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MERCURY FISH CONSUMPTION WITH NUTRITIONAL IMPLICATIONS IN INDONESIA: A LITERATURE REVIEW

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ABSTRACT
Mercury poisoning is a global health issue that can be found in fish, and it is a source of concern in Indonesia, where fish consumption is on the rise due to small-scale gold mining and steam power plants. A literature review was conducted to see the distribution of mercury issues observed from the nutritional aspect in Indonesia. The literature review study analyzed previous research results using Google Scholar, Scopus, Pubmed, and Semantic Scholar databases. Keywords were mercury fish consumption, nutrition, Indonesia/konsumsi ikan bermerkuri, gizi, and Indonesia. Three experimental research articles were obtained, which were conducted in Indonesia. The study by Sofia et al. (2016) showed variations in mercury concentrations in seafood and human hair. Exposure to mercury was linked with noticeable symptoms and a decrease in body weight. Reza et al. (2016) found a correlation between the frequency of fish eating and the risk of mercury exposure. Research by Muflihatul Muniroh (2022) showed the exposure to mercury in pregnant women is due to the intake of seafood but had no significant effect on infant birth weight or length. Consumption of mercury-containing seafood affects weight loss and decreases body mass index (BMI). It is hoped that more research will be conducted on the nutritional implications of mercury fish consumption in Indonesia.

Keywords: *Mercury; fish consumption; nutritional status; Indonesia; heavy metal*

BACKGROUND

Consuming fish is a good way to get omega-3 fatty acids (3FA) and other essential nutrients, making fish a crucial component of a balanced diet.[1] Additionally, fish may expose consumers to chemical contaminants, such as mercury (Hg), which is a serious issue for any consumer, including pregnant women.[2] Mercury (Hg) is known to have toxic effects on fish and humans, including fetuses, and can cause various health problems.[3,4] Numerous short- and long-term health impacts have been linked to mercury.[5] The risk of mercury toxicity is also contingent upon the chemical form of mercury, the dose, the duration of exposure, and the patterns of fish consumption.[6] Post-exposure, mercury accumulates in the liver, nervous system, and is associated with neuropathic effects and subsequent neuro-behavioral conditions.[7–9] Infants and young children are particularly susceptible to neurotoxic effects due to differences in bone growth and physiological processes compared to adults.[5] It is crucial to disseminate information about the risk associated with Hg toxicity and provide guidance on safe fish consumption, particularly for pregnant women.[6]

Prior research revealed that mercury can cause oxidative stress, cell damage, DNA damage, and disruption of antioxidant metabolism in the body.[10] A study conducted by Purum Kang and colleagues revealed that exposure to Hg had a significant effect on the incidence of dyslipidemia in men.[11] Joseph et al. investigated 15 mothers and their 16 infants under 24 months, revealing that 3 of the 16 infants had hair mercury levels exceeding 6.0 µg/g (threshold), correlating with the highest incidence of anemia and motor delays among 11-month-old infants. Additionally, 4 of the 16 infants were stunted, and 6 of the 12 infants aged 6-24 months were anemic. Nine of the fifteen mothers displayed mercury levels surpassing 6.0 µg/g (threshold), with an average of 7.56 µg/g. Furthermore, 6 mothers were classified as overweight, 1 as obese, and the average maternal hemoglobin level was 13.3 g/dL, with 15.4% exhibiting anemia.[12]

The main nutritional problem in Indonesia is stunting, which is a chronic nutritional problem caused by various factors, including malnutrition, maternal nutrition during pregnancy, insufficient intake in infants,[13] and infectious diseases.[14] In Indonesia, the incidence of stunting will remain at 21.6 in 2022.[15] Indonesia is also one of the largest archipelagic countries in the world, with a marine area of 6.4 million km2, which affects the level of fish consumption.[16] Since the last 5 years, Indonesia has continued to experience an increase in fish consumption; in 2022, Indonesia's fish consumption will be at 57.27%.[17]

Research on mercury exposure in the Indonesian population, considering various exposure sources such as artisanal small-scale gold mining (ASGM), steam power plant operations (PLTU), fish and seafood consumption, and contaminated areas, is notably scarce. Furthermore, studies linking this exposure to nutritional factors, including malnutrition, dietary patterns, alterations in nutritional status (weight, height/length, BMI), and metabolism, remain exceedingly rare. Therefore, it is necessary to review the distribution of mercury fish consumption with implications for nutritional aspects in Indonesia to determine the distribution of mercury cases in Indonesia. Based on these problems, it is very important to conduct a literature review related to the issue of mercury fish consumption associated with nutritional aspects in Indonesia.

