO warns that iron deficiency during the last trimester of pregnancy can affect children's cognitive development, a critical stage for brain maturation[28]. This finding is consistent with the report by Quin R, et al., who found that higher intake of heme iron during pregnancy is associated with better cognitive performance in infants[15].

The studies included in this review show that the quality of the maternal diet, particularly adherence to dietary patterns such as the Mediterranean diet, is associated with better outcomes in cognitive, motor, and communication domains during early childhood[16, 21, 23]. In particular, Dai F, et al. reported significant benefits in multiple areas of child development associated with greater adherence to this dietary pattern [17]. These findings are consistent with the Technical Guidelines of the Peruvian Ministry of Health, which emphasize the need to ensure adequate energy and nutritional intake during pregnancy, as well as the consumption of iron-rich foods to

prevent anemia[2]. However, while recent scientific evidence highlights the impact of comprehensive dietary patterns and their potential effect on fetal neurological programming, national guidelines focus primarily on the prevention of immediate obstetric complications, such as low birth weight or preterm birth, without explicitly addressing the implications for long-term neurodevelopment[2].

We refer to studies such as those by Na X et al. [20], which offer a complementary perspective by incorporating neuroimaging evidence to analyze child neurodevelopment. Their findings show that the quality of the maternal diet can directly influence the brain structure and function of the fetus and infant, reinforcing the idea that dietary patterns during pregnancy generate early biological effects that precede clinical manifestations of development.

On the other hand, it is important to note that both pre-pregnancy overweight or obesity and gestational weight gain below the recommended level have been associated with an increased risk of neurodevelopmental delay across various domains (fine and gross motor skills, problem-solving, personal-social); particularly in the area of communication, as reported by Motoki N, et al.[22, 23].

Finally, it is worth noting the limited availability of studies conducted in Peru that comprehensively evaluate the relationship between maternal nutrition and child neurodevelopment. Research such as that by Huamán E, et al., although valuable, highlights the need to increase national scientific output, as while they analyze the effect of food insecurity, they do not directly address maternal nutritional status[19]. Furthermore, although maternal diets with higher protein intake are often considered beneficial due to their nutritional density, studies such as that by Kou X, et al. suggest that they may also constitute a route of exposure to environmental toxins, with potential negative effects on neurodevelopment [18]. In contrast to countries where clinical practice guidelines on maternal nutrition are periodically updated to incorporate emerging evidence on dietary patterns and neurodevelopmental outcomes, in our country the main regulatory documents have not been systematically updated nor do they explicitly integrate the most recent evidence on dietary quality and neurobiological programming. This gap between international scientific research and national policy updates limits the incorporation of recommendations based on current evidence and reinforces the need to review and modernize existing technical guidelines[2, 29].

Conclusions

Based on the studies reviewed, we can conclude the following:

Maternal nutritional status and dietary quality during pregnancy have a decisive influence on a person's neurodevelopment.

Adequate micronutrient intake and adherence to healthy dietary patterns are associated with better outcomes in cognitive, motor, and language domains; whereas malnutrition and maternal weight abnormalities increase the risk of neurodevelopmental delay. Neuroimaging studies reinforce these findings by demonstrating early effects on fetal brain structure and function.

There is a notable lack of research in the Peruvian context, highlighting the need to promote local studies and prenatal nutritional care to prevent neurodevelopmental impairments.

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