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Relationship between Total Mercury Concentration and Fish Size in Two Pelagic Fish Species: Implications for Consumer Health

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ABSTRACT

Total mercury concentrations were determined in different size classes of two pelagic fish species of great commercial importance, horse mackerel (*Trachurus trachurus*) and Mediterranean horse mackerel (*Trachurus mediterraneus)*, to evaluate the relationship between total mercury concentration and fish size and to determine whether any differences might affect the quantitative assessment of mercury exposure for consumers. Mercury concentrations in horse mackerel and in Mediterranean horse mackerel were between 0.16 and 2.41 $\mu g\ g^{-1}$ of weight wet (mean, 0.68 $\mu g\ g^{-1}$) and between 0.09 and 1.62 $\mu g\ g^{-1}$ (mean, 0.51 $\mu g\ g^{-1}$), respectively. The regression curves revealed a significant relationship between mercury concentration and fish size (length and weight) for both species. Concentrations exceeding the proposed limit for human consumption were observed in 33.3% of the samples of both species and were associated with larger specimens. The consumption of the larger specimens could lead to an increase in mercury exposure for consumers. Estimated weekly intakes, calculated on the basis of concentrations relative to each size class, revealed a high exposure associated with the consumption of fish larger than 30 cm (horse mackerel, 11.63 to 20.16 μg/kg of body weight; Mediterranean horse mackerel, 5.86 to 13.55 μg/kg of body weight). An understanding of the factors leading to an increase in mercury exposure can help consumers make informed decisions about eating fish.

Seafood rich in proteins and unsaturated essential fatty acids is an important component of a healthy diet. A large body of data strongly demonstrates the health benefits related to fish consumption *(6, 11)*. However, fish consumption can also be associated with health risks related to contamination of fish with toxic metals. Mercury is recognized as one of the most deleterious pollutants with regard to both its effect on marine organisms and its potential hazard to humans. The toxic effects of mercury have been highlighted in some cases of collective poisoning of people who consumed a lot of fish. Seafood consumption appears to be the most important source of mercury exposure in humans, as indicated by findings of significant differences between subpopulations with high and low fish consumption *(7, 9)*. Several factors may affect accumulation of this nonessential heavy metal in marine organisms. Wren *(25)* listed both biotic and abiotic factors affecting accumulation of this element in wildlife. Feeding habits and habitat play a key role in the uptake of mercury by organisms. Animal size also is recognized as important for determining the total body mercury load in marine organisms. These observations are of special interest in relation to potential human health hazards from fish consumption. In earlier studies, lower human dietary exposure to mercury has been associated with either the consumption of pelagic fish rather than benthic species *(19, 21)* or the consumption of smaller fish *(18, 20)*. An understanding of these key issues, which strongly affect mercury load, is of fundamental importance when advising consumers to avoid certain fish types and certain fish sizes.

The concentrations of total mercury were determined in different size classes of two pelagic fish species of great commercial importance, the horse mackerel (*Trachurus trachurus*) and the Mediterranean horse mackerel (*Trachurus mediterraneus*), to evaluate differences in mercury concentration as a function of fish size. In particular we were interested in verifying to what extent eventual concentration differences affect the quantitative assessment of consumer mercury exposure. Such an analysis could provide a framework for designing a targeted risk-communication strategy to help consumers make informed decisions about eating fish.

MATERIALS AND METHODS

From June through August 2004 during several trawl surveys, 253 horse mackerel and 273 Mediterranean horse mackerel specimens were caught in the southern Adriatic Sea. Specimens of each species were divided into 12 groups based on the size of each fish (Tables 1 and 2). From the fish in each group, the muscle tissue of the middle portion of both lateral sides was removed and preserved at −25°C until analysis. The tissues were dissected with plastic tools that were washed with 5% HNO_3 and rinsed with distilled and deionized water to avoid metal contamination. For

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TABLE 1. *Concentrations of total mercury and estimated human weekly mercury intake from the consumption of horse mackerel*[a]