METHODS

A literature review was conducted to review, accumulate, synthesize, and analyze the results of previous studies on mercury fish consumption associated with nutritional aspects in Indonesia. Articles discussing the consumption of mercury fish with nutritional implications in Indonesia were one of the main inclusion criteria to be used in the database. The search began by identifying research articles conducted in Indonesia sourced from four openly accessible Google Scholar databases: Semantic Scholar, Pubmed, and Scopus, with the keywords 'mercury fish consumption', 'nutrition', and 'Indonesia' in Google Scholar. Google Scholar searches totaled 21,900, Semantic Scholar totaled 171, Pubmed totaled 296, and Scopus totaled 2.

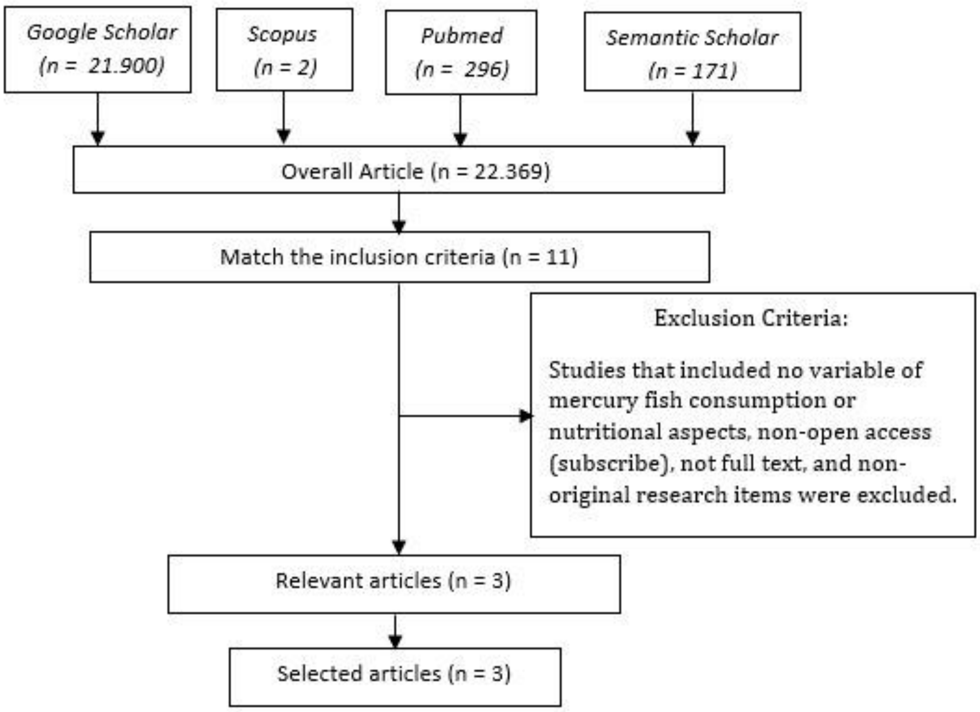

Figure 1. Flowchart for Identifying Eligible Studies.

Articles were selected according to the topic, namely consumption of fish with mercury implications for nutritional aspects in Indonesia. The selection of this article is based on inclusion factors, studies that reported mercury concentrations in fish, studies that examined the health effects of consuming mercury-contaminated fish, namely publication within 10 years (2014–2024), original research paper, open access, full text, and using Indonesian and English. A cohort and cross-sectional study was chosen because it aims to examine the distribution of mercury from fish consumption and its nutritional implications in Indonesia. The study selection process was conducted in two stages: firstly, title and abstract screening to eliminate irrelevant studies, and secondly, full text assessment to ensure the studies met all inclusion criteria. Quality assessment tools, such as the Newcastle-Ottawa Scale, were used to assess the risk of bias in the included studies.

Articles were found from the selection process that are suitable and appropriate for further studies related to the consumption of fish with mercury implications for nutritional aspects in Indonesia.

RESULTS AND DISCUSSION

Overview of the Study

Based on the findings from the database, studies on mercury exposure in Indonesia are numerous, especially in small-scale gold mining (ASGM) activities that are associated with health risks. However, there are very few studies on fish consumption involving nutritional aspects in Indonesia. The results of the findings of articles that are considered relevant within the theme of this studies were 3 articles. The results of these studies are averaged in Table 1. The study were located in Bombana Regency, Aceh Province, and Semarang City Indonesia. Based on the findings from the research database related to this matter, there are still very few and only 3 original researches found on the consumption of mercury fish with implications for nutritional status, so the researcher raised these 3 original researches to conduct a literature review.

