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Risk estimation to human health caused by the mercury content of *Sushi* and *Sashimi* sold in Japanese restaurants in Brazil

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ABSTRACT

Although fish is a healthy alternative for meat, it can be a vehicle for mercury (Hg), including in its most toxic organic form, methylmercury (MeHg). The objective of the present study was to estimate the risk to human health caused by the consumption of *sushi* and *sashimi* as commercialized by Japanese food restaurants in the city of Campinas (SP, Brazil). The total Hg content was determined by atomic absorption spectrometry with thermal decomposition and amalgamation, and the MeHg content calculated considering that 90% of the total Hg is in the organic form. The health risk was estimated from the values for the provisional tolerable weekly ingestion (PTWI) by both adults and children. The mean concentrations for total Hg were: 147.99, 6.13, and 3.42 μg kg^{-1} in the tuna, kani, and salmon *sushi* samples, respectively, and 589.09, 85.09, and 11.38 μg kg^{-1} in the tuna, octopus and salmon *sashimi* samples, respectively. The tuna samples showed the highest Hg concentrations. One portion of tuna *sashimi* exceeded the PTWI value for MeHg established for children and adults. The estimate of risk for human health indicated that the level of toxicity depended on the type of fish and size of the portion consumed.

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Introduction

Fish consumption has grown exponentially the world over in a search to select healthier foods and improve the quality of life. Surveys have shown that raw fish are becoming more and more available in lunch bars, restaurants, specialized restaurants and *sushi* bars.[1]

Fish are an important source of protein in human feeding, presenting all the essential amino acids.[2] Fish is also a source of various essential nutrients, including vitamins and minerals, and lipids.[2–3] On the other hand, fish can be vehicles for undesirable contaminants such as mercury (Hg). Hg is a nonnutrient metal that can be found naturally in the environment or be liberated by human actions.[4]

Mercury can be found in vegetables products such as mushrooms,[5] but seafood products, especially large predators, are the main dietary sources of Hg.[6] In an aquatic environment, Hg can be converted into its organic form, methylmercury (MeHg) by methylation, entering rapidly into the aquatic food chain and accumulating in biological tissues. Methylmercury represents about 90% of the total Hg detected in fish.[7]

In a study of the total Hg levels in *sushis* containing 5 different species of tuna, commercialized in restaurants in the states of New York, New Jersey and Colorado (USA), Lowenstein et al.[8] found elevated contents of this element with means between 0.307 and 1.028 mg kg^{-1}, all the samples exceeding the maximum value permitted by JETRO (0.4 mg kg^{-1}). According to the authors of the study, the Hg level found for the species bluefin *akami* (1.028 mg kg^{-1}) also exceeded the value permitted by the FDA (2000), Health Canada (2007) and EFSA (2008), all situated in 1.00 mg kg^{-1}.

The Hg is retained in the organism and its concentration increases with time. The toxicity is expanded since the Hg concentrations are capable of increasing at each level of the food chain, affecting those that occupy the top of the chain with greater intensity.[9]

According to World Health Organization,[10] Brazil presents less than 1% of the data referring to the Hg content of food products, amongst which fish is the main representative. Considering the increase in consumption of fish due to Japanese cuisine, and the lack of data referring to the Hg content of the fish used in this cuisine in Brazil, it is important to investigate the Hg content and estimate the risk of consumer exposition to Hg.

Materials and methods

Samples and chemical analyses

Samples of three fish species used in both *sushi* and *sashimi* were taken at random in restaurants specialized in Japanese food in the region of Campinas (SP, Brazil). In the case of *sushi*, samples were taken twice from 5 restaurants, and the three fish species were Yellowfin tuna (*Thunnus albacares*) ($n = 10$), kani

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(a mix of fish species flavoring with crab meat) ($n = 10$) and salmon (*Salmo salar*) ($n = 10$). In the case of *sashimi*, samples were taken on 4 occasions from 4 restaurants, the fish species being Yellowfin tuna (*Thunnus albacares*) ($n = 8$), octopus (*Octopus vulgaris*) ($n = 8$) and salmon (*Salmo salar*) ($n = 10$). The samples were homogenized using a domestic food processor and then filled into new polyethylene bags and maintained under refrigeration until analyzed.

The samples were separately triturated according to their specie, taking a complete dish with all ingredients, using a domestic processor to obtain a homogenized mass. The homogeneous mass samples were kept under freezing until analyses. Sample portions weight was determined experimentally as, approximately, 150 g (6 pieces of *sushi*) which was assumed as the adult portion size. For children we used the value of 50 g, considering a minor portion.

All the reagents used were of analytical grade and the water was purified by reverse osmosis, presenting a resistivity of 18.2 MΩ cm (Gehaka, São Paulo, Brazil) and the nitric acid used was purified using a sub-boiling distiller (Distillacid, Berghof, Eningen, Germany). A 0.5% (v/v) HNO_3 solution was used to prepare the analytical curves, and a 1000 mg L^{-1} certified standard mercury solution (Fluka, Sigma–Aldrich, Steinheim, Germany) were used. The calibration curves were prepared in the two detection cells (high sensitivity: 0.5 to 50 $\mu g\ kg^{-1}$ and low sensitivity: 100 to 1000 $\mu g\ kg^{-1}$) of the equipment.

The total Hg content was determined using an atomic absorption spectrophotometer with thermal decomposition and amalgamation (DMA-80, Milestone srl, Italy), as described by Morgano et al.[11] The optimized conditions for the sample drying and combustion (pyrolysis) temperatures were 200°C for 60s and 600°C for 180s, respectively. The mercury was desorbed at a temperature of 850°C and quantified at 253.7 nm using the absorption intensity (peak height). All the analyses were carried out in triplicate.

