applied sciences

MDPI

Article

The Threat of Mercury Poisoning by Fish Consumption

Felicia Dragan [1], Marieta Lestyan [1], Vasile Valeriu Lupu [2,*], Florin Mihai Marcu [1], Alina Cozma [3], Katalin Fodor [1], Anamaria Ciubara [4], Corina Florentina Moisa [1], Diana Teaha [5], Ancuta Lupu [2,*], Iuliana Magdalena Starcea [2], Alina Elena Ignat [6] and Alexandru Bogdan Ciubara [4]

1 Faculty of Medicine and Pharmacy, University of Oradea, 410087 Oradea, Romania
2 Faculty of General Medicine, "Grigore T. Popa" University of Medicine and Pharmacy, 700115 Iasi, Romania
3 Faculty of Chemistry, University of Oradea, 410087 Oradea, Romania
4 Faculty of Medicine and Pharmacy, "Dunarea de Jos" University of Galati, 800008 Galati, Romania
5 "Dr. Gavril Curteanu" Clinical Municipal Hospital Oradea, 410469 Oradea, Romania
6 Faculty of Biology, "Al. I. Cuza" University, 700506 Iasi, Romania
* Correspondence: valeriulupu@yahoo.com (V.V.L.); anca_ign@yahoo.com (A.L.)

Abstract: (1) Background: Fish is a good source of protein, iron, and zinc, which are key nutrients for infant growth and development, as well as a source of energy for adults and the elderly. Due to mercury contamination in both the terrestrial and aquatic environments, there is a risk that considerable levels of mercury will be ingested by the population, causing undesired illnesses and metabolic symptoms once they reach the body. The purpose of this research was to show and emphasize the hazardous effect of mercury in diverse marine products; (2) Methods: We conducted a comparative, open, randomized, non-interventional study on a study group of 119 adults from varied social and demographic backgrounds to assess the bad repercussions of mercury poisoning from fish consumption. A questionnaire with 18 questions was prepared in order to obtain information about the impact, i.e., the dangers present in fish meat. The research was carried out in Oradea and Bihor County, Romania; (3) Results: The largest age group was between the ages of 25–34, but we had respondents from almost all age groups. Most of them considered the fish healthy (30%) and that the omega-3 fatty acids have beneficial effects on the body (25.10%). More than a half of respondents (55%) were unaware of the hidden danger in fish meat in the form of mercury derivatives. Most respondents (65%) considered that they did not consume enough amounts of fish to suffer the consequences of this phenomenon. More than a half of respondents (59%) agreed that they should have been made aware beforehand by displaying the hazards of excessive intake of some high mercury concentration fish species; (4) Conclusions: It is imperative that the population be informed about dangers of mercury toxicity when consuming fish. Mercury must be gradually eliminated worldwide by replacing it with safer alternatives.

Keywords: fish; acids; omega-3; mercury; toxicity

check for updates

Citation: Dragan, F.; Lestyan, M.; Lupu, V.V.; Marcu, F.M.; Cozma, A.; Fodor, K.; Ciubara, A.; Moisa, C.F.; Teaha, D.; Lupu, A.; et al. The Threat of Mercury Poisoning by Fish Consumption. *Appl. Sci.* **2023**, *13*, 369. https://doi.org/10.3390/app13010369

Academic Editor: Antonio Valero

Received: 6 December 2022
Revised: 22 December 2022
Accepted: 23 December 2022
Published: 27 December 2022

Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

According to statistics, the average person consumes 0.44 g of Omega-3 per day, while the optimal amount is 2.44 g each day for a man and 2.22 g each day for a woman [1]. Fatty acids from fish oil help patients cope with viruses and infections [2,3], balance the immune system and slow aging process, and have a beneficial effect on the cardiovascular system [3], as they lower triglyceride levels, reduce inflammation and platelet aggregation, and prevent arrhythmias, which can significantly lower the risk of coronary heart disease [2,3]. Omega-3 fatty acids are also significant in other aspects of the diseases, such as lowering the chance of acquiring certain forms of cancer, neurological diseases, or issues associated with diabetes and metabolic syndrome [4]. Omega-3 polyunsaturated acids are essential in the battle against depression, and a deficiency of this nutrient can cause anxiety or even panic attacks, as well as a considerable reduction in physical pleasure perception [2,3]. Salmon meat

includes vitamin D, vitamin B12, selenium, omega-3, and anchovies, sardines, and tiny fish, in contrast to predators, are high in iron, making them a valuable element of a balanced diet [1,5].