Mercury fish consumption with nutritional implications

Based on Table 1, there are 3 studies. Two studies by Sofia (2016) in Aceh Province and Reza (2016) in Bombana Regency identified a correlation between body weight, BMI, and mercury exposure from fish consumption, whereas a study by Muflihatul Muniroh (2022) in Semarang City found no correlation between mercury levels in maternal hair and the weight and birth length of newborns.Two studies, one by Sofia (2016) in Aceh Province and another by Reza (2016) in Bombana Regency, demonstrated a correlation between body weight, BMI, and mercury exposure from fish consumption. Conversely, a study by Muflihatul Muniroh (2022) in Semarang City found no correlation between mercury levels in maternal hair and the weight and birth length of newborns. The 3 studies tested mercury levels from hair samples, urine samples, and fish consumption of the subjects.

Table 1. Identify Articles that Match the Literature Review Criteria.

Authors and year	Journal, Vol, Number	Title	Keywords	Database
Sofia et al. 2016	International Journal of Public Health Science. Vol 5 No 3.	Acute and Chronic Toxicity of Mercury Exposure in Seafood and Human Populations Near a Small-Scale Gold Mining Area	Exposure, Aceh, gold miners, mercury toxicity.	Google Scholar
Reza et al. 2016	Jurnal Ilmiah Mahasiswa Kesehatan Masyarakat. Vol 1 No. 4.	Analisis perbedaan potensi risiko keterpaparan merkuri pada masyarakat di Desa Tahi Ite Kecamatan Rarowatu Kabupaten Bombana Tahun 2016	Risk of mercury exposure, age, BMI, frequency of fish consumption, distance from home, length of stay, urine.	Google Scholar
Muflihatul Muniroh et al. 2022	International Journal Of Environmental Research and Public Health. Vol 19 No. 10684.	The first exposure assessment of mercury levels in hair among pregnant women and its effects on birth weight and length in Semarang, Central Java, Indonesia	Hair mercury level, pregnant women, birth weight and length, Indonesia, fish consumption.	Google Scholar

The articles reviewed in this study were conducted in 2016 and 2022, coming from 2 international journals and 1 national journal. All studies used keywords containing‘mercury’, and as many as two studies used the keyword ‘fish consumption’ found from the Google Scholar database. The results of article searches regarding these keywords are shown in Table 1.

A study conducted by Sofia et al. in Aceh, Indonesia, employed a quantitative methodology to ascertain the level of mercury exposure in both marine biota and scalp hair and evaluate acute and chronic toxicity in samples (n = 72), They reported that mercury (Hg) concentrations in seafood were found to differ substantially across species ($p = 0.013$). The fish species *Osteochilus sp.* had the lowest mercury levels, whereas *P. lastristiga* had the highest values (10.62 µg/g wet weight). Human population amounts of mercury in their hair revealed that the highest mean concentration was found in samples residing in Paya Seumantok village (48.32 µg/g), and samples from Curek village had the lowest mean concentration (11.23 µg/g). Mercury exposure from small-scale gold mining operations and fish eating results in a broad spectrum of clinical symptoms. As evidenced by mercury exposure, 72 samples experienced weight loss (10.9%). This is compatible with research conducted by Tore

Syversen et al., who treated Wistar rats. The rats in the group that were administered a dosage of 5 mg/kg of methyl mercury exhibited a reduction in body weight following 20 doses. Reduced body weight, rapid toxicity symptoms, and reduced protein synthesis were detected at cerebellar Hg concentrations 3–6 µg Hg/g.[18]

Table 2. Identification of Research Framework Articles on Mercury Fish Consumption with Implications for Nutrition in Indonesia