The contribution of each *sushi* component (seaweed, rice, kani, and/or fish) was determined in a previous work of our group. The obtained values were, in average: 65% of rice, 30% of fish and/or kani and 5% of seaweed.[11]

Evaluation of the health risk

The estimated exposure to MeHg was calculated considering a consumption of *sushi* and *sashimi* of 150 g, these value being experimentally obtained by weighing 6 pieces each of the commercially available *sushi* and *sashimi* samples. The sample weights of *sushi* and *sashimi* were weighed using a balance (Shimadzu, model EAU, 220), and assuming 150 g as a medium value for portions of *sushi* and *sashimi* commercialized in Japanese food restaurants.

Considering this parameter, the weekly ingestion estimate was calculated for each fish species using the mean values for total Hg determined. The MeHg content was calculated assuming that 90% of the total Hg found in the fish was in the form of MeHg.[7]

The health risk, defined by the food exposition value when this exceeded the Provisional Tolerable Weekly Intake (PTWI), was calculated using the following equation:[12]

$$\text{Exposition} = \text{mean concentration of the element } (\mu g\ /\ kg) \times \text{quantity consumed (kg) body weight (kg)}$$

The calculation of exposition can be underestimated or overestimated as a function of body weight. The risk evaluation to the human health was estimated using the body weight established by the WHO of 60 kg for adults and 15 kg for children.[12] Considering that the targeted public of the restaurants surveyed was composed mainly of Brazilians, the Brazilian health risk was evaluated using the body weight of this public.

For this purpose, the weights of the Brazilians were used in 3 life phases: children (5 to 9 year old; 25 kg), teenagers (10 to 19 year old; 50 kg) and adults (20 to 64 year old; 68 kg).[13] Due to the absence of values defined for the PTWI in Brazil, the dietetic exposition was evaluated using the values defined by JECFA[14], EFSA[15] and USEPA.[16]

A number of *sushi* and *sashimi* consumption situations were considered: occasional consumption (1 portion/week) ranging to moderate consumption (7 portions/week), by children and adults.

Statistical analysis

A McCulloch and Searle[17] mixed model was used for the statistical analysis of both the *sushi* and *sashimi* data, as follows:

$$yijkl = m + ti + qj + bk + (tq)ij + (tb)ik + (qb)jk + (tqb)ijk + eijkl$$

where *yijkl* is the total Hg of triplicate *l* of the sample containing fish species *i* collected in restaurant *j* at time *k*; *m* was the constant common to all the observations; *ti, qj*, and *bk* correspond, respectively, to the effects of the fish species *i* in restaurant *j* at time *k*; the terms in brackets refer to the interactions between these principal factors, and *eijkl* refers to the variation between the triplicates of each sample. The terms *ti* and *qj* and the interaction between them, were considered to be of a fixed nature. The collection times served as the control and their effect was considered to be of a random nature, as also the effects of the interactions involving the collection times.

The mixed procedure of the SAS software[18] was adopted since it deals with a mixed model and also because the second group of data have a certain lack of balance. Differences with $P<0.05$ were considered significant. When there was a significant difference between the levels of some factor according to the *F* test, the minimal squared means of this factor were compared using the Tukey-Kramer test.

Results and discussion

Hg concentration

Considering a significance level of 5%, the *F* tests showed a significant difference between the fish species, both for the *sushi*

Table 1. Total Hg concentration and MeHg estimation in *sushi* and *sashimi* prepared with different species of fish.

Sushi	[Hg] [1] μg kg^{-1}	[Hg] Minimal value (μg kg^{-1})	[Hg] Maximal value (μg kg^{-1})	[MeHg][2] μg kg^{-1}	Standard error (μg kg^{-1})
Tuna fish	147.99^a	27.20	464.20	133.19	22.85
Kani	6.13^b	1.91	13.17	5.51	22.85
Salman	2.43^b	0.40	4.91	2.19	22.85
Sashimi					
Tuna fish	589.09^a	251.59	1790.67	530.18	122.63
Octopus	85.09^b	7.25	14.82	76.59	122.61
Salman	11.38^b	9.65	304.93	10.25	113.53

[1]Means followed by the same letter for *sushi* or *sashimi* are statistically equal by the Tukey–Kramer test.
[2][MeHg] = [Hg] × 0.9 (James [7]).

and *sashimi* data. The differences between the restaurants were not significant and neither were the interactions between these and the fish species. For both data groups, the components of variance referring to the collection times and the interactions between the collection times and the fish species presented a null estimate.

The tuna *sushi* was the species presenting the highest Hg contents, significantly different from the kani and salmon *sushi* samples, which were not statistically different. Similarly the tuna *sashimi* also presented the highest Hg contents, while the Hg concentrations in the salmon and octopus *sashimi* samples were lower and did not differ statistically (Table 1).

On comparing the Hg contents found in the present study with the values established by FAO/WHO,[19] FDA,[20] ANVISA,[21] European Commission,[22] and JETRO,[23] it was observed that none of the *sushi* samples exceeded the limits permitted by the 5 different legislations. However, in the case of *sashimi* the content found in the tuna samples exceeded the limit allowed by the Japanese legislation (Table 2). Should be noted that fish consumption in Japan is usually higher than in most other countries.

The results obtained by Zmozinski et al.[24] showed higher values for Hg in predatory fish species, principally tuna (2.33 mg kg^{-1}), above the value established for the Hg content by the European Commission.[22] The current study exhibit higher Hg values in the tuna *sushi* and *sashimi* samples.