Mercury is a hazardous metal that, in small concentrations, may cause and maintain severe toxicity. The amount of mercury in food is generally low, at 0.02 μg/g [6]. Mercury mostly accumulates in the aquatic environment through the food chain, which represents a serious danger for children's health [7,8]. Methylmercury is the most dangerous type of mercury found in numerous fish species [1,6]. Internal organ analysis revealed a buildup in the heart, liver, spleen, and kidneys, as well as in the blood, and 50% of Hg is deposited in the bones [6]. Mercury's and other heavy metals' high toxicity is due to protein binding, which affects the metabolic processes of protein forms such as erythrocytes, certain enzymes, and chromosomes [9]. Because organomercurics enter through the placenta and can induce congenital disorders, ingesting Hg-contaminated food poses a significant risk to fetuses [10]. Because the toxic effect passes through the placenta before the pregnant mother exhibits signs of mercury poisoning, the development of the baby's nervous system may be hampered [10]. Mercury can also be found in breast milk and therefore have an impact on the health of newborns [10]. Anorexia, weight loss, hypersalivation, tiredness, and muscular weakness are the first symptoms. Mercury buildup in the kidneys produces nephrotic syndrome, and mercury accumulation in the brain induces neurological dysfunctions and behavioral abnormalities [11]. Neurological abnormalities, such as tiny muscle tremors, are among the first symptoms to develop, beginning with the eyes, tongue, or fingers and proceeding down the limb [12,13]. Writing is substantially hindered and can be used as a qualitative assessment of detoxification therapy efficacy [5]. Irritability, memory loss, sleeplessness, tremors, and emotional instability accompanied by depression are examples of behavioral disorders. The combination of neuropsychiatric symptoms is accompanied by facial reddening and excessive perspiration, a sign known as heretism [14]. Mercury may also be to blame for the emergence of immunoallergic responses and a decline in antimicrobial resistance [2]. Menstrual problems and abortions are prevalent in females [10,14,15]. Women considering a pregnancy, pregnant or lactating women, and infants are among the most sensitive groups of people to the harmful effects of mercury [11].

Fish and seafood are key components of a healthy and important human diet, both traditionally and culturally, in many European countries, including for children [15,16]. The acute or chronic exposure to mercury may have side effects in any period of development. Mercury is an extremely toxic element: neuro-, nefro- and immuno-toxic; there is not any safe level of exposure known. Ideally, neither children, nor adults should have mercury in their body because there is no physiological benefit. Prepartum and postpartum exposure to mercury are frequent in many different ways. A developing child in the uterus and at the beginning of their life is very exposed to the risk [10].

Fish are recommended components of nutrition which provide high quality proteins, vitamins, minerals and omega-3 fatty acids, especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Despite all of these, these products may be also the principal source of methylmercury for humans. In general, over 90% of the mercury in fish is methylmercury, but the quantity of methylmercury may vary considerably from a species to another. The highest quantity of mercury is found in predatory fish, such as tuna, shark, swordfish, northern pike and marlin [17].

The population groups most vulnerable groups to the toxic effects of mercury are: women who plan on having a baby, pregnant women or women breastfeeding [7].

Methylmercury is an environmental pollutant that can have irreversible effects on children's development. Although there is no doubt that high exposure can cause neurodevelopmental deficits, the threshold that will adversely affect the developing fetus is not well defined. The lowest concentration of mercury in hair with observable adverse effect (LOAEHC—the lowest observable adverse effect hair concentration) was set at 0.3 micrograms/g of mercury in maternal hair. In the clinical context, most pregnant women consume less mercury-containing fish than

LOAEHC. Changing the diet can reduce the content and risk to the body; it would be necessary to analyze the mercury content in the mother's hair before pregnancy [8].

The toxicity of MeHg in humans is well-established and the main source of exposure is the consumption of large marine fish. It is important that pregnant women, children and women of childbearing potential avoid consuming MeHg. There is a direct correlation in the concentration of mercury in maternal hair and children in the same family, which indicates a similar exposure [15]. The group analysis showed that 95% of mothers who eat fish only once a week, without other seafood, have a mercury level of 0.55 μg/g. Thus, the 95th percentile of distribution in the group is about half of the US-EPA recommended threshold of 1 μg/g of mercury in the hair [15,18].

The purpose of this paper is to present and emphasize the consequences of inadequate nutrition, both in terms of quantity and quality, as well as a lack of information about the hidden dangers in fish meat and other marine products [7,9]. Because of the nutrients it provides, fish is an ideal meal, but we must also consider the presence of a concealed enemy—mercury—lurking behind the healthy proteins, omega-3 oils, zinc, vitamin D, and, of course, the pleasant flavor [8,17].

2. Materials and Methods

The purpose of this paper is to present and emphasize the consequences of inadequate nutrition, both in terms of quantity and quality, as well as a lack of information about the hidden dangers in fish meat and other marine products [7,19]. Because of the nutrients it provides, fish is an ideal meal, but we must also consider the presence of a concealed enemy—mercury—lurking behind the healthy proteins, omega-3 oils, zinc, vitamin D, and, of course, the pleasant flavor [16,20].

We conducted a comparative, open, randomized, non-interventional study on a study group of 119 adults, aged 18 to 55 years old, from varied social and demographic backgrounds to assess the bad repercussions of mercury poisoning from fish consumption. A questionnaire with 18 questions was prepared in order to obtain information about the impact, i.e., the dangers present in fish meat. The research was carried out in Oradea and Bihor County, Romania.

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethical Commission of the Faculty of Medicine and Pharmacy, University of Oradea (16/7 November 2019).

3. Results

3.1. Distribution of Respondents by Age

The distribution by age is shown in Figure 1 during the development of the individual questionnaire and the compilation of the responses. Respondents spanned practically all age categories, resulting in a rather uniform distribution. There were four age divisions (in years): 18–24, 25–34, 35–44, and 45–55. The age group with the highest proportion of respondents (50%) was 25–34 years old; however, responders of virtually all ages were recorded.

3.2. Distribution of Respondents by Level of Education

As indicated in Figure 2, according to the questionnaire, respondents had completed different levels of education. Most participants had completed secondary education or had been to university with results of 45% and 50%, respectively.

3.3. Distribution of Respondents by Social Background

The respondents who answered the questionnaire came from both backgrounds, urban and rural. The distribution was approximately equal, urban 54% and rural 46% as ilustrated in Figure 3.

