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Methylmercury determination in fish and seafood products and estimated daily intake for the Spanish population

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Additives/Contaminants:	Heavy metals - mercury
Food Types:	Fish and fish products

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Table I. Analytical parameters.

	Inorganic mercury	Methylmercury
Limit of detection [*] (n = 9)		
Dry matter ($\mu\text{g kg}^{-1}$)	170	181
Fresh matter ($\mu\text{g kg}^{-1}$)	51	54
Limit of quantification ^{**}		
Dry matter ($\mu\text{g kg}^{-1}$)	563	603
Fresh matter ($\mu\text{g kg}^{-1}$)	170	181
Precision (RSD%) (Between-day) (n = 9)	--	4.32
Accuracy (n = 8)		
CRM 463 (mg kg^{-1})	n.d.	2.82 ± 0.156
Methylmercury Certified value: $2.82 \pm 0.15 \text{ mg kg}^{-1}$		

^{*}Limit of detection is calculated as three times the standard deviation of 9 reagent blanks. ^{**}Limit of quantification is calculated as ten times the standard deviation.

n = number of samples

n.d.= non-detectable

Table II. Methylmercury contents (mean \pm standard deviation) in fresh fish and seafood.

Seafood		Dry weight		Wet weight	
		Methylmercury $\mu\text{g kg}^{-1}$	Mean value	Methylmercury $\mu\text{g kg}^{-1}$	Mean value
Fresh tuna (<i>Thunnus thynnus</i>)	a	2269 \pm 240	2294 \pm 266	530 \pm 56	596 \pm 103
	b	2318 \pm 218		662 \pm 63	
Anchovy (<i>Engraulis encrasicolus</i>)	a	246 \pm 38	246 \pm 38	58 \pm 56.08	58 \pm 56
Mackerel (<i>Scomber scombrus</i>)	a	306 \pm 23		67 \pm 5	64 \pm 5
	b	279 \pm 4	293 \pm 25	61 \pm 1	
Chuccla (<i>Spicara maena</i>)	a	233 \pm 27	233 \pm 27	59 \pm 7	59 \pm 7
Swordfish (<i>Xiphias gladius</i>)	a	927 \pm 152		195 \pm 52	479 \pm 333
	b	3370 \pm 229	2148 \pm 1428	763 \pm 52	
Prawn cooked (<i>Palaemon serratus</i>)	a	<181	-	<54	-
	b	<181		<54	
Fresh prawn (<i>Palaemon serratus</i>)	a	<181		<54	-
	b	<181		<54	
Sole (<i>Solea vulgaris</i>)	a	239 \pm 37	120* \pm 141	56 \pm 9	28* \pm 33
	b	<181		<54	
Llisa (<i>Mugil spp</i>)	a	<181	-	<54	-
Fresh mussel (<i>Mytilus edulis</i>)	a	<181		<54	-
	b	<181		<54	
Hake (<i>Merluccius merluccius</i>)	a	879 \pm 17	644 \pm 272	202 \pm 4	143 \pm 69
	b	409 \pm 3		83 \pm 1	
Mollera (<i>Mora Moro</i>)	a	908 \pm 140	908 \pm 140	199 \pm 31	199 \pm 31
Pagre (<i>Pagrus pagrus</i>)	a	674 \pm 38	674 \pm 38	153 \pm 9	153 \pm 9

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2						
3	Perch	a	323 ± 62	323±62	70 ± 12	70±12
4						
5	(<i>Micropterus</i>					
6	<i>salmoides</i>)					
7						
8	Salmon	a	<181	-	<54	-
9						
10	(<i>Salmon salar</i>)	b	<181		<54	
11						
12	Sardine	a	<181	-	<54	-
13						
14	(<i>Sardina pichardus</i>)	b	<181		<54	
15						
16	Serrano	a	618 ± 103	618±103	131 ± 22	131±22
17	(<i>Serranus cabrilla</i>)					

D.L. = Detection limit.

*D.L. has been considered zero in the calculation of the mean value.

Table III. Methylmercury concentration in canned seafood.

Sample		Dry weight		Wet weight	
		Methylmercury $\mu\text{g kg}^{-1}$	Mean value	Methylmercury $\mu\text{g kg}^{-1}$	Mean value
Natural tuna (A)	a	2770 \pm 109	2692 \pm 147	627 \pm 25	609 \pm 33
(<i>Thunnus thynnus</i>)	b	2614 \pm 91		592 \pm 21	
Tuna in vegetal oil	a	879 \pm 22	1383 \pm 590	289 \pm 7	455 \pm 194
(A)	b	1887 \pm 117		620 \pm 38	
(<i>Thunnus thynnus</i>)					
Tuna in vegetal oil	a	<181	667* \pm 772	<54	207* \pm 240
(B)	b	1333 \pm 72		414 \pm 22	
(<i>Thunnus thynnus</i>)					
Tuna in vegetal oil	a	1439 \pm 51	1425 \pm 135	427 \pm 15	423 \pm 40
(C)	b	1411 \pm 156		419 \pm 46	
(<i>Thunnus thynnus</i>)					
Mackerel	a	279 \pm 4	309 \pm 43	90 \pm 1	94 \pm 8
(<i>Scomberomorus spp</i>)	b	340 \pm 29		97 \pm 8	
Mussel	a	<181	-	<54	-
(<i>Mytilus edulis</i>)	b	<181		<54	
Octopus	a	<181	-	<54	-
(<i>Octopus spp.</i>)	b	<181		<54	
Smoked salmon	a	<181	-	<54	-
(<i>Oncorhynchus nerka</i>)					

D.L. detection limit

*D.L. has been considered zero in the calculation of the mean value. "a" and "b" corresponded to samples from different batches.