The largest São Paulo State (Brazil) fish distributor (Companhia de Entrepostos e Armazéns Gerais de São Paulo – CEAGESP) reported that the fish sold in the local market and restaurants came from limited Brazilian cities, with the tuna fish coming from the South and Southwest areas of the Brazilian coast. Salmon samples came from the Chilean coast and kani was acquired from distribution centers located in the Southeast of Brazil.

Bosch et al.[25] studying the accumulation of Hg in tuna (*Thunnus albacares*), found total Hg concentrations of between 0.45 and 1.52 mg kg^{-1}, with 28.6% of the samples exceeding the maximum limit permitted by the legislations considered by the authors (1.0 mg kg^{-1}). For MeHg the values varied from 0.23 to 1.24 mg kg^{-1}, with 14% of the tuna samples analyzed being inadequate for human consumption.

The fact of in *sushi* and *sashimi* were prepared and consumed with raw fish can be considered as advantage with regards of Hg concentration. Recently researchers showed that Hg concentration was generally higher in the cooked than in raw fish samples. This increase can be related to the effect of Hg pre-concentration, formation of complexes involving mercury species and sulfhydryl groups present in tissues and/or loss of water and fat.[26] The toxicity of ingested Hg and MeHg could be modified if dietary components that reduce the quantity of soluble (bioaccessible) Hg are present. Compounds that reduced Hg solubility were assayed in seafood subjected to gastrointestinal digestion and Lignin (95% CI: 77–88%), tannic acid (95% CI: 61–75%), pectin (95% CI: 48–65%), hydroxypropylmethylcellulose (95% CI: 40–59%), methylcellulose (95% CI: 44–53%), and carboxymethylcellulose (95% CI: 34–51%) are among the ones that produced the highest reductions in Hg bioaccessibility.[27]

Table 2. Maximum tolerable level of Hg in fish according to distinct regulatory agencies.

Regulatory agencies	Fish	Maximum tolerable level
FAO/WHO CODEX [19]	Species of fish not predators	0.5 mg kg^{-1} MeHg
	Species of fish predators	1.0 mg kg^{-1} MeHg
United States—FDA [20]	Fish	1.0 mg kg^{-1} MeHg
Japan—JETRO [23]	Fish	0.4 mg kg^{-1} Hg total and 0.3 mg kg^{-1} MeHg
European Union—EC [22]	Fish products with some exceptions	0.5 mg kg^{-1} Hg total
	Species of fish predators	1.0 mg kg^{-1} Hg total
Brazil—ANVISA [21]	Species of fish not predators	0.5 mg kg^{-1} Hg total
	Species of fish predators	1.0 mg kg^{-1} Hg total

Risk to human health

The various regulatory agencies have used different methodologies to set a safe limit for Hg ingestion, resulting in a range of values. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) proposed a PTWI value for MeHg of 1.6 μg kg^{-1} of body weight. This value was established based on epidemiological studies that analyzed the neurotoxicity for development in more sensitive humans. JECFA also fixed a value for the PTWI for inorganic Hg of 4 μg kg^{-1} of body weight, this value also being applicable for food exposure to total Hg.[14] The European Common Market proposed a PTWI for MeHg of 1.3 μg kg^{-1} of body weight.[15] The United States Environmental Protection Agency (USEPA) used a reference dose for chronic oral exposition (RfD) of 0.1 μg kg day^{-1} of MeHg, which corresponds to a PTWI of 0.7 μg kg week^{-1}.[16] The

Table 3. Risk estimation to human health according to the content of total Hg and MeHg in *sushi*.

		Adults						Children					
Portions/ week*	*Sushi*	Hg total	%PTWI	MeHg	%PTWI (JECFA)	%PTWI (EFSA)	%PTWI (EPA)	Hg total	%PTWI	MeHg	%PTWI (JECFA)	%PTWI (EFSA)	%PTWI (EPA)
1	**Tuna**	0.370	9.25	0.333	20.81	25.61	47.568	0.493	12.33	0.444	27.75	34.15	63.42
2		0.740	18.50	0.666	41.62	51.23	95.136	0.987	24.67	0.888	55.50	68.30	**126.85**
3		1.110	27.75	0.999	62.43	76.84	**142.705**	1.480	37.00	1.332	83.24	**102.45**	**190.27**
4		1.480	37.00	1.332	83.24	**102.45**	**190.273**	1.973	49.33	1.776	**110.99**	**136.61**	**253.70**
5		1.850	46.25	1.665	**104.06****	**128.07**	**237.841**	2.467	61.66	2.220	**138.74**	**170.76**	**317.12**
6		2.220	55.50	1.998	**124.87**	**153.68**	**285.409**	2.960	74.00	2.664	**166.49**	**204.91**	**380.55**
7		2.590	64.75	2.331	**145.68**	**179.30**	**332.978**	3.453	86.33	3.108	**194.24**	**239.06**	**443.97**
1	**Kani**	0.015	0.38	0.014	0.86	1.06	1.968	0.020	0.51	0.018	1.15	1.41	2.62
2		0.031	0.77	0.028	1.72	2.12	3.936	0.041	1.02	0.037	2.30	2.83	5.25
3		0.046	1.15	0.041	2.58	3.18	5.904	0.061	1.53	0.055	3.44	4.24	7.87
4		0.061	1.53	0.055	3.44	4.24	7.871	0.082	2.04	0.073	4.59	5.65	10.50
5		0.077	1.92	0.069	4.30	5.30	9.839	0.102	2.55	0.092	5.74	7.06	13.12
6		0.092	2.30	0.083	5.17	6.36	11.807	0.123	3.07	0.110	6.89	8.48	15.74
7		0.107	2.68	0.096	6.03	7.42	13.775	0.143	3.58	0.129	8.04	9.89	18.37
1	**Salmon**	0,006	0.15	0.005	0.34	0.42	0.782	0.008	0.20	0.007	0.46	0.56	1.04
2		0,012	0.30	0.011	0.68	0.84	1.564	0.016	0.41	0.015	0.91	1.12	2.09
3		0,018	0.46	0.016	1.03	1.26	2.346	0.024	0.61	0.022	1.37	1.68	3.13
4		0,024	0.61	0.022	1.37	1.68	3.129	0.032	0.81	0.029	1.83	2.25	4.17
5		0,03	0.76	0.027	1.71	2.11	3.911	0.041	1.01	0.037	2.28	2.81	5.21
6		0,036	0.91	0.033	2.05	2.53	4.693	0.049	1.22	0.044	2.74	3.37	6.26
7		0,043	1.06	0.038	2.4	2.95	5.475	0.057	1.42	0.051	3.19	3.93	7.30