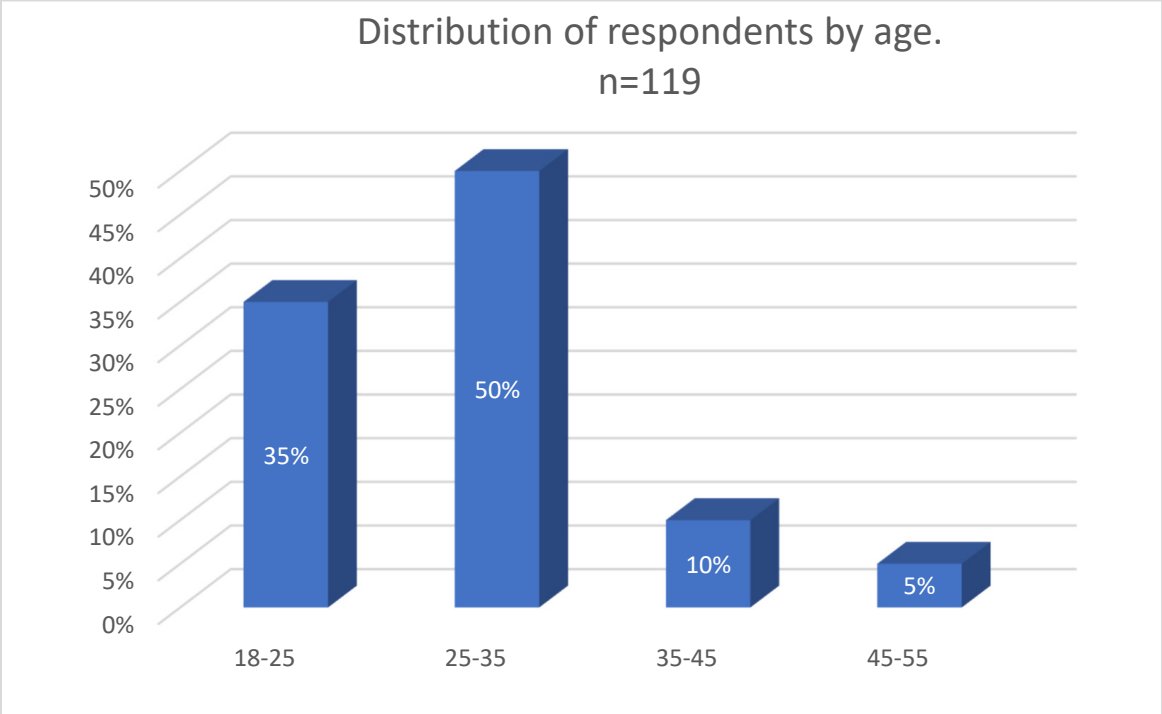

Figure 1. Distribution of respondents by age.

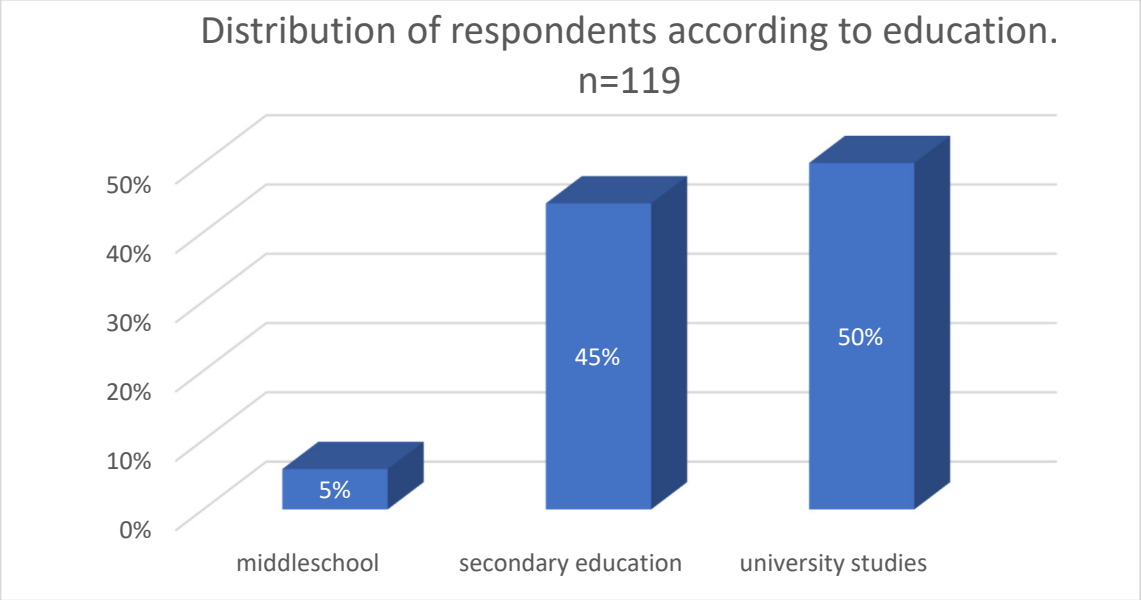

Figure 2. Distribution of respondents according to education level.

3.4. Distribution of Respondents According to the Reason of Buying Fish

When asked about the reasons for consuming fish and fish products, respondents considered themselves well-informed on its health benefits. Respondents interpreted this information in different ways, justifying the purchase of fish with various reasons. Most of them considered it healthy (30%) and that omega-3 fatty acids had beneficial effects on the body (25.10%), as presented in Figure 4.