Authors	Method	Analyzed	Sample	Results
Sofia et al. 2016	Design: Community–based and cross– sectional study design Treatment: A gold amalgamation process using mercury was practiced. Seafood and hair samples were analyzed to evaluate mercury content. Symptoms of chronic and acute poisoning were observed, and personal protective equipment was worn by gold miners.	Seafood, hair mercury levels, and symptoms of toxicity.	Seafood samples and hair samples of 72 people from 4 villages.	The mercury levels were highest in Puntius latristrigai, with a measurement of 172,299 ± 10,626 µg/g dry weight. This was followed by the mollusk Polymesoda Carolinians, which had a mercury level of 160,032i ± 0,522i µg/g wet weight. R. ikanagurta had a mercury level of 149 ± 2,000 µg/g wet weight, while the shrimp Penaeus monodon had a mercury level of 116,975 ± 4,807 µg/g wet weight. The hair mercury contents varied between 5.7 µg/g to 88.1 µg/g. The predominant symptoms included cephalalgia, myalgia, coughing, and oral ulcers. The use of personal protective equipment, such as respirators, masks, gloves, and clothes, is significantly associated with elevated levels of mercury (p<0.05).
Reza et al. 2016	Design: A community-based cross-sectional study design Observational (cross-sectional) Treatment: guided interview using a questionnaire and urine mercury screening.	Urine mercury levels	Questionnaire and urine mercury 46 people	The relationship between age and risk of mercury exposure is statistically significant (p = 0.000). Similarly, there is a significant association between BMI and risk of mercury exposure (p = 0.000). Additionally, the frequency of fish eating is also significantly associated with the risk of mercury exposure (p = 0.003), distance from home and length of stay are not associated with risk of mercury exposure. Age was more influential on mercury exposure than BMI, with a standardized canonical discriminant function value for the age of 0.705, age being the most important compared to BMI 00.498. With the discriminant equation model, Z score =-19.678 + (0.136) age + 0.584 BMI, where the cut-off point value is -0.000173.
Muflihatul Muniroh et al. 2022	Design: A community-based cohort study design Treatment: Data on maternal characteristics, birth outcomes, and fish consumption were collected. Hair samples were used to determine the total mercury concentration.	Hair, birth weight and length, and fish consumption.	Hair samples were taken from 118 pregnant women–babies.	The median (min-max) maternal hair Hg level was 0.434 (0.146–8.105) µg/g. Pregnant mothers living in lowland areas, near the sea, showed higher hair Hg concentrations and fish consumption than those living in highland areas {[0.465 (0.146–8.105) vs. 0.385 (0.150–1.956) µg/g; pu = 0.043] and 85.71 (0-500.0). 49.76 (0.0–428.57) g/day; p < 0.01], respectively}. Maternal hair Hg levels had no association with the birth weight or length of infants.

Another study conducted in Bombana Regency by Reza et al. observed differences in potential exposure risk in terms of several related factors involving 46 multistage random sampling samples with a mercury analytical observational approach, reporting that the results of correlation analysis between the frequency of fish consumed considering the harmful effects of mercury exposure were significant (p = 0.003), which means that the higher the frequency of fish consumption, the greater the risk of mercury exposure. The body mass index of respondents whose average age was 37–41 years had a significant relationship (p = 0.001) with the risk of mercury exposure, and it can be concluded that the higher the body mass index, the greater the risk of mercury exposure.[19] These results are consistent with research conducted by Zhen-Yan Gao et al., there is a strong positive correlation between the level of mercury found in seafood and the physichal measurements of children, such as their body mass index (BMI; $p < 0.05$), a significant correlation between elevated blood mercury levels, and an increase in BMI z-scores ($p < 0.0001$).[20] On the other hand, research conducted by Guo et al. The investigation found no significant association between mercury levels in the placenta, hair of mothers, cord blood, or babies and the measurement of the babies' physichal characteristics. The study involved 213 pairs of mothers and infants.[21]

Eleni Papadopoulou et al.'s research found a significant relationship between mother's intake of fish fat and child weight and BMI, but only for those kids who had higher ercury exposure (p-interaction = 0.045) [22]. The World Health Organization (WHO) suggests using a weight scale that includes degrees of underweight and gradations of overweight or obesity that are associated with the risk of several non-communicable diseases.

This categorization is determined by the body mass index (BMI). The calculation involves dividing weight (measured in kilos) by height (measured in meters) (kg/m2).[23,24] A relatively recent study in Semarang, conducted by Muflihatul Muniroh, evaluated the impact of dietary fish on fetal MeHg exposure and the resulting changes in birth weight and length in 118 mother-infant pairs using a cohort technique. The outcomes of this research indicated that there was no statistically significant correlation between the mother's hair's level of mercury (0.434 µg/g) and the baby's birth weight (p = 0.182) or length (p = 0.902), but compared to those who lived in the highlands, those who lived in low-lying areas ate more fish and had higher hair mercury levels.[25] So although the results were not significant, it is likely that Hg levels in maternal hair came from fish or seafood consumption. Researchers sampled fish or seafood consumption based on estimates using a daily consumption questionnaire during pregnancy, including types of fish and frequency of consumption using pictures and seafood models.[25] According to this study, which is consistent with Miyashita et al., the average concentrations of hair mercury and total PBC were 1.41 µg/g and 108 ng/g of lipid, respectively. Overall, there was no link established between the levels of mercury and the dimensions of the fetal head, chest circumference, or birth weight (Miyashita et al., 2015).