*Portions of 150 g for adult and teenager and of 50 g for children.
**Values greater than 100% of the PTWI are indicated in bold.

results obtained in the evaluation of the risk for human health were presented as a percentage based on the PTWI.

In the present study, on carrying out an evaluation of food exposition per age group and the frequency of consuming *sushi* and *sashimi*, it could be seen that frequently the consumption could be considered inadequate as a function of frequency (Table 3 and 4).

With respect to total Hg in adults and children, there was no consumer health risk for the consumption of *sushi*, regardless of consumption frequency. However, *sashimi* presented a health risk when tuna *sashimi* was consumed more than three times a week.

With respect to MeHg in adults, the consumption of tuna *sushi* offered risks as from a frequency of 5 times per week according to JECFA,[14] whilst according to the parameters of EFSA [15] and USEPA,[16] this frequency was of four and three times, respectively (Table 3). For tuna *sashimi*, the risk is present in consumption frequencies of twice a week according to JECFA [14] and just once a week according to EFSA [15] and USEPA.[16] With respect to the last two parameters cited, it can

Table 4. Risk estimation to human health according to the content of total Hg and MeHg in *sashimi*.

		Adults						Children					
Portions/ week*	*Sashimi*	Hg total	%PTWI	MeHg	%PTWI (JECFA)	%PTWI (EFSA)	%PTWI (EPA)	Hg total	%PTWI	MeHg	%PTWI (JECFA)	%PTWI (EFSA)	%PTWI (EPA)
1	**Tuna**	1.473	36.82	1.325	82.84	**101.96**	**189.35**	1.964	49.09	1.767	**110.45**	**135.94**	**252.47**
2		2.945	73.64	2.651	**165.68**	**203.92**	**378.70**	3.927	98.18	3.535	**220.91**	**271.89**	**504.93**
3		4.418	**110.45****	3.976	**248.52**	**305.87**	**568.05**	5.891	**147.27**	5.302	**331.36**	**407.83**	**757.40**
4		5.891	**147.27**	5.302	**331.36**	**407.83**	**757.40**	7.855	**196.36**	7.069	**441.82**	**543.78**	**1009.87**
5		7.364	**184.09**	6.627	**414.20**	**509.79**	**946.75**	9.818	**245.45**	8.836	**552.27**	**679.72**	**1262.34**
6		8.836	**220.91**	7.953	**497.04**	**611.75**	**1136.10**	11.782	**294.55**	10.604	**662.73**	**815.66**	**1514.80**
7		10.309	**257.73**	9.278	**579.89**	**713.71**	**1325.45**	13.745	**343.64**	12.371	**773.18**	**951.61**	**1767.27**
1	**Octopus**	0.213	5.32	0.191	11.97	14.73	27.35	0.284	7.09	0.255	15.96	19.64	36.47
2		0.425	10.64	0.383	23.93	29.46	54.70	0.567	14.18	0.511	31.91	39.27	72.94
3		0.638	15.95	0.574	35.90	44.18	82.06	0.851	21.27	0.766	47.87	58.91	**109.41**
4		0.851	21.27	0.766	47.87	58.91	**109.41**	1.135	28.36	1.021	63.82	78.55	**145.88**
5		1.064	26.59	0.957	59.83	73.64	**136.76**	1.418	35.45	1.276	79.78	98.19	**182.35**
6		1.276	31.91	1.149	71.80	88.37	**164.11**	1.702	42.55	1.532	95.73	**117.82**	**218.82**
7		1.489	37.23	1.340	83.77	**103.10**	**191.47**	1.985	49.64	1.787	**111.69**	**137.46**	**255.29**
1	**Salmon**	0.028	0.71	0.026	1.60	1.97	3.66	0.038	0.95	0.034	2.14	2.63	4.88
2		0.057	1.42	0.051	3.20	3.94	7.32	0.076	1.90	0.068	4.27	5.26	9.76
3		0.085	2.13	0.077	4.80	5.91	10.98	0.114	2.85	0.102	6.41	7.88	14.64
4		0.114	2.85	0.102	6.41	7.88	14.64	0.152	3.79	0.137	8.54	10.51	19.52
5		0.142	3.56	0.128	8.01	9.85	18.30	0.190	4.74	0.171	10.68	13.14	24.40
6		0.171	4.27	0.154	9.61	11.82	21.96	0.228	5.69	0.205	12.81	15.77	29.28
7		0.199	4.98	0.179	11.21	13.80	25.62	0.266	6.64	0.239	14.95	18.39	34.16

*Portions of 150 g for adult and teenager and of 50 g for children.
**Values greater than 100% of the PTWI are indicated in bold.

be seen that the consumption of octopus *sashimi* can offer health risks to adults if consumed seven and four times a week, respectively (Table 4).