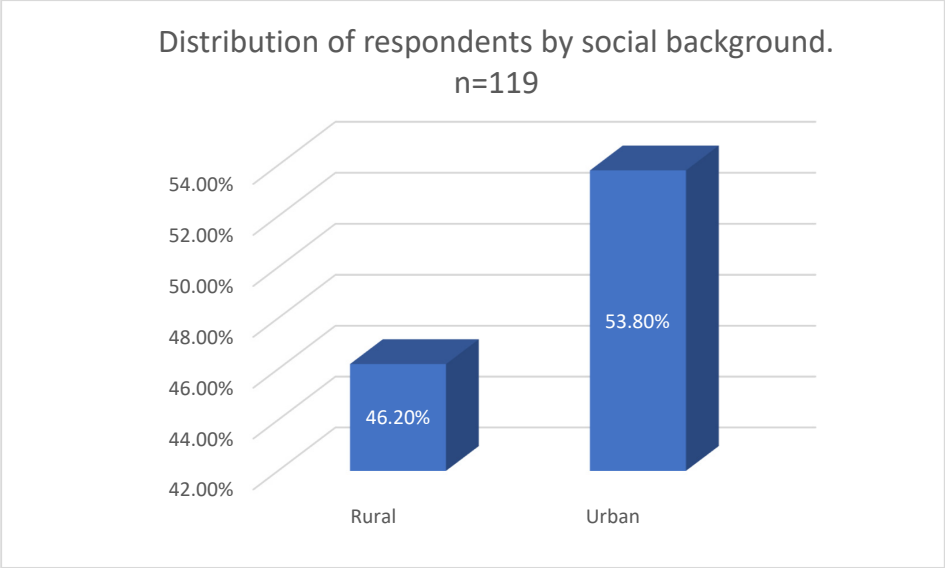

Figure 3. Distribution of respondents by social background.

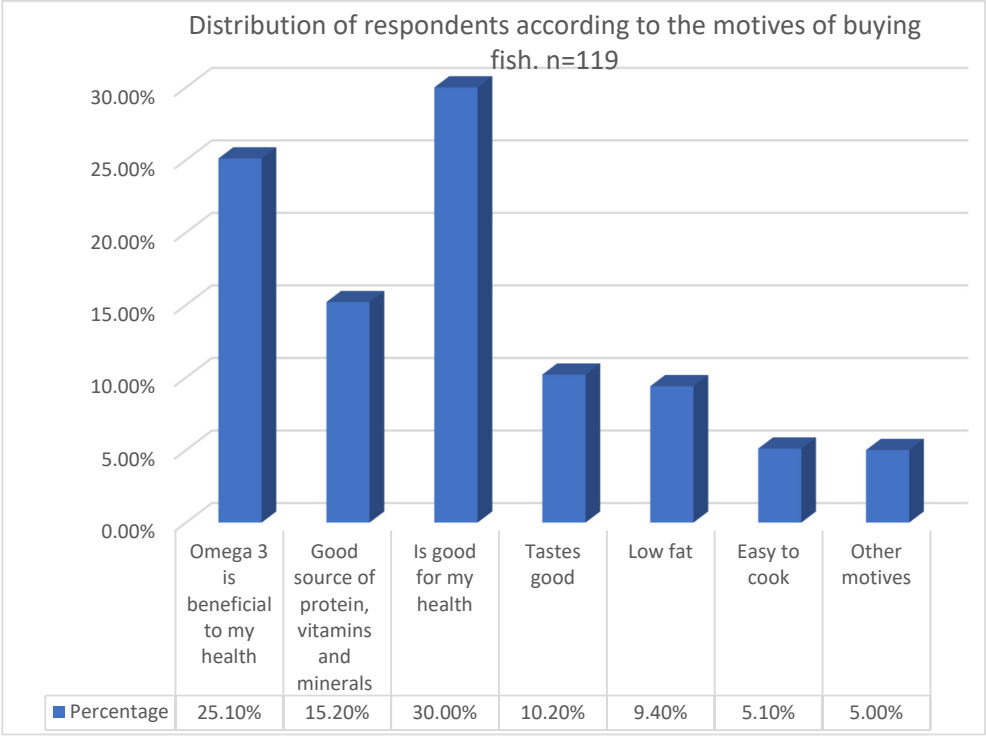

Figure 4. Distribution of respondents according to the reason of buying fish.

3.5. Distribution of Respondents According to Their Knowledge on Mercury Exposure Associated with Fish Consumption

Regarding the answers to the questions about the knowledge of dangers hidden in fish meat due to the presence of mercury Figure 5 emphesizes that more than half of the respondents (55%) were uninformed about the secret dangers in fish meat in the form of mercury derivatives, 5% did not care while only 40% were aware of them.