(A), (B) and (C) corresponded to different commercial brands.

Table IV. Estimated mean fish and methylmercury intakes by the Spanish population.

Species	Methylmercury ($\mu\text{g kg}^{-1}$)	Mean daily consumption for fish and seafood (kg/person/day) * Spain	Methylmercury intake ($\mu\text{g/person/day}$) Spain
Tuna	596	0.0013	0.775
Canned tuna	443	0.0052	2.301
Anchovy	58	0.0077	0.447
Fresh mackerel	64	0.0011	0.064
Canned mackerel	94	0.0003	0.028
Swordfish	479	0.0021	1.006
Prawn	<54	0.0043	-
Sole	56	0.0023	0.128
Hake	143	0.0120	1.717
Fresh mussel	<54	0.0036	-
Canned mussel	<54	0.0006	-
Perch	70	0.0015	0.105
Canned squid	<54	0.0001	-
Salmon	<54	0.0021	-
Sardine	<54	0.0077	-
Pagre	674	Data not found	-
Chuccla	233	Data not found	-
Serrano	618	Data not found	-
Mollera	908	Data not found	-
Llisa	<54	Data not found	-
Total methylmercury $\mu\text{g/person/day}$			6.571

*Total consumption is considered: both fresh and frozen product.

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3 1 **Methylmercury determination in fish and seafood**
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5 2 **products and estimated daily intake for the Spanish**
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7 3 **population**
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10 4

11 5 **Abstract**
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13 6

14 7 The mercury content of 25 samples of fish and seafood products
15 8 most frequently consumed in Spain were determined. A simple
16 9 method comprising cold vapor and atomic absorption
17 10 spectrometry was used to separately determine inorganic and
18 11 organic mercury. In all samples, inorganic mercury content was
19 12 below 50 $\mu\text{g kg}^{-1}$. There was wide variability, not only among
20 13 the mercury levels of different fish species, but also among
21 14 different samples of the same species - with methylmercury
22 15 content ranging from below 54 to 662 $\mu\text{g kg}^{-1}$. The highest mean
23 16 methylmercury content was found in fresh tuna. Based on an
24 17 average total fish consumption of 363 g/person/week, the
25 18 methylmercury intake was estimated to be 46.2 $\mu\text{g/person/week}$.
26 19 Therefore, the mercury intake of Spanish people with a body
27 20 weight ≤ 60 kg is lower than the JECFA PTWI of 1.6 $\mu\text{g/kg}$ body
28 21 weight, but exceeds the US-NRC limit of 0.7 $\mu\text{g/kg}$ bw/week
29 22 based on a benchmark dose.
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46 25 **Keywords:** Methylmercury determination, mercury determination,
47 26 seafood contamination, fish contamination, methylmercury
48 27 intake.
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3 1 shown that mercury is bioamplified in the food chain - high-
4 2 trophic level predatory species (such as shark, swordfish and
5 3 tuna) containing more mercury than herbivorous species (Park
6 4 and Curtis, 1997; Burger et al., 2001 and Sakamoto et al.,
7 5 2002). This is the reason why different guidelines have been
8 6 established to regulate mercury intake, especially in relation
9 7 to fish and seafood consumption. The Joint Expert Committee on
10 8 Food Additives and Contaminants defined 1.6 µg/week/ kg of
11 9 body as the provisional tolerable weekly intake (PTWI) for
12 10 methylmercury (JECFA, 2003). In comparison, the U.S. National
13 11 Research Council established an intake limit of 0.7 µg/ kg bw
14 12 per week (NRC, 2000). The European Commission Regulation
15 13 466/2001/EC (amended by Regulation 221/2002/EC) set maximum
16 14 levels for total mercury in fish of 0.5 mg kg⁻¹ wet weight,
17 15 except for some species (for instance swordfish and tuna),
18 16 where the maximum level was raised to 1.0 mg kg⁻¹ wet weight.
19 17 For physiological and ecological reasons, predatory fish which
20 18 are at the top of the food chain concentrate mercury more
21 19 easily in their tissues. The maximum levels set for total
22 20 mercury by Commission Regulation 466/2001/EC are under
23 21 revision, and in the European Union assessment is required of
24 22 the risk from dietary exposure to mercury (EFSA, 2004).

25 23 From the analysis of the SCOOP (scientific co-operation on
26 24 questions relating to food) data within the European Union
27 25 (EFSA, 2004