With respect to children, consumption of tuna *sushi* presents health risks when consumed two to three times a week, according to the limits established by EFSA [15] and USEPA.[16] For JECFA [14] the risk is present as from four times a week (Table 3). With respect to the ingestion of tuna *sashimi*, the health risk is present with a frequency of just once a week for the three organizations. However, for octopus *sashimi* the risk commence at three times a week according to USEPA,[16] at six times a week according to EFSA [15] and at seven times a week according to JECFA [14] (Table 4).

With respect to the consumption risk according to frequency and age range for the Brazilian population, it was shown that for total Hg the health risk was present for the consumption of tuna *sashimi* four times weekly for children and adults and three times a week for adolescents (Table 5).

Using the data for MeHg, the health risk for children is present for the consumption of three portions of tuna *sushi* according to the USEPA,[16] five portions according to EFSA [15] or seven portions per week according to JECFA [14] (Table 6).

It was also shown there was risk in consuming just one portion of tuna *sashimi* according to PTWI of USEPA [16] and two portions a week according EFSA [15] and JECFA,[14] and for octopus *sashimi* when consumed from five times a week according to the USEPA [16] (Table 7).

The data for teenagers show that the consumption of tuna *sushi* offers a health risk if consumed two, four or five times a week according to the agencies USEPA,[16] EFSA [15] or JECFA,[14] respectively (Table 6). With respect to tuna *sashimi*, the consumption of one portion offers a health risk according to USEPA [16] and EFSA,[15] and two portions according to JECFA.[14] The consumption of octopus *sashimi* also offered a health risk to adolescents if consumed four or more times a week according to USEPA,[16] six or more times a week according to EFSA [15] or seven or more times a week according to JECFA [14] (Table 7). Adults would be at risk if they consumed six portions of tuna *sushi* according to JECFA,[14] five portions according to EFSA [15] or three portions according to USEPA.[16] (Table 6). The tuna *sashimi* offered risks if consumed twice or more a week based on the analysis of the PTWI of JECFA[14] and of EFSA,[15] or just once a week according to the PTWI of USEPA.[16] It can also be seen that the consumption of five portions of octopus *sashimi* can represent a risk to adults, considering the PTWI of USEPA [16] (Table 7).

Lowenstein et al.[8] evaluated the exposition resulting from the ingestion of total Hg, reporting values for *akami tuna* (0.351 μg kg day^{-1}) and for *toro tuna* (0.344 μg kg day^{-1}) that correspond to 0.316 and 0.309 μg kg day^{-1} of MeHg, respectively. On analyzing the current value for the PTWI of MeHg established by JECFA [14] (1.6 μg kg week^{-1}) corresponding to 0.23 μg kg day^{-1}, it can be seen that the value found by Lowenstein et al.[8] was above the recommended value, and hence the samples studied were inadequate for consumption. In addition, all the samples exceeded the maximum daily consumption (reference dose for chronic oral exposition = RfD) permitted by the USEPA [16] (0.10 μg kg day^{-1}).

Strom et al.[28] estimated the MeHg ingestion amongst women of a fertile age and found a mean daily ingestion of MeHg of 0.06 μg kg^{-1} of body weight, with 11% of the women exceeding the RfD of 0.10 μg kg^{-1} of body weight. When 3 portions of fish were consumed per week of species with the higher levels of MeHg, approximately 100% of the population studied exceeded the RfD, whereas with the consumption of fish with lower MeHg concentrations, the

Table 5. Risk estimation to human health according to the content of total Hg in *sushi* and *sashimi* (Brazil).

		Adults		Adolescents		Children			Adults		Adolescents		Children	
Portions/week*	*Sushi*	Hg Total	% PTWI	Hg Total	% PTWI	Hg Total	% PTWI	*Sashimi*	Hg Total	% PTWI	Hg Total	% PTWI	Hg Total	% PTWI
1	**Tuna**	0.326	8.16	0.444	11.10	0.296	7.40	**Tuna**	1.299	32.49	1.767	44.18	1.178	29.45
2		0.653	16.32	0.888	22.20	0.592	14.80		2.599	64.97	3.535	88.36	2.356	58.91
3		0.979	24.48	1.332	33.30	0.888	22.20		3.898	97.46	5.302	**132.55**	3.535	88.36
4		1.306	32.64	1.776	44.40	1.184	29.60		5.198	**129.95****	7.069	**176.73**	4.713	**117.82**
5		1.632	40.81	2.220	55.50	1.480	37.00		6.497	**162.43**	8.836	**220.91**	5.891	**147.27**
6		1.959	48.97	2.664	66.60	1.776	44.40		7.797	**194.92**	10.604	**265.09**	7.069	**176.73**
7		2.285	57.13	3.108	77.69	2.072	51.80		9.096	**227.41**	12.371	**309.27**	8.247	**206.18**
1	**Kani**	0.014	0.34	0.018	0.46	0.012	0.31	**Octopus**	0.188	4.69	0.255	6.38	0.170	4.25
2		0.027	0.68	0.037	0.92	0.025	0.61		0.375	9.38	0.511	12.76	0.340	8.51
3		0.041	1.01	0.055	1.38	0.037	0.92		0.563	14.08	0.766	19.15	0.511	12.76
4		0.054	1.35	0.074	1.84	0.049	1.23		0.751	18.77	1.021	25.53	0.681	17.02
5		0.068	1.69	0.092	2.30	0.061	1.53		0.938	23.46	1.276	31.91	0.851	21.27
6		0.081	2.03	0.110	2.76	0.074	1.84		1.126	28.15	1.532	38.29	1.021	25.53
7		0.095	2.37	0.129	3.22	0.086	2.15		1.314	32.85	1.787	44.67	1.191	29.78
1	**Salmon**	0.005	0.13	0.007	0.18	0.005	0.12	**Salmon**	0.025	0.63	0.034	0.85	0.023	0.57
2		0.011	0.27	0.015	0.36	0.01	0.24		0.050	1.26	0.068	1.71	0.046	1.14
3		0.016	0.40	0.022	0.55	0.015	0.36		0.075	1.88	0.102	2.56	0.068	1.71
4		0.021	0.54	0.029	0.73	0.019	0.49		0.100	2.51	0.137	3.41	0.091	2.28
5		0.027	0.67	0.036	0.91	0.024	0.61		0.126	3.14	0.171	4.27	0.114	2.85
6		0.032	0.80	0.044	1.09	0.029	0.73		0.151	3.77	0.205	5.12	0.137	3.41
7		0.038	0.94	0.051	1.28	0.034	0.85		0.176	4.39	0.239	5.97	0.159	3.98