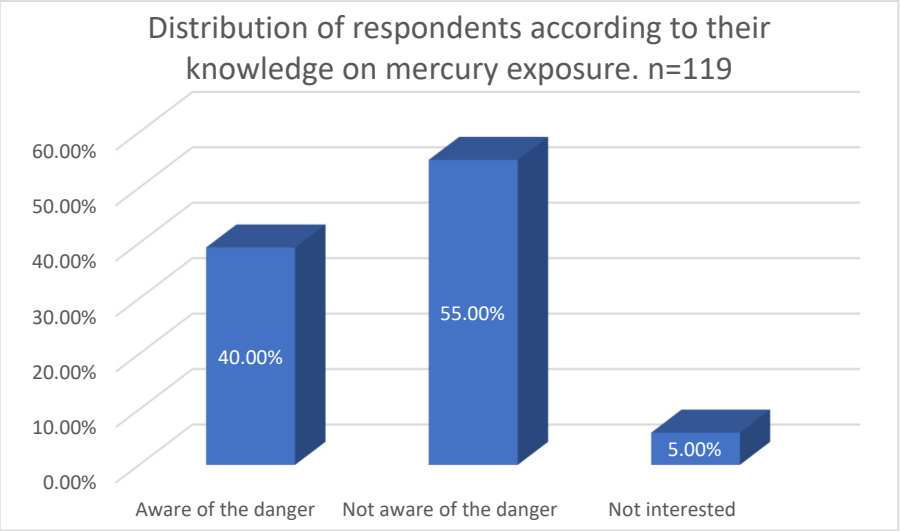

Figure 5. Distribution of respondents according to their knowledge on mercury exposure associated with fish consumption.

3.6. Distribution of Respondents on the Introduction of Fish Products into Children's Food

The topic of incorporating fish into children's diets elicited a variety of opinions. The respondents were not completely convinced either of the beneficial role of fish meat in children's diet or the possible toxic effects due to fish consumption. A total of 46.2% (n = 55) chose the answer corresponding to giving children nutritional supplements that contain fish-specific nutrients, i.e., fish oil with omega-3, calcium and zinc supplements, vitamin D, while only 12.8% (n = 15) chose the answer referring the inclusion of fish or fish-based products in their children's diet. We should underline the fact that 41% (n = 49) of the respondents did not introduce fish or fish-based products into their children's diet. The results of the questionnaire are shown in Figure 6.

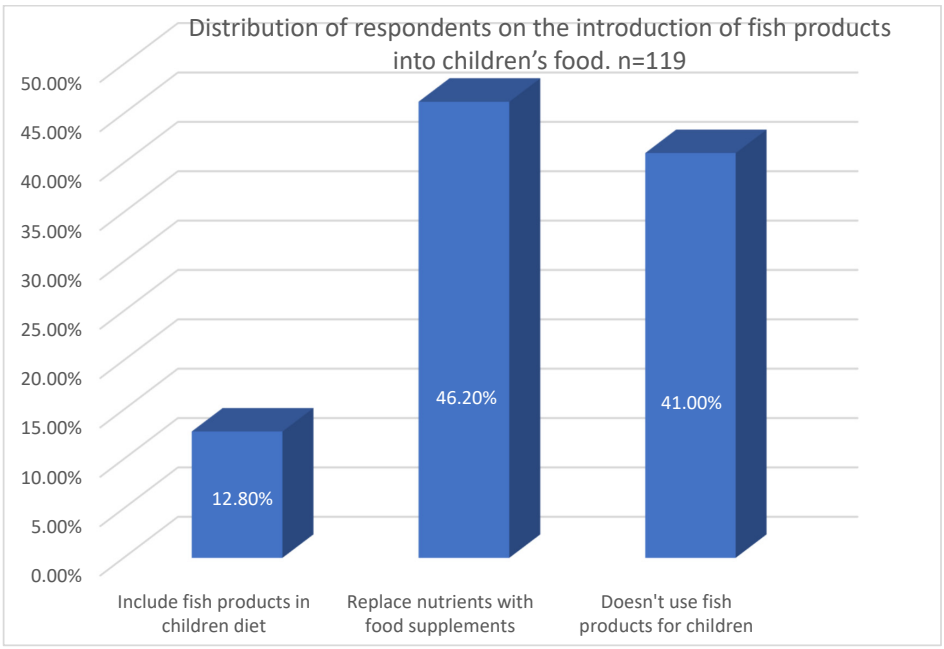

Figure 6. Distribution of respondents on the introduction of fish products into children's food.

3.7. The Influence of Commercial Advertisements and Mass Media

A sizable proportion of those polled believed the information supplied by the media about the dangers of ingesting mercury-contaminated seafood. This influenced the

respondent's decisions upon deciding which product to purchase, having mainly bought fish of the silver carp species, those with a relatively short life span, thus, unable to be infested with toxic substances, and fewer species of predator fish. Most (42%), took into consideration the information received, 13% searched for information online and 20% read the product label, while 25% did not, as shown in Figure 7