The sources and causes of contaminants

Based on the study, mercury exposure in lowland mothers is primarily due to fish consumption, with higher frequency resulting in higher exposure.[25] Mercury waste from gold extraction and small-scale gold mining also contribute to mercury exposure.[27,28] Mercury originates from the earth's crust and accumulates in seafood, with levels influenced by human activities such as mining, industrial processes, and forest burning. Exposure also comes from industrial waste, mining, marine life contamination, and products like dental amalgam, insecticides, cosmetics, and dyes.[29–31]

Small-scale gold mining activities have been conducted in Krueng Sabee Sub-district, western Aceh Province, Indonesia, since 2008. The uncontrolled use of mercury for gold extraction has become widespread, with mercury released into the air through amalgam burning and the waste discharged into the Krueng Sabee River.[28] Traditional gold mining activities have been carried out since 2008 in Tahi Ite village in Bombana, and the use of mercury as a raw material in the gold processing process in the area, resulting in contamination of the river and air in the Tahi Ite village area in Bombana. Research on mercury content in Bombana showed that mercury levels at gold processing sites reached 0.0315 mg/l, which exceeded the quality standard limit of 0.005 mg/l at both processing and mining sites.[32] The mercury content of seafood consumed by pregnant women in the Semarang City area is known to come from seawater that has undergone a biomagination process in marine biota in the waters of Semarang City, Central Java.[25]

Type of Fish, Amount of Fish Consumption, and Frequency of Mercury Exposure in Fish and Humans

The questionnaire and fish food model were essential in assessing the varieties of fish and the frequency of fish or seafood consumption among the respondent mothers, mentioning ten freshwater fish species, eight marine fish, and six other marine species but not listing the type of fish in the journal article. Researchers listed the average daily fish and seafood consumption and categorized it into quartiles of <40 g/day (31 respondents), 40–79 g/day (30 respondents), 80–159 g/day (30 respondents), and >160 g/day (27 respondents).[25] The source of fish consumed came from the sea (24 respondents) and rivers (22 respondents); the frequency of fish consumed was 1.87 times per week, and the average fish intake was 4.67 g/kg body weight.[27] Fish, shrimp, and molluscs were analyzed as samples classified into several species, namely *P. caroliniana* (160 µ/g wet weight), *P. monodon* (110 µ/g wet weight), *H. macrolepitoda* (90 µ/g wet weight), *P. latristriga* (172 µ/g wet weight), *Osteochilus sp* (26 µ/g wet weight), *E. affinis* (49 µ/g wet weight), *Selaroides sp* (60 µ/g wet weight), and *R. kanagurta* (150 µ/g wet weight). While swordfish, shark, king mackerel, and tilefish are classified as fish with high levels of methyl mercury contamination,[33] other fish with lower levels of mercury contamination include salmon, shrimp, pollock, and catfish.[34–36] The level of mercury contamination in fish depends on its position in the food chain and the level of exposure to methylmercury.[37] It is important to be cautious about the selection of the type of fish to be consumed, especially for pregnant women, infants, and young children, to avoid the potential risk of mercury poisoning.[38] WHO-FAO recommendations on mercury-containing foods are suggested to be around 200 µg/person/week (3.3 µg/kg BW/week), 0.5 ppm/mg/kg/mg/L in processed fish, and 1.0 ppm/mg/kg/mg/L in predatory fish such as spiny dogfish, tuna, sharks, marlin, etc.[39]

The study conducted in Krueng Sabee Aceh did not show the type of fish most consumed by respondents, but the researchers recorded the highest mercury exposure in fish species such as *P. latristriga* (172.29 ± 10.62 µg/g wet weight), followed by mollusk species *P. caroliniana*, fish species *R. kanagurta*, shrimp species *P. monodon* and fish species *H. macrolepidota*.[28] In contrast to the research conducted in Tahi Ite Village, Bombana, researchers only displayed the average frequency of respondents' fish consumption habits, and the average respondent's fish consumption habits were 2 times a week.[19] In a study conducted in Semarang City, showing a list of the types of fish most consumed by respondents, it was stated that the most consumed types of fish were milkfish, pomfret, and mullet. Mullet and milkfish come from sea water and pomfret from fresh water.[25]