Group no.	No. of fish	Fish length (cm)	Fish weight (g)	Mean total Hg ($\mu g\ g^{-1}$)	Estimated weekly Hg intake (μg/kg of body weight) from consuming: 251 g of fish	502 g of fish
1	23	19.5	51.2	0.17	0.71	1.42
2	22	21.4	68.4	0.20	0.84	1.67
3	24	24.4	105.7	0.16	0.60	1.20
4	31	25.0	106.2	0.26	1.09	2.18
5	25	29.0	114.6	0.43	1.80	3.60
6	28	23.1	119.4	0.29	1.22	2.43
7	18	27.1	132.6	0.42	1.76	3.51
8	15	28.5	184.9	0.44	1.84	3.68
9	16	32.1	233.6	0.59	2.47	4.94
10	15	32.6	243.9	1.39	5.82	11.63
11	18	34.4	322.6	1.42	5.94	11.88
12	18	37.2	429.3	2.41	10.08	20.16
Mean		27.9	176.0	0.68	2.85	5.69

[a] The PTWI is 5 μg/kg of body weight.

analyses of total mercury, homogenized samples of tissue (2 g wet weight) were digested to a transparent solution with 10 ml of 65% concentrated nitric acid and 95 to 97% sulfuric acid (1:1) under reflux. The resultant solutions were then diluted to a known volume with deionized water *(5)*, and the total mercury concentrations were measured with atomic absorption spectrophotometry (Analyst 800, Perkin Elmer, Norwalk, Conn.) by the cold vapor technique after reduction by $SnCl_2$ (FIAS-Furnace, Perkin Elmer). Acid-washed glassware, analytical grade reagents, and double-distilled deionized water were used in the tissue analysis. To verify the purity of the chemicals, chemical blanks were analyzed, and no evidence of contamination was observed in these blanks. Analytical quality control was achieved with TORT-1 lobster hepatopancreas (National Research Council of Canada, Ottawa). The mean result from three replicate analyses of total mercury (0.32 $\pm$ 0.02 $\mu g\ g^{-1}$ dry weight) was in the range of the certified material (0.33 $\pm$ 0.06 $\mu g\ g^{-1}$ dry weight). Each sample was analyzed in duplicate, and all data were computed as micrograms of mercury per gram of wet weight.

RESULTS AND DISCUSSION

Total mercury concentrations in the muscle tissue of the two different species of fish from Adriatic Sea are shown in Tables 1 and 2. The concentrations in horse mackerel and Mediterranean horse mackerel were 0.16 to 2.41 $\mu g\ g^{-1}$ (mean, 0.68 $\mu g\ g^{-1}$) and 0.09 to 1.62 $\mu g\ g^{-1}$ (mean, 0.51 $\mu g\ g^{-1}$), respectively. The range of concentrations was not significantly different between the two species ($P >$ 0.04). Differences in feeding habits can be used to generally separate species by trophic level, and species belonging to higher trophic levels are thought to contain higher concentrations of mercury. The comparable mercury concentrations found in these two pelagic species might be the result of similar feeding behaviors. In some studies that have included qualitative descriptions of diet *(13, 14)*, these carangid fishes from the Adriatic Sea have been assigned to the same trophic level *(16)* because both are zooplanktivores.

TABLE 2. *Concentrations of total mercury and estimated human weekly mercury intake from the consumption of Mediterranean horse mackerel*[a]

Group no.	No. of fish	Fish length (cm)	Fish weight (g)	Mean total Hg ($\mu g\ g^{-1}$)	Estimated weekly Hg intake (μg/kg of body weight) from consuming: 251 g of fish	502 g of fish
1	30	18.5	46.6	0.09	0.38	0.75
2	26	19.9	60.0	0.09	0.38	0.75
3	23	22.9	96.4	0.21	0.88	1.76
4	21	23.4	98.1	0.16	0.67	1.34
5	20	24.3	100.4	0.21	0.88	1.76
6	25	24.6	116.6	0.26	1.09	2.18
7	18	26.5	130.6	0.28	1.17	2.34
8	26	29.1	184.0	0.41	1.72	3.43
9	17	29.6	228.1	0.54	2.34	4.68
10	23	34.1	263.5	0.70	2.93	5.86
11	22	36.9	356.4	1.55	6.48	12.97
12	22	39.7	442.3	1.62	6.78	13.55
Mean		27.5	176.9	0.51	2.13	4.27

[a] The PTWI is 5 μg/kg of body weight.