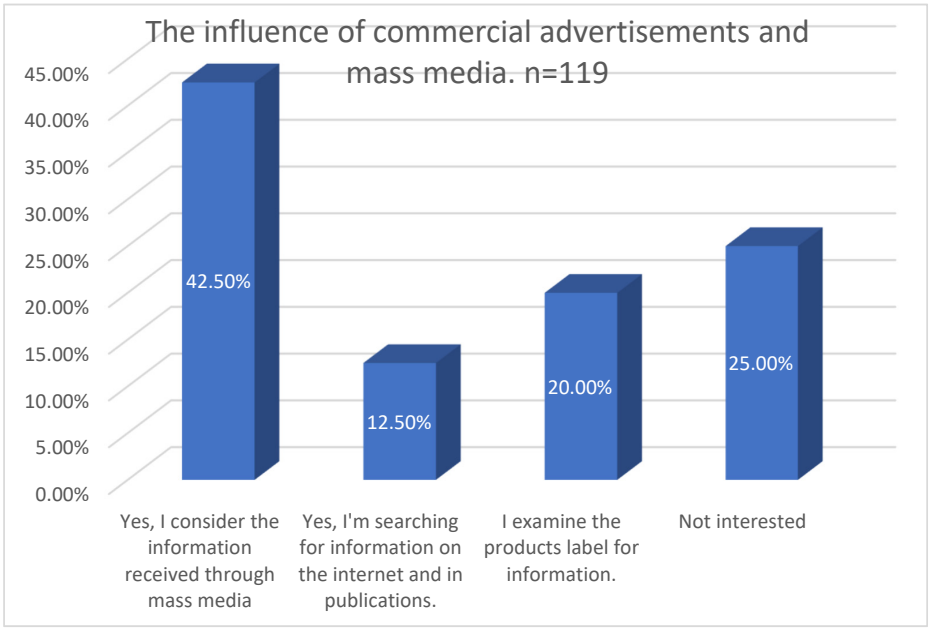

Figure 7. The influence of commercial advertisements and mass media.

3.8. Distribution of Respondents Regarding Possible Diseases Associated with Fish Consumption

Most of the responders (65%) considered that they did not consume enough fish to suffer the consequences of this phenomenon, 10% were not concerned, 3% thought it was possible and 22% did not believe about the possible diseases, as seen in Figure 8.

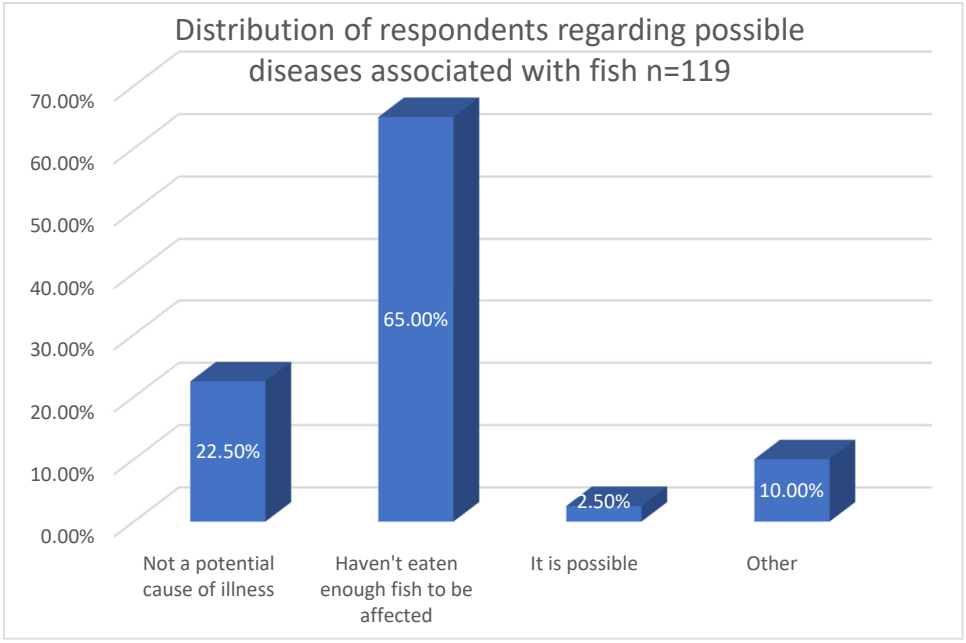

Figure 8. Distribution of respondents regarding possible diseases associated with fish consumption.

3.9. Distribution of Respondents Regarding Suggestions on Improving People's Access to Information on the Toxicity of Fish Products

More than half of the participants (67.5%) thought that they did want to be informed about the hazards of consuming fish products. Another 17.5 percent believed merchants should tell customers about mercury levels in their products. Figure 9 displays how the responses were divided.

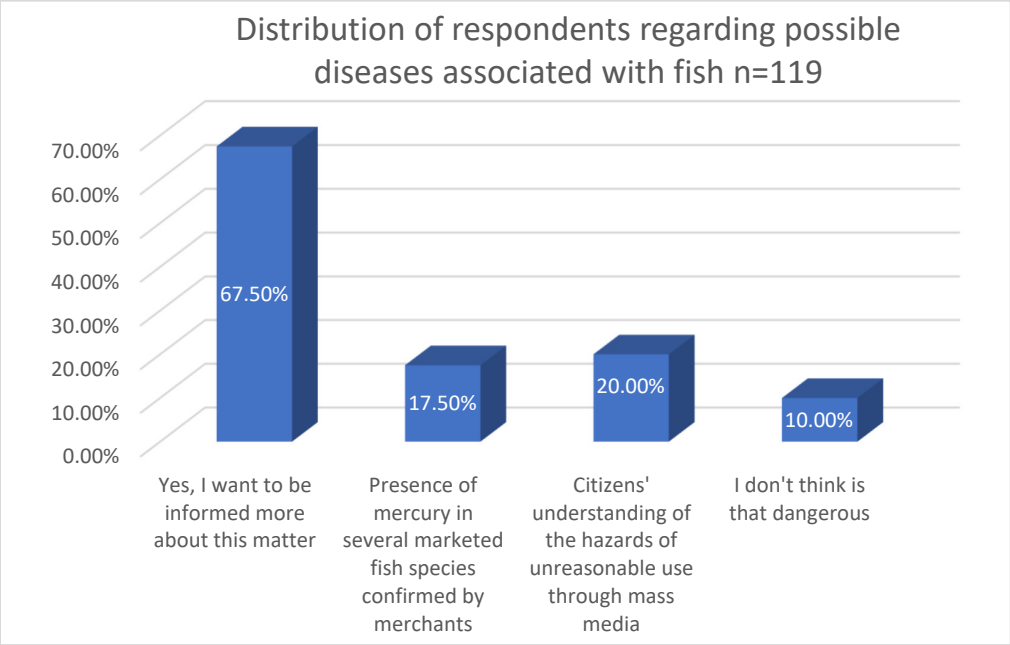

Figure 9. Distribution of respondents regarding suggestions on improving access to information on the toxicity of fish products.