*Portions of 150 g for adult and teenager and of 50 g for children.
**Values greater than 100% of the PTWI are indicated in bold.

Table 6. Risk estimation to human health according to the calculated amount of MeHg in *sushi* (Brazil).

		Adults				Adolescents				Children			
Portions/ week*	*Sushi*	MeHg	%PTWI (JECFA)	%PTWI (EFSA)	%PTWI (EPA)	MeHg	%PTWI (JECFA)	%PTWI (EFSA)	%PTWI (EPA)	MeHg	%PTWI (JECFA)	%PTWI (EFSA)	%PTWI (EPA)
1	**Tuna**	0.294	18.36	22.60	41.972	0.400	24.97	30.74	57.082	0.266	16.65	20.49	38.055
2		0.588	36.73	45.20	83.944	0.799	49.95	61.47	**114.164**	0.533	33.30	40.98	76.109
3		0.881	55.09	67.80	**125.916**	1.199	74.92	92.21	**171.246**	0.799	49.95	61.47	**114.164**
4		1.175	73.45	90.40	**167.888**	1.598	99.89	**122.95**	**228.327**	1.066	66.60	81.96	**152.218**
5		1.469	91.81	**113.00**	**209.860**	1.998	**124.87**	**153.68**	**285.409**	1.332	83.24	**102.45**	**190.273**
6		1.763	**110.18****	**135.60**	**251.832**	2.397	**149.84**	**184.42**	**342.491**	1.598	99.89	**122.95**	**228.327**
7		2.057	**128.54**	**158.20**	**293.804**	2.797	**174.81**	**215.15**	**399.573**	1.865	**116.54**	**143.44**	**266.382**
1	**Kani**	0.012	0.76	0.93	1.736	0.017	1.03	1.27	2.361	0.011	0.69	0.85	1.574
2		0.024	1.52	1.87	3.473	0.033	2.07	2.54	4.723	0.022	1.38	1.70	3.149
3		0.036	2.28	2.80	5.209	0.050	3.10	3.81	7.084	0.033	2.07	2.54	4.723
4		0.049	3.04	3.74	6.945	0.066	4.13	5.09	9.446	0.044	2.76	3.39	6.297
5		0.061	3.80	4.67	8.682	0.083	5.17	6.36	11.807	0.055	3.44	4.24	7.871
6		0.073	4.56	5.61	10.418	0.099	6.20	7.63	14.169	0.066	4.13	5.09	9.446
7		0.085	5.32	6.54	12.154	0.116	7.23	8.90	16.530	0.077	4.82	5.93	11.020
1	**Salmon**	0.005	0.30	0.37	0.690	0.007	0.41	0.51	0.939	0.004	0.27	0.34	0.626
2		0.010	0.60	0.74	1.380	0.013	0.82	1.01	1.877	0.009	0.55	0.67	1.251
3		0.014	0.91	1.11	2.070	0.020	1.23	1.52	2.816	0.013	0.82	1.01	1.877
4		0.019	1.21	1.49	2.761	0.026	1.64	2.02	3.754	0.018	1.10	1.35	2.503
5		0.024	1.51	1.86	3.451	0.033	2.05	2.53	4.693	0.022	1.37	1.68	3.129
6		0.029	1.81	2.23	4.141	0.039	2.46	3.03	5.631	0.026	1.64	2.02	3.754
7		0.034	2.11	2.60	4.831	0.046	2.87	3.54	6.570	0.031	1.92	2.36	4.380

*Portions of 150 g for adult and teenager and of 50 g for children.
**Values greater than 100% of the PTWI are indicated in bold.

proportion exceeding the RfD was only 5%. The authors recommended restriction of the consumption of fish species with high MeHg concentrations.

Burger et al.[29] interviewed 1,289 people in a university community concerning their consumption of fish and *sushi* commercialized in shops and supermarkets in New Jersey, New York, and Chicago (USA). Of those interviewed, 92% reported consuming an average of 5.06 meals/month composed of fish or *sushi* elaborated with fish. Eight of those interviewed reported eating fish or *sushi* at least once a day, and 7 of these reported that half of their meals were composed of *sushi*. In this study it was possible to observe that some people eat Japanese food every day, implicating a greater probability of chronic intoxication depending on the type of fish and the portion consumed. Individuals with a more sporadic consumption show a lower risk of chronic intoxication, with the possibility of acute intoxication for those who consume elevated amounts with less frequency, a fact which can occur in buffet type restaurants.