Health status impacts of the consumption of mercury fish Signs and Symptoms

Nine subjects were found to be exposed to Hg in the maternal hair sample test, which was above the threshold, but there were no effects during pregnancy or childbirth such as miscarriage, the baby's birth weight showed normal status, the baby's birth length was ≥50 cm, and the APGAR score was normal in the baby. On the other hand, the 22-year-old mother subject had a miscarriage at 22 months of pregnancy; the known Hg exposure in the mother's hair sample was 0.589 µg/g. In previous studies, it was stated that there was a relationship between Hg exposure and the incidence of miscarriage, even though it was below the threshold number, but in this case, further research needs to be done with a larger number of types of miscarriage case subjects.[25] The amount of mercury in the body is influenced by age, with a higher likelihood of buildup throughout periods of growth and old age due to the declining functionality of body parts such as the kidneys, liver, and brain., while children are vulnerable as their organs are still growing. Of the 18 samples, all were of productive age, with excellent physical condition and optimal organ function in managing toxic substances. The average BMI of the respondents was 24.20 (normal), having a minimum value of 22.40 and a maximum value of 26.60. The results showed a significance value of 0.000 ($P < 0.05$), which indicates a significant correlation between BMI and the risk of mercury exposure.[27] All respondents had their vital signs checked, and acute symptoms such as chills, dental and oral problems, metallic taste in the mouth, nausea, vomiting, fever, diarrhea, shortness of breath, and chest tightness were found. Including cough, muscle cramps, and headaches were common symptoms noted among the mercury-exposed population. Symptoms of chronic toxicity noted include sematosensory impairment, weight loss, headache, hearing loss, tremor, insomnia, erythema, emotional disturbance (agitation), anxiety, anorexia, depression, muscle cramps, and memory loss.[28]

Long-term and short-term effects

Acute poisoning from exposure to large amounts of mercury over a short period of time can cause symptoms such as tremors, visual and hearing impairment, loss of coordination, and irritation of the skin and mucous membranes.[40,41] Mercury can affect the central and peripheral nervous systems, causing symptoms such as tingling, muscle weakness, and loss of motor control.[41,42] Long-term exposure to mercury can cause permanent damage to the brain, affecting memory, cognition, and motor skills.[33,43,44] Mercury can accumulate in the kidneys and cause damage to kidney function, which can become permanent over time.[40,43,45] Chronic mercury exposure can weaken the immune system, making individuals more susceptible to infections and other diseases.[45] Past studies have shown a link between long-term mercury exposure and an increased risk of cardiovascular diseases such as hypertension and heart disease.[43,45,46] In pregnant women, mercury exposure can affect fetal development, causing neurodevelopmental problems and developmental delays in children exposed in utero.[45]

Interactions between mercury and nutrients in the body

Proteins and amino acids can bind to mercury and affect its distribution in the body. Protein deficiency can increase susceptibility to mercury toxicity due to a lack of ability to bind and neutralize mercury. Selenium can interact with mercury and form a less toxic complex. Adequate selenium intake can help protect the body from the harmful effects of mercury.[43,47–50] Zinc and copper play a role in mercury detoxification. Zinc and copper deficiency can increase mercury toxicity due to the body's reduced ability to eliminate mercury.[48] Vitamins E and C can reduce oxidative damage caused by mercury, and cells in the body will be protected due to their antioxidant properties.[46] The anti-inflammatory properties of omega-3 fatty acids can help reduce inflammation caused by mercury exposure and are therefore important for healthy brain development and nerve function.[51]

This is a literature review study designed to identify previous studies on fish consumption with nutritional implications in Indonesia. As a literature review study, this research has limitations. We realize that in this type of research, we are unable to provide sufficient information needed to represent Indonesia in the distribution of research in this area, as very little research has been conducted in Indonesia.

CONCLUSION

There are implications between the consumption of mercury fish and the nutritional aspect of weight loss and decreased body mass index (BMI). Further investigation should be conducted in this very important field to provide a sustainable step that can ultimately supply new information and knowledge for future costomers and show how consistent research in this area is in Indonesia.

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