4. Discussion

Communities that consume various species of fish daily can contract serious diseases due to methylmercury (CH_3Hg^+) intoxication. They are either not adequately informed or neglect warnings, disregarding the high level of mercury from consuming fish. Severe neurological diseases (mental retardation, microcephaly, seizures) caused by consumption of fish contaminated with (CH_3Hg^+) have been reported in S.U.A., Korea and Japan [6,9,12,13].

The purchase of fish with potentially low levels of mercury depends on the moderately dear price of these species that are mainly found in supermarkets. The information on the level of toxic substance, for example, Hg, is not always mentioned on the labels of the commercially purchased products. Respondents consider it imperative that the population be informed about the hidden dangers of mercury toxicity when consuming fish, fish-based products or seafood by any means.

To resolve this issue, the use of mercury must be gradually eliminated worldwide by replacing it with safer alternatives. Secondly, people must be better informed about the ways of preventing the accumulation of mercury in their bodies, to protect the health of the future generations.

It is vital to educate and create knowledge about safe fish handling and conservation, as well as the advantages of eating fish or fish products, in the context of the regulations and standards that must be adhered to prior to the sale of the fish.

Young individuals between the ages of 24 and 25, from both rural and urban origins, who have finished secondary or university education, are the most familiar with fish eating, according to our questionnaire.

The majority of respondents (30%) believed that eating fish products is healthy and that omega-3 fatty acids are advantageous to the body (25.10%). We confirmed our assumption that the vast majority of individuals are unaware of the hazards of mercury poisoning from

eating fish products. Furthermore, incorporating fish items in children's diets has supplied us with an intriguing view point on potential harmful consequences, the vast majority of our respondents were apprehensive about the health of their children, going for food supplements that contain fish-specific nutrients, i.e., fish oil with omega-3, calcium and zinc supplements, vitamin D or the exclusion of fish products in children. The influence of commercial advertisements and mass media is also a topic that influences the consumption of fish.

We were alarmed to learn that the majority of those questioned were uninformed of the risks linked with the quantity of fish they were ingesting, with more than half of them (65%) believing they were not eating enough fish to be at risk of mercury poisoning.

We were also gratified to discover that the significant majority of participants (67.5%) wished to learn more about this topic through reliable sources such as published articles, or the mass media.

Respondents believe it is vital and necessary to warn the public in any way possible about the hidden hazards of mercury poisoning from eating fish or seafood products.

5. Conclusions

Fish meat has a high nutritional value. It is high in protein and monounsaturated fats, but pollution is causing more and more fish species to contain mercury. Communities that consume a variety of fish species in their daily diet may be exposed to serious illnesses as a result of methylmercury poisoning, owing to a lack of knowledge or disregard for warnings, assuming that the quantity of mercury in fish intake is insignificant.

Although the risk of low doses of mercury is modest on an individual basis, this should not prevent us from taking proper measures. The consequences of today's progress will have a long-term influence on the whole population.

To safeguard future generations' health, mercury must be phased out internationally and replaced with safer alternatives, and people must be better informed about how to avoid mercury buildup in their bodies.

Supplementary Materials: The questionnaire is available online at: https://www.mdpi.com/article/10.3390/app13010369/s1.

Author Contributions: Conceptualization, F.D. and V.V.L.; methodology, F.D. and K.F.; validation, M.L., A.C. (Alina Cozma), A.E.I., I.M.S. and A.C. (Anamaria Ciubara); formal analysis, A.L., D.T., F.M.M. and A.B.C.; investigation, A.C. (Alina Cozma), M.L. and K.F.; data curation, F.D.; writing—original draft preparation, F.D., M.L., D.T. and A.C. (Alina Cozma); writing—review and editing, K.F., A.C. (Anamaria Ciubara), V.V.L., F.M.M., A.B.C., A.E.I., C.F.M., A.L., I.M.S.; supervision, C.F.M.; project administration, A.B.C., F.M.M., M.L., A.C. (Alina Cozma), K.F., A.C. (Anamaria Ciubara), A.E.I., D.T., C.F.M. and I.M.S. contributed equally with F.D. to this article. All authors contributed equally to this article. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by Ethical Commission of the Faculty of Medicine and Pharmacy, University of Oradea (16/7 November 2019).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data available from the first author on request. Data from questionnaire have been cited in Supplementary Materials.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Gammone, M.A.; Riccioni, G.; Parrinello, G.; Orazio, N. Omega-3 Polyunsaturated Fatty Acids: Benefits and Endpoints in Sport. *Nutrients* **2019**, *11*, 46. [CrossRef] [PubMed]
2. Zaloga, G.P. Narrative Review of n-3 Polyunsaturated Fatty Acid Supplementation upon Immune Functions, Resolution Molecules and Lipid Peroxidation. *Nutrients* **2021**, *13*, 662. [CrossRef] [PubMed]