Should be emphasized that Brazil, the number of persons spending money on food away from their homes is increasing.

Table 7. Risk estimation to human health according to the calculated amount of MeHg in *sashimi* (Brazil).

		Adults				Adolescents				Children			
Portions/ week*	*Sashimi*	MeHg	%PTWI (JECFA)	%PTWI (EFSA)	%PTWI (EPA)	MeHg	%PTWI (JECFA)	%PTWI (EFSA)	%PTWI (EPA)	MeHg	%PTWI (JECFA)	%PTWI (EFSA)	%PTWI (EPA)
1	**Tuna**	1.170	73.09	89.96	**167.07**	1.591	99.41	**122.35**	**227.22**	1.060	66.27	81.57	**151.48**
2		2.339	**146.19****	**179.93**	**334.15**	3.181	**198.82**	**244.70**	**454.44**	2.121	**132.55**	**163.13**	**302.96**
3		3.509	**219.28**	**269.89**	**501.22**	4.772	**298.23**	**367.05**	**681.66**	3.181	**198.82**	**244.70**	**454.44**
4		4.678	**292.38**	**359.85**	**668.30**	6.362	**397.64**	**489.40**	**908.88**	4.241	**265.09**	**326.27**	**605.92**
5		5.848	**365.47**	**449.81**	**835.37**	7.953	**497.04**	**611.75**	**1136.10**	5.302	**331.36**	**407.83**	**757.40**
6		7.017	**438.57**	**539.78**	**1002.44**	9.543	**596.45**	**734.10**	**1363.32**	6.362	**397.64**	**489.40**	**908.88**
7		8.187	**511.66**	**629.74**	**1169.52**	11.134	**695.86**	**856.45**	**1590.54**	7.423	**463.91**	**570.96**	**1060.36**
1	**Octopus**	0.169	10.56	13.00	24.13	0.230	14.36	17.67	32.82	0.153	9.57	11.78	21.88
2		0.338	21.12	25.99	48.27	0.460	28.72	35.35	65.65	0.306	19.15	23.56	43.76
3		0.507	31.68	38.99	72.40	0.689	43.08	53.02	98.47	0.460	28.72	35.35	65.65
4		0.676	42.23	51.98	96.54	0.919	57.44	70.69	**131.29**	0.613	38.29	47.13	87.53
5		0.845	52.79	64.98	**120.67**	1.149	71.80	88.37	**164.11**	0.766	47.87	58.91	109.41
6		1.014	63.35	77.97	**144.81**	1.379	86.16	**106.04**	**196.94**	0.919	57.44	70.69	131.29
7		1.183	73.91	90.97	**168.94**	1.608	**100.52**	**123.72**	**229.76**	1.072	67.01	82.48	153.17
1	**Salmon**	0.023	1.41	1.74	3.23	0.031	1.92	2.36	4.39	0.020	1.28	1.58	2.93
2		0.045	2.83	3.48	6.46	0.061	3.84	4.73	8.78	0.041	2.56	3.15	5.86
3		0.068	4.24	5.22	9.69	0.092	5.76	7.09	13.18	0.061	3.84	4.73	8.78
4		0.090	5.65	6.96	12.92	0.123	7.69	9.46	17.57	0.082	5.12	6.31	11.71
5		0.113	7.06	8.69	16.15	0.154	9.61	11.82	21.96	0.102	6.41	7.88	14.64
6		0.136	8.48	10.43	19.38	0.184	11.53	14.19	26.35	0.123	7.69	9.46	17.57
7		0.158	9.89	12.17	22.61	0.215	13.45	16.55	30.74	0.143	8.97	11.04	20.50

*Portions of 150 g for adult and teenager and of 50 g for children.
**Values greater than 100% of the PTWI are indicated in bold.

A survey on the family budget conducted during 2002–2003 found that 24.1% of money was spent on food away from home, while the 2008–2009 survey reported 31.1% of the family budget was spent on this.[30]

Vieira et al.[31] proposed that fish should be consumed considering their potential risks and benefits and our results pointed out that more attention of the Brazilian health authorities is required concerning these products in order to reduce the risk of consumer exposure to Hg. A recent study performed in the Northeast of the Brazilian cost also found Hg values that suggest the necessity of the monitoring of the Hg concentration in seafood commercialized.[26]

Conclusions

The estimate of the health risk indicated that the level of toxicity to human health depended on the portion consumed and the type of fish involved. Children were the most vulnerable to risk in relation to the other age groups. On the other hand, the analysis of the total Hg content showed a greater Hg concentration in the tuna *sushi* and *sashimi*, and hence a higher concentration of MeHg was estimated in these products. The Hg contents detected in the fish exceeded the maximum limit permitted by JETRO in the tuna *sashimi* samples. A single portion (50 g) of tuna *sashimi* exceeded the MeHg PTWI according to JECFA, EFSA, and EPA for children and according to EFSA and EPA for adults (150 g). Greater attention by the health authorities is required concerning these products in order to reduce the risk of consumer exposure to Hg.