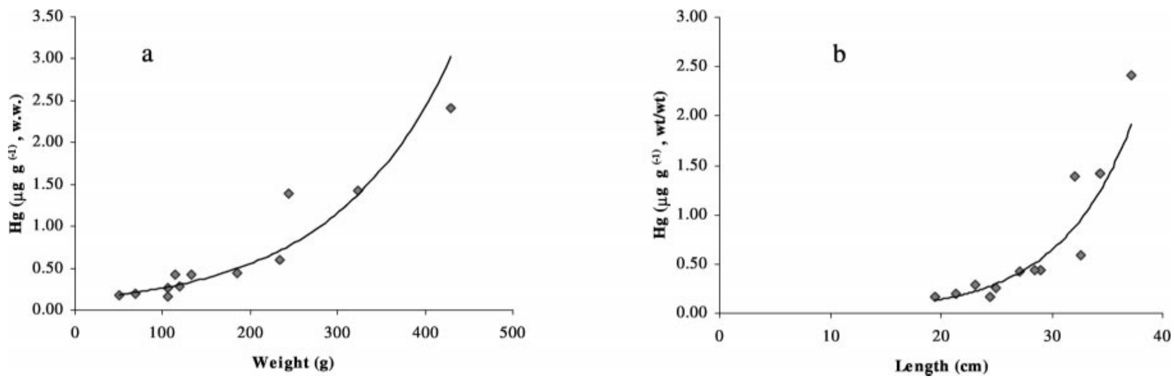

FIGURE 1. *Relationship between total mercury concentrations and weight (a) or length (b) of horse mackerels.*

These investigations also revealed that horse mackerel and Mediterranean horse mackerel begin life as zooplanktivores but become piscivores at adult lengths of more than 30 cm. Such changes in diet for these fishes focus attention on two important issues. First, piscivorous species appear to have higher mercury concentrations than omnivores, herbivores, or planktivores *(10, 17, 19)*. Second, there is a relationship between the age and/or size of the fish and the concentration of mercury, i.e., larger and/or older fish have generally higher mercury concentrations than do smaller and/or younger fish *(8, 17, 20)*. These observations are in agreement with the findings of the present study. Adult specimens (length > 30 cm) had the highest mercury concentrations (horse mackerel, 1.39 to 2.41 μg g^{-1}; Mediterranean horse mackerel, 0.70 to 1.62 μg g^{-1}), and an increase in concentration was noted with increasing length and weight for both species (horse mackerel, weight $r = 0.94$, $P < 0.0001$, length $r = 0.94$, $P < 0.0001$; Mediterranean horse mackerel, weight $r = 0.97$, $P < 0.0001$, length $r = 0.99$, $P < 0.0001$) (Figs. 1 and 2). These issues have been addressed with supporting data in the environmental health sciences literature *(15, 23)* and are important for evaluating the potential risks for seafood consumers. Within different fish size classes, the considerable variation in total mercury concentration is a crucial point that requires more attention in relation to maximum permissible size limits above which seafood would be considered unsuitable for human consumption or the assessment of human exposure via ingestion of such food. European Commission Decision 93/351 of 19 May 1993 *(1)* set the maximum limit for mercury in seafood at 0.5 μg g^{-1} of wet weight, increasing to 1 μg g^{-1} for the edible parts of some species (Annex A of the same decision) that for physiological and ecological reasons concentrate mercury more easily in their tissues. For fish analyzed in the present study, total mercury concentrations should not exceed 0.5 μg g^{-1}. In the present study, concentrations exceeding this limit were found in 33.3% of samples of both species and were associated with larger fish. A fish that exceeds the food standard maximum is not necessarily unfit for human consumption, because these limits are conservatively set for regulatory purposes and assume worst-case scenarios *(22)*. The international toxicological references for a given contaminant as set by the Joint Expert Committee on Food Additives constitute an appropriate guideline for evaluating the food exposure risk. The provisional tolerable weekly intake (PTWI) for total mercury, set by the Joint Expert Committee on Food Additives *(24)*, is 300 μg per person, which is equivalent to 5 μg/kg of body weight. Based on a mean weekly fish consumption of 502 g *(4)*, the mean mercury concentrations in each species (horse mackerel, 0.68 μg g^{-1}; Mediterranean horse mackerel, 0.51 μg g^{-1}), and a human body weight of 60 kg, the calculated weekly intake was below the established PTWI for Mediterranean horse mackerel (4.27 μg/kg of body weight) and the estimate exposure for the consumption of horse mackerel (5.69 μg/kg of body weight) was slightly above the safe level (Tables 1 and 2). However, because mercury concentrations vary with fish size, it is necessary to take into account these variations in health risk assessment. Estimated weekly intakes, calculat-

