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Effects of methylmercury toxicity on fetal brain development: review of mechanisms of action, maternal influences and nutritional guidelines

Efeitos da toxicidade do metilmercúrio no desenvolvimento cerebral fetal: revisão dos mecanismos de ação, influências maternas e diretrizes nutricionais

Efectos de la toxicidad del metilmercurio en el desarrollo del cerebro fetal: revisión de los mecanismos de acción, influencias maternas y directrices nutricionales

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ABSTRACT
This study aims to investigate the effects of mercury (Hg) toxicity on the fetal brain. Methylmercury (MeHg) is widely recognized for its severe toxic effects on the developing embryonic nervous system compared to mature neurons. Studies show that immature neurons are more vulnerable to Hg toxicity. Furthermore, maternal nutrition plays a critical role in fetal brain development. From this perspective, this review aims to address the definition of Hg, its metabolism in the human body, and the effects and mechanisms of action related to its toxicity, emphasizing the impact on the health of pregnant women and the fetal brain. The influence of daily fish consumption during pregnancy was also discussed, particularly in the Amazon region, where fish consumption is high and is an essential source of exposure to Hg. The review presents

guidelines for the consumption of fish in pregnant women's diet, aiming to promote their health and reduce fetal exposure to Hg.

Keywords: neurotoxicity, maternal health, mercurial exposure, fetal health, prenatal exposure, pregnant women, food safety.

RESUMO
Este estudo se propõe a investigar os efeitos da toxicidade do mercúrio (Hg) no cérebro fetal. O metilmercúrio (MeHg) é amplamente reconhecido por seus graves efeitos tóxicos no sistema nervoso embrionário em desenvolvimento, em comparação com neurônios maduros. Estudos demonstram que neurônios imaturos são mais suscetíveis à toxicidade do Hg. Além disso, a nutrição materna desempenha um papel de vital importância no desenvolvimento do cérebro fetal. Diante dessa perspectiva, esta revisão tem como objetivo abordar a definição do Hg, seu metabolismo no corpo humano e os efeitos e mecanismos de ação relacionados à sua toxicidade, com ênfase nos impactos na saúde da gestante e no cérebro fetal. A influência do consumo diário de pescado durante a gestação também foi discutida, principalmente na região amazônica, onde o consumo de pescado é elevado e representa importante fonte de exposição ao Hg. A revisão apresenta orientações para gestantes quanto ao consumo de dietas à base de peixes, visando promover a saúde das gestantes e reduzir a exposição fetal ao Hg.

Palavras-chave: neurotoxicidade, saúde materna, exposição mercurial, saúde fetal, exposição pré-natal, gestantes, segurança alimentar.

RESUMEN
Este estudio pretende investigar los efectos de la toxicidad del mercurio (Hg) en el cerebro fetal. El metilmercurio (MeHg) es ampliamente conocido por sus graves efectos tóxicos sobre el sistema nervioso embrionario en desarrollo, en comparación con las neuronas maduras. Los estudios demuestran que las neuronas inmaduras son más susceptibles a la toxicidad del Hg. Además, la nutrición materna desempeña un papel de vital importancia en el desarrollo del cerebro fetal. Desde esta perspectiva, esta revisión pretende abordar la definición de Hg, su metabolismo en el cuerpo humano y los efectos y mecanismos de acción relacionados con su toxicidad, haciendo hincapié en los impactos sobre la salud de las mujeres embarazadas y el cerebro fetal. También se discutió la influencia del consumo diario de pescado durante el embarazo, especialmente en la región amazónica, donde el consumo de pescado es elevado y representa una fuente importante de exposición al Hg. La revisión presenta directrices para mujeres embarazadas sobre el consumo de dietas basadas en pescado, con el objetivo de promover la salud de las embarazadas y reducir la exposición fetal al Hg.

Palabras clave: neurotoxicidad, salud materna, exposición mercurial, salud fetal, exposición prenatal, mujeres embarazadas, seguridad alimentaria.

1 INTRODUCTION

Mercury (Hg) is present in the environment in three distinct chemical forms: elemental Hg (in liquid and vapor form), inorganic Hg (mercurous and mercuric compounds), and organic Hg. In the Amazon ecosystem, artisanal gold mining releases significant quantities of elemental and inorganic Hg during mercury-gold amalgams (Hg-Au) production, constituting one of the primary sources of contamination in the region (Tong *et al*., 2021).