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References

[1] Corson, T. *The zen of fish: The story of sushi, from samurai to supermarket*. Harper Collins: New York, 2007.
[2] FAO. Fisheries and Aquaculture topics. Composition of fish. Topics Fact Sheets. Rome, 2005. Available at http://www.fao.org/fishery/topic/12318/en. (accessed October 2014).
[3] FAO. The state of world fisheries and aquaculture; FAO: Rome, 2012.
[4] Storelli, M.M.; Storelli, A.; Giacominelli-Stuffler, R.; Marcotrigiano, G.O. Mercury speciation in the muscle of two commercially important fish, hake (*Merluccius merluccius*) and striped mullet (*Mullus barbatus*) from the Mediterranean sea: Estimated weekly intake. Food Chem. **2005**, *89*, 295–300.
[5] Kalač. P.; Svoboda, L. A review of trace element concentrations in edible mushrooms. Food Chem. **2010**, *69*, 273–281.
[6] EFSA. Scientific opinion on the risk for public health related to the presence of mercury and methylmercury in food. EFSA J. **2012**, *10*(12), 2985.
[7] James, D. Risks and benefits of seafood consumption, Globefish Consultant; FAO: Rome, 2013.
[8] Lowenstein, J.H.; Burger, J.; Jeitner, C.W.; Amato, G.; Kolokotronis, S.O.; Gochfelf, M. DNA barcodes reveal species-specific mercury levels in tuna *sushi* that pose a health risk to consumers. Biol Lett. **2010**, *6*, 692–695.
[9] USEPA. How People are Exposed to Mercury. 2014. Available at http://www.pubweb.epa.gov/mercury/exposure.htm. (accessed Dec 2014).
[10] WHO. Safety evaluation of certain contaminants in food; Seventy-second meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA): Geneva, 2011.
[11] Morgano, M.A.; Milani, R.F.; Perrone, A.A.M. Determination of total mercury in *sushi* samples employing direct mercury analyzer. Food Anal Methods. **2015**, *8*, 2301–2307.
[12] WHO. Principles and methods for the Risk Assessment of Chemicals in Food, Chapter 6: Dietary Exposure Assessment of Chemicals in Food; WHO: Geneva, 2009.
[13] IBGE. Pesquisa de Orçamentos Familiares 2008–2009: antropometria e estado nutricional de crianças, adolescentes e adultos no Brasil; IBGE: Rio de Janeiro, 2010.
[14] JECFA. Working document for information and use in discussions related to contaminants and toxins in the GSCTFF, Eighth session; FAO/WHO: The Hague, The Netherlands, 2014.
[15] EFSA. Statement on the benefits of fish/seafood consumption compared to the risks of methylmercury in fish/seafood. EFSA J. **2015**, *13*(1), 3982.
[16] USEPA. Methylmercury (MeHg), CASRN 22967–92-6; US EPA: Washington, D.C., 2001.
[17] McCulloch, C.E.; Searle, S.R. *Generalized, Linear, and Mixed Models*. John Wiley and Sons: New York, 2001.
[18] Littel, R.C.; Milliken, G.A.; Stroup, W.W.; Wolfinger, R.D. *SAS system for mixed models*. Statistical Analysis System Institute: Cary, 1996.
[19] FAO/WHO. Codex general standard for contaminants and toxins in food and feed, (Codex Stan 193–1995); FAO: Rome, 2009.
[20] FDA. Fish and Fishery Products Hazards and Controls Guidance, (Fourth Edition); US Department of Health and Human Services: Gainesville, 2011.
[21] Brasil. Resolução RDC 42, de 24 de agosto 2013 - Dispõe sobre o Regulamento Técnico MERCOSUL sobre Limites Máximos de Contaminantes Inorgânicos em Alimentos; Diário Oficial da União: Brasília, 2013; 33–35.
[22] Commission of the European Communities. Commission Regulation No 1881/2006 of 19 December 2006. Setting maximum levels for certain contaminants in foodstuffs, Off J Eur Union. Brussels, 2006, 445, 1–35.
[23] JETRO. Specifications and standards for foods, food additives, etc. Under the Food Sanitation Act (Abstract 2010); JETRO: Tokyo, 2011.
[24] Zmozinski, A.V.; Carneado, S.; Ibáñez-Palomino, C.; Sahuquillo, A.; López-Sánchez, J.F.; da Silva, M.M. Method development for the simultaneous determination of methylmercury and inorganic mercury in seafood. Food Control. **2014**, *46*, 351–359.
[25] Bosch, A.C.; O'Neill, B.; Sigge, G.O.; Kerwath, S.E.; Hoffman, L.C. Mercury accumulation in Yellowfin tuna (Thunnus albacares) with regards to muscle type, muscle position and fish size. Food Chem. **2016**, *190*, 351–356.
[26] Costa, F.N.; Korn, M.G.A.; Brito, G.B.; Ferlin, S.; Fostier, A.H. Preliminary results of mercury levels in raw and cooked seafood and their public health impact. Food Chem. **2016**, *192*, 837–841.
[27] Piedra, C.J.; Sánchez, V.; Vélez, D.; Devesa, V. Reduction of mercury bioaccessibility using dietary strategies. LWT - Food Sci Technol. **2016**, *71*, 10–16.
[28] Ström, S.; Helmfrid, I.; Glynn, A.; Berglund, M. Nutritional and toxicological aspects of seafood consumption an integrated exposure and risk assessment of methylmercury and polyunsaturated fatty acids. Environ Res. **2011**, *111*, 274–280.
[29] Burger, J.; Gochfeld, M.; Jeitner, C.; Donio, M.; Pittfield, T. *Sushi* consumption rates and Mercury levels in *sushi*: Ethnic and demographic differences in exposure. J Risk Res. **2014**, *17*, 981–997.
[30] IBGE. Pesquisa de Orçamentos Familiares 2008–2009: despesas, rendimentos e condições de vida; IBGE: Rio de Janeiro, 2010.
[31] Vieira, H.C.; Morgado, F.; Soares, A.M.V.M.; Abreu, S.N. Fish consumption recommendations to conform to current advice in regard to mercury intake. Environ. Sci. Pollut Res. **2015**, *22*, 9595–9602.