3. Hilleman, D.; Teply, R.; Packard, K.A. Knowledge, Perceptions, and Patterns of Fish Oil Use in Cardiac Patients. *J. Pharm. Pract.* **2020**, *33*, 580–585. [CrossRef] [PubMed]
4. Telle-Hansen, V.H.; L. Gaundal; Myhrstad, M. Polyunsaturated Fatty Acids and Glycemic Control in Type 2 Diabetes. *Nutrients* **2019**, *11*, 1067. [CrossRef] [PubMed]
5. Tyśkiewicz, K.; Gieysztor, R.; Maziarczyk, I.; Hodurek, P.; Rój, E.; Skalicka-Woźniak, K. Supercritical Fluid Chromatography with Photodiode Array Detection in the Determination of Fat-Soluble Vitamins in Hemp Seed Oil and Waste Fish Oil. *Molecules* **2018**, *23*, 1131. [CrossRef] [PubMed]
6. Day, N.K.; Schmidt, T.; Roberts, J.; Osmundson, B.; Willacker, J.J.; Eagles-Smith, C.A. Mercury and selenium concentrations in fishes of the Upper Colorado River Basin, southwestern United States: A retrospective assessment. *PLoS ONE* **2020**, *15*, e0226824. [CrossRef] [PubMed]
7. Bose-O'Reilly, S.; McCarty, K.M.; Steckling, N.; Lettmeier, B. Mercury Exposure and Children's Health. *Curr. Probl. Pediatr. Adolesc. Health Care* **2010**, *40*, 186–215. [CrossRef] [PubMed]
8. Schoeman, K.; Bend, J.R.; Hill, J.; Nash, K.; Koren, G. Defining a lowest observable adverse effect hair concentrations of mercury for neurodevelopmental effects of prenatal methylmercury exposure through maternal fish consumption: A systematic review. *Ther. Drug. Monit.* **2009**, *31*, 670–682. [CrossRef] [PubMed]
9. Park, K.; Seo, E. Association between Toenail Mercury and Metabolic Syndrome Is Modified by Selenium. *Nutrients* **2016**, *8*, 424. [CrossRef] [PubMed]
10. Stratakis, N.; Conti, D.V.; Borras, E.; Sabido, E.; Roumeliotaki, T.; Papadopoulou, E.; Agier, L.; Basagana, X.; Bustamante, M.; Casas, M.; et al. Association of Fish Consumption and Mercury Exposure During Pregnancy With Metabolic Health and Inflammatory Biomarkers in Children. *JAMA Netw Open.* **2020**, *3*, e201007. [CrossRef] [PubMed]
11. Fields, C.A.; Borak, J.; Louis, E.D. Mercury-induced motor and sensory neurotoxicity: Systematic review of workers currently exposed to mercury vapor. *Crit. Rev. Toxicol.* **2017**, *47*, 811–844. [CrossRef] [PubMed]
12. Eto, K.; Marumoto, M.; Takeya, M. The pathology of methylmercury poisoning (Minamata disease). *Neuropathology* **2010**, *30*, 471–479.
13. Keibo, O. *Rowing the Eternal Sea: The Story of a Minamata Fisherman*; Rowman & Littlefield Publisers: Lanham, MD, USA, 2001; ISBN 0-7425-0021-7.
14. Park, J.D.; Zheng, W. Human Exposure and Health Effects of Inorganic and Elemental Mercury. *J. Prev. Med. Public Health* **2012**, *45*, 344–352. [CrossRef] [PubMed]
15. Castaño, A.; Cutanda, F.; Esteban, M.; Pärt, P.; Navarro, C.; Gómez, S.; Rosado, M.; López, A.; López, E.; Exley, K.; et al. Fish consumption patterns and hair mercury levels in children and their mothers in 17 EU countries. *Environ. Res.* **2015**, *141*, 58–68. [CrossRef] [PubMed]
16. Drăgan, F.; Lupu, V.V.; Pallag, A.; Barz, C.; Fodor, K. Rational consumption of nutrients at school-aged children. *IOP Conf. Ser. Mater. Sci. Eng.* **2017**, *200*, 012063. [CrossRef]
17. Mania, M.; Wojciechowska-Mazurek, M.; Starska, K.; Rebeniak, M.; Postupolski, J. Fish and seafood as a source of human exposure to methylmercury. *Rocz Panstw Zakl Hig.* **2012**, *63*, 257–264. [PubMed]
18. Bussan, D.D.; Douvris, C.; Cizdziel, J.V. Mercury Methylation Potentials in Sediments of an Ancient Cypress Wetland Using Species-Specific Isotope Dilution GC-ICP-MS. *Molecules* **2022**, *27*, 4911.
19. Angyus, S.B.; Levei, E.; Petreus, D.; Etz, R.; Covaci, E.; Moldovan, O.T.; Ponta, M.; Darvasi, E.; Frentiu, T. Simultaneous Determination of As, Bi, Sb, Se, Te, Hg, Pb and Sn by Small-Sized Electrothermal Vaporization Capacitively Coupled Plasma Microtorch Optical Emission Spectrometry Using Direct Liquid Microsampling. *Molecules* **2021**, *26*, 2642. [CrossRef] [PubMed]
20. Pertovici, M.; Pacioglu, O. Heavy metal concentrations in two species of fish from the Crișul Negru River, Romania. *AACL Bioflux* **2010**, *3*, 51–60.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.