Methylmercury (MeHg) is the most toxic form of Hg produced in the environment and results from the inorganic Hg methylation process, which occurs mainly in aquatic sediments (Jones *et al*., 2022). Methylmercury bioaccumulates throughout the aquatic food chain, and consuming fish contaminated with MeHg is a significant route of human exposure to MeHg (Smith *et al*., 2020). Hg is rapidly absorbed in the gastrointestinal tract and distributed throughout the body. In pregnant women, MeHg crosses the placenta and blood-brain barrier to reach the developing fetus. Research has demonstrated that Hg concentrations in the umbilical cord are elevated relative to maternal blood, indicating that the fetus may be exposed to a substantial proportion of the mother's circulating Hg (Dack *et al*., 2022; Fagundes *et al*., 2022).

Experimental and epidemiological studies have indicated that the fetal development and early childhood life stages are particularly vulnerable to MeHg toxicity (Sakamoto *et al*., 2021). Consequently, women of childbearing age, pregnant women, and lactating women are considered to be at risk. MeHg is widely recognized for its severe toxic effects on the developing embryonic nervous system compared with mature neurons. Research indicates immature neurons are more vulnerable to Hg toxicity, and maternal nutrition is critical in fetal brain development (Fagundes *et al*., 2022). Consequently, regulatory agencies worldwide have instituted recommendations for fish consumption during pregnancy, aiming to mitigate the neurotoxic effects of Hg during fetal development (Abbott & Nigussie, 2021; Branco *et al*., 2021).

The present study aims to explore the knowledge of Hg human metabolism and the effects and mechanisms of action related to Hg toxicity, focusing on pregnant women's health and fetal development.

2 THEORETICAL FRAMEWORK

2.1 THE FETAL BRAIN

Fetal brain development occurs in three main phases: the embryonic period (from conception to the eighth week of pregnancy), the early fetal period (mid-gestation), and the late fetal period (from mid-gestation to birth) (Lautaresco *et al*., 2020).

The developing brain contains billions of neurons produced during the second trimester of pregnancy. Brain development involves neurons' production, migration, connection, and differentiation. At the beginning of the fetal period, the brain already has the structures necessary for its mature functioning, although it still has a smooth cortical plate. Between 12 and 20 weeks of gestation, neuronal migration toward the cortical region peaks (Pulli *et al*., 2019). Myelin, which increases the speed and precision of neuronal communication, forms between the 20th and 28th weeks of pregnancy. In the second half of gestation, the specialization of different brain regions and pathways occurs, and synapse formation begins.

In the second half of pregnancy, different brain regions and pathways specialize, and synapses begin to form. By 34 weeks, around 40,000 new synapses are formed every second, a process that continues throughout early postnatal life (Pulli *et al*., 2019).

This logic suggests that the baby's brain is organized into functional networks and that fetal growth and brain maturation are asynchronous. For example, sensory regions develop early and quickly, while associative regions, such as the frontal cortex, develop later and more slowly until the end of adolescence (Dubois *et al*., 2014).

These anatomical changes allow the child to acquire new psychomotor and cognitive skills. It is known that brain changes are particularly intense during the last weeks of pregnancy and the first months of life, as evidenced by the non-linear increase in cranial circumference, which grows by about 14 cm during the first two years of life and then by only 7 cm until adulthood (Dubois *et al*, 2014). During the first six weeks of embryonic life, the development of the central nervous system (CNS) progresses through three sequential and overlapping phases, described in Table 1.

Table 1. Stages of fetal CNS development.

Phase of CNS	Description
Gastrulation	Formation of the three primary germ layers: ectoderm, mesoderm, and endoderm.
Dorsal Induction	Formation of the neural tube and the three primitive vesicles: forebrain, midbrain, and hindbrain.
Telencephalisation	Separating two cerebral hemispheres and forming optic vesicles, olfactory bulbs, and associated facial structures.

Source: Autors, 2025.

2.2 FETAL BRAIN FORMATION

The nervous system begins to form at the end of the third week of development through the action of the notochord, which induces the differentiation of the embryonic ectoderm into neural ectoderm and superficial ectoderm. The neural ectoderm consists of a thickening of cells in the medial region of the embryonic disc, which corresponds to the neural plate. The neural plate's edges rise while the central part deepens, forming the neural furrow. The edges of the neural ectoderm approach the midline and fuse to form the neural tube (Gault & Szele, 2021).

Closure of the neural tube begins at the level of the fourth pair of somites. It progresses in a cephalic and caudal direction so that the rostral or cephalic neuropore and the caudal neuropore can be recognized during this process. The rostral neuropore closes between 25 and 26 days of development, while the caudal neuropore closes about two days later. The region of the neural tube located in the anterior part of the fourth pair of somites corresponds to the future brain, while the region posterior to the fourth pair of somites will give rise to the spinal cord. The neural tube completely closes around 29-30 days of development (Nazari, 2011).

During this time, the wall of the neural tube is composed of neuroepithelial cells. Immediately after the neural tube closes, these cells rapidly proliferate to form the neuroepithelial layer, the neuroepithelium. Neuroepithelial cells give rise to primitive nerve cells, called neuroblasts, and the primordial supporting cells of the nervous system, called glioblasts. As embryonic development progresses, the walls of the neural tube thicken to form the spinal cord and brain (Nazari, 2011).

The neural tube's central canal becomes the spinal cord's central canal and the brain's ventricular system. The mesoderm surrounding the neural tube condenses to form a membrane called the primitive meninges, which is divided into three layers. The outer layer thickens and gives rise to the dura mater, while the inner layer, derived from neural crest cells, divides. The

pia-arachnoid comprises the pia-mater (inner) and the arachnoid-mater (Rivron *et al*., 2004).

Within the pia-arachnoid, spaces coalesce to form the subarachnoid space. Cerebrospinal fluid begins to be produced during the fifth week of embryonic development. The cephalic end of the neural tube, before the fourth pair of somites, will form the brain. At the end of the fourth week, the cephalic part of the neural tube shows three dilations corresponding to the primary brain vesicles: the prosencephalon (front brain), the mesencephalon (middle brain), and the rhombencephalon (back brain) (Rivron *et al*., 2004).

2.3 FETAL CEREBRAL CORTEX

Neocortical maturation in humans begins around day 16 of gestation, with neurulation followed by regional specification and expansion of the prefrontal cortex. This process is regulated by intrinsic transcription factors and extrinsic growth factors that tightly interact to define the boundaries of the prefrontal cortex. After the formation of the neural tube, around 5 weeks of gestation, the neurons destined to form the neocortex begin to differentiate from neuroblasts (Chini & Opatz, 2021).

The proliferation of neuroblasts is a long process with specific dynamics for each area, generally peaking between 6 and 18 weeks of gestation. Excitatory neurons are generated from apical precursors in the ventricular zone due to a complex interaction between cell-autonomous mechanisms and local and long-range environmental signals. At the end of the neurogenic period, the formation of glial cells begins (Chini & Opatz, 2021).

Between 10 and 12 weeks of gestation, the prefrontal cortex is formed from the marginal zone, cortical plate, and subplate - a transient layer of heterogeneous neurons at the interface with the white matter. Migrating cortical neurons organize the layers of the prefrontal cortex in an "inside-out" spatiotemporal pattern, with first-generation neurons forming the deep layers and later-generation neurons being incorporated into the more superficial layers. The migration of prefrontal neurons is regulated by several signaling pathways, most common to all neocortical areas (Chini & Opatz, 2021).

After reaching their destination, from the perinatal period until the end of the first year of life, neurons begin to extend axons and arborize dendrites, allowing the assembly of prefrontal circuits. The newly formed connections are highly dynamic and are refined as embryonic

development progresses. In the prefrontal cortex, this process continues until adolescence, around 16 years of age (Chini & Opatz, 2021).

2.3.1 Prenatal exposure to methylmercury and its neurotoxic effects on fetus and neonates: the role of the placental barrier

Exposure to Hg during pregnancy has been associated with serious complications and developmental problems in fetuses and neonates. Studies have already shown that mercurial exposure during pregnancy can result in spontaneous abortion, premature birth, congenital malformations, and changes in fetal neurodevelopment. Even small amounts of fish contaminated with MeHg consumed during the gestational period can increase Hg levels in maternal blood, negatively impacting embryonic development (Chen & Dong, 2022).

The placenta is an essential embryonic organ that transfers nutrients, oxygen, and other essential elements from the mother to the fetus. Furthermore, it acts as a semi-permeable barrier that protects the fetus from the passage of toxic substances. However, this protection is not absolute; it also allows the transfer of non-essential elements, including heavy metals such as methylmercury (MeHg), lead (Pb), and cadmium (Cd). Fetal nutrition, mediated by placental blood flow, also facilitates the transfer of elements essential for development, such as selenium (Se), zinc (Zn), and copper (Cu). The transfer of toxic and essential metals is often investigated by comparing the concentrations of these substances in maternal blood, umbilical cord blood, or fetal red blood cells (Bjørklund *et al*., 2019; Needhan *et al*., 2011).

The placental barrier in the syncytiotrophoblast region plays a fundamental role in the exchange of nutrients and the elimination of metabolic waste between mother and fetus. This region functions as a highly regulated system, promoting the transfer of substances from the intervillous space to the syncytiotrophoblast and, subsequently, to the fetal circulation. Despite its barrier function, toxic substances such as mine can easily overcome it, reaching the developing fetus (Sakamoto *et al*., 2013; Bai *et al*., 2020).

The MeHg easily crosses the placental barrier, concentrating mainly on the blood and brain of the developing fetus. Studies show that fetal Hg concentrations can be up to 30% higher than maternal concentrations, especially in erythrocytes, due to the concentration gradient "in favor" of the fetus. This accumulation significantly increases the risk of neurotoxicity and fetal

intoxication, enhancing the harmful effects of Hg on the development of the central nervous system (Sakamoto *et al*., 2021; Branco *et al*., 2021).

3 METHODOLOGY

This study consists of a literature review that aims to address the definition of Hg, its metabolism in the human body, and the effects and mechanisms of action related to its toxicity, emphasizing the impacts on the health of pregnant women and the fetal brain.

The bibliographic research was carried out to gather information about prior knowledge on the topic and seek well-founded and scientifically based answers. The study is theoretical and reflective in nature, preserving fidelity to the ideas and interpretations of the authors consulted (Souza *et al*., 2010).

The bibliographic search covers the period from January to December 2024. This interval was chosen to collect recent data and ensure the relevance and contemporaneity of the information for the development of this study. A search was carried out in the following databases: PubMed, Virtual Health Library (VHL), and ScienceDirect. Keywords used included *“Neurotoxicity," "Mercurial Exposure," "Fetal Health," "Prenatal Exposure," and "Fetal cerebral córtex."*

The results were filtered using the Boolean operator 'and'. After the initial selection, the keywords were adjusted according to the DECS (Health Sciences Descriptors). The articles were pre-selected by reading the abstracts, and those that addressed the impacts of mercurial neurotoxicity on fetal health and brain development were selected.

Publications in Portuguese or English that addressed the aforementioned relationships were included, in addition to possible guidelines to mitigate these effects. In the first phase of bibliographic research, three articles in Portuguese and 37 articles in English were used, resulting in 40 articles at the end of the study.

4 RESULTS AND DISCUSSIONS

This study showed that the following matrices can currently be used as more viable biomarkers for the analysis of Hg exposure in pregnant women and fetuses: blood, umbilical cord tissue, hair, urine, breast milk, and umbilical cord. Most of these matrices can be collected non-invasively (except blood) with relatively simple storage. In studies involving pregnant women and newborns, the main biomarkers of exposure to methylmercury used are blood, hair, umbilical cord tissue, and breast milk (WHO, 2008).

Hg in the blood reflects recent or current exposure to the metal. There is a direct relationship between hg concentrations in the blood and the consumption of fish contaminated with MeHg. After ingesting the fish, MeHg is quickly absorbed by the gastrointestinal tract and distributed throughout the body through the blood. It is worth noting that around 95% of the hg present in the blood is in the form of methylmercury, reflecting the main route of exposure to the metal in populations living in areas environmentally contaminated by hg (Dakeishi *et al*., 2005; WHO, 2008).

Hair is one of the routes of hg elimination, the primary biomarker to identify chronic mercury exposure (Dakeish *et al*., 2005; Sakamoto, 2013; Sakamoto, 2015). During hair follicle formation, the blood that irrigates the hair root transports hg, which is incorporated into keratin, especially while the hair is actively growing. Once Hg is fixed in the hair's keratin, it remains trapped there, providing a stable exposure record. Hair grows an average of 1 cm per month, which allows hair analysis to provide information about Hg levels over time. This characteristic makes hair an excellent chronological marker of Hg exposure over time.

Umbilical cord tissue is also widely used as a biomarker in studies on Hg exposure, including the initial studies in Minamata and others carried out later. In particular, when expressed relative to the dry weight of umbilical cord tissue, Hg concentrations correlate strongly with hg levels in umbilical cord blood (Grandjean *et al*., 2005; Sakamoto *et al*., 2013; Kim *et al*., 2015). According to the WHO, there is a linear relationship between maternal and umbilical cord blood levels, with cord blood concentrations often 30% to 70% higher than maternal Hg levels (Sakamoto *et al*., 2013).

Breast milk is widely used as a biomarker to assess mercury exposure in lactating women, providing relevant information about the metal transfer from mother to newborn. Hg

concentrations in breast milk vary according to the mother's diet and individual characteristics and are generally higher in colostrum than in transitional and mature milk. Measuring Hg in breast milk is a practical and non-invasive tool to monitor exposure to Hg in newborns resulting from maternal-fetal transfer (Oddy, 2002; WHO, 2017).

The World Health Organization (WHO) establishes reference limits for Hg levels as indicators of safe exposure. These limits are based on population studies and risk analyses that evaluate the neurotoxic effects of Hg, mainly in vulnerable groups such as fetuses and neonates. When these values are exceeded, there may be a risk of compromising neurological development and general health.

The United States Environmental Protection Agency (EPA) is more conservative in its guidelines, especially in my case, prioritizing the protection of vulnerable populations, such as pregnant women and fetuses, with lower limits for safe exposure. On the other hand, the WHO adopts slightly higher values based on global population risk assessments. This difference reflects different approaches to safety factors and the databases used to establish limits (table 2).

Table 2. Main human biomarkers of mercury exposure and their respective reference values.

Human Biomarkers	Main Correlations	Reference Values
Blood	The presence of Hg in the blood indicates recent or current exposure to Hg	3,5 µg/L
Hair	Important long-term biomarker of MeHg exposure	1-2 µg/g
Breast Milk	Colostrum, transitional milk and mature milk can be sources of Hg exposure to the newborn	1,4–1,7 µg/L
Umbilical Cord**	Biomarcador direto do feto e bom preditor de déficits neurológicos	0,3mk/kg
Placental Tissue**	Placental chorionic tissue is a good predictor of Hg concentration in newborns	0,3mg/kg
Urine	Considered the best measure of recent exposures to inorganic Hg or elemental Hg vapors	50 µg/g of creatinine*

*Urine Hg levels rarely exceed 5 µg/g creatinine in people who are not occupationally exposed

**Both the placenta and umbilical cord tissue are considered excellent biomarkers for evaluating Hg concentrations in newborns. However, there is still no consensus in the literature regarding reference values for these biomarkers (US Environmental Protection Agency (EPA). Water quality criterion for protecting human health: methylmercury).

Source: Autors, 2025.

Concerning dietary pattern during pregnancy and fetal neurotoxicity due to MeHg, Our analysis revealed that a healthy dietary intake pattern before and during pregnancy is associated with a reduced risk of several complications, including gestational diabetes mellitus (GDM), preterm birth, pre-eclampsia, gestational hypertension, and obesity-related complications. A balanced diet, rich in micro and macronutrients, promotes better perinatal outcomes and offers ideal conditions for fetal development.

Nutritious and healthy diets include the consumption of vegetables, fruits, whole foods, grains, nuts, legumes, fish, and oils enriched in monounsaturated fat and fiber and avoid the consumption of simple sugars, processed foods, and saturated fats (Marshall *et al*., 2021). Fish, in particular, are foods rich in long-chain polyunsaturated fatty acids, such as docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), which are associated with the reduction of inflammatory processes and bring significant benefits to fetal neurological development. (Malmir *et al*, 2021).

However, the main form of Hg exposure during pregnancy is consuming fish contaminated with MeHg (Oliveira *et al*., 2022). MeHg readily passes across the placental barrier via a methylmercury-cysteine (MeHg-Cys) conjugate and accumulates in the brain tissues of the developing fetus. The cerebellum and cerebral cortex are the main sites of Hg deposition, making the central nervous system highly vulnerable to toxicity (Branco *et al*., 2021).

The research by Oliveira *et al.* (2022) warns that the consumption of fish-eating species, such as Tucunaré (*Cichla spp*.) and Pescada branca (Plagioscion squamosissimus), should be avoided by pregnant women, as these species often contain total Hg levels greater than 0.5 mg/kg, putting fetal health at risk. Given this, great caution must be exercised when recommending a fish-rich diet for pregnant women living in the Amazon, where the effects of exposure to Hg may outweigh the nutritional benefits of fish consumption.

Ingesting non-piscivorous fish, which have lower levels of HgT, may be a safer alternative to ensure the nutritional benefits of fish consumption during pregnancy. However, it is important to pay attention to the amount consumed, as even fish with low levels of Hg, when consumed in large quantities, can contribute to cumulative exposure, posing a risk to the developing fetus.

Another important factor in nutritional guidelines for women of childbearing age and pregnant women observed in our research concerns folic acid supplementation, also known as

folate or vitamin B9. Folate is an umbrella term for vitamin B9, which includes several forms found naturally in foods (natural folate). All forms of folate have a typical structure but differ concerning the pteridine ring and whether they are reduced or oxidized. Folate, derived from foods such as green leafy vegetables, is a polyglutamate, while synthetic folic acid is a monoglutamate (Ledowsky *et al*., 2022).

Folic Acid (FA) or Folate has antioxidant properties and is involved in the synthesis and metabolic processing of cysteine, a Glutathione (GSH) precursor. Folate also participates in the metabolism of GSH through one-carbon metabolism and is involved in the Hg detoxification process. Furthermore, inadequate maternal folate intake may increase the risk of neural tube defects (NTDFs). The effectiveness of folic acid in preventing NTFDs is already proven, and strategies to reduce the occurrence of these defects through fortification of the diet with FA are underway in several parts of the world (Bailey *et al*., 2015; Kim *et al*., 2020).

Brazil adopted mandatory fortification of wheat and corn flour in 2002, with at least 150 µg of FA per 100 g of flour, according to the recommendations of the WHO (2017). The country is reformulating the mandatory fortification law, establishing a minimum value of 140 µg and a maximum of 220 µg of AF per 100 g of flour. According to Brazilian legislation, both wheat and corn flour for domestic (retail) and industrial use, local or imported, must be enriched with iron and AF (Palchetti *et al*., 2019).

Supplementation for all women of childbearing age should be encouraged with doses of 0.4 to 0.8 mg of folic acid per day, regardless of whether they are planning a pregnancy. This recommendation is strengthened by the fact that half of pregnancies occur without planning, reducing the risk of NTDF by 69% (recommendation grade A). Therefore, women planning pregnancy should be informed of the benefits of FA supplementation of at least 400 µg per day from one month before conception to 12 weeks of gestation. In this context, the American Environmental Protection Association (US EPA) encourages women who are pregnant or may become pregnant, breastfeeding mothers, and young children to limit their fish consumption to no more than 340 g of fish per week (Schlindwein e Kassouf, 2007; De-Regil *et al*., 2015; Palchetti *et al*., 2019; Eaves *et al*., 2023).

It is worth highlighting that the North and Northeast regions of Brazil have the highest proportions of food insecurity at mild, moderate, and severe levels, while the South and Southeast regions have the highest proportions of food security and that, within this scenario, the North

region includes the states covered by the Amazon Forest and is a region marked by the presence of substantial social inequalities related to reduced access to food, basic sanitation, and drinking water (Salles-Costa *et al*, 2022).

In this context, we know that there are numerous possibilities in primary health care services for implementing preconception care during prenatal consultations, including guidelines relevant to the early introduction of folate supplementation in women of childbearing age. However, other interventions seem to be more important in primary care services, such as prenatal care, when a pregnancy is underway. In this prerogative, studies show that there is little provision of preconception care for women of reproductive age in Brazil.

Likewise, the Brazilian study of Borges *et al*. (2016) showed that few women of reproductive age adopt preconception measures, such as seeking medical assistance, starting to eat healthier, taking folic acid, stopping or reducing alcohol consumption and smoking, even having experienced a planned pregnancy, this reality becomes even more noticeable within the reality of Indigenous women in Brazil.

5 CONCLUSION

Exposure to mercury during pregnancy, mainly due to the frequent consumption of contaminated fish, represents a significant challenge for public health, especially in regions such as the Amazon, where fish is one of the main sources of protein and nutrients. Although fish consumption offers important benefits, such as the presence of omega-3 fatty acids essential for fetal neurological development, Hg exposure poses serious risks to the neurodevelopment of fetuses and neonates. This duality between benefits and risks requires careful dietary guidance for pregnant women.

The placental transfer of MeHg and its accumulation in the fetal central nervous system highlight the need for effective strategies to mitigate exposure to the metal. The use of biomarkers, such as hair, blood, nails, and breast milk, has proven to be an important tool for monitoring Hg levels in pregnant women, allowing for early interventions. Furthermore, robust public policies and food education programs must be strengthened, providing clear guidance on the consumption of safe species and intake limits. These actions are especially critical for riverine

and traditional communities in the Amazon, ensuring that maternal and child health is protected while the nutritional benefits of fish are preserved.

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