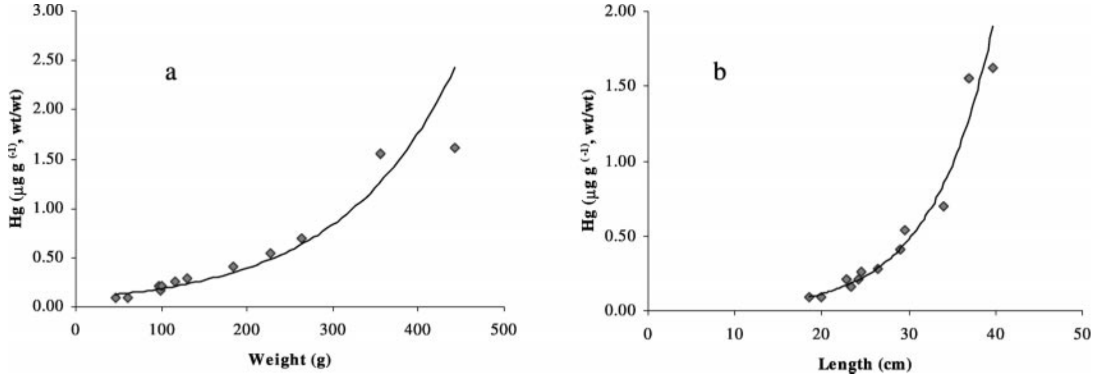

FIGURE 2. *Relationship between total mercury concentrations and weight (a) or length (b) of Mediterranean horse mackerels.*

ed on the basis of the concentrations relative to the each fish size class, revealed that higher levels of exposure were associated with the consumption of fish larger than 30 cm (horse mackerel, 11.63 to 20.16 μg/kg of body weight; Mediterranean horse mackerel, 5.86 to 13.55 μg/kg of body weight). These findings are particularly relevant for the assessment of potential health hazard for consumers. The use of mean concentrations of a given contaminant for the calculation of exposure risk often leads to underevaluation because extreme contamination levels are not taken into account. The findings from the present study clearly indicate that consumers that eat larger fish may be exposed to higher concentrations of mercury than those that eat smaller fish. This situation is even more alarming if one considers that when half the amount of fish is eaten per week (251 g) this trend remains unaltered, and the estimated weekly intake is still higher than the PTWI (Tables 1 and 2).

Healthy eating has been heavily promoted during the last few decades, and considerable attention has been focused on the benefits of consuming fish. The regular consumption of fish provides proteins of high biological value, unsaturated essential fatty acids, certain minerals, and vitamins. Data indicate that the consumption of fish reduces the risk of coronary heart disease, decreases mild hypertension, prevents certain cardiac arrhythmias, lowers the incidence of diabetes, and appears to alleviate symptoms of rheumatoid arthritis *(2, 3, 11, 12)*. Considering the nutritional and health benefits, fish consumption should be encouraged. However, an understanding of the links between fish size, mercury concentrations in fish, and intake concentrations of this contaminant is crucial for consumers to make decisions about eating fish. Changes in consumption behavior are possible only if people are aware of the risks from consumption of larger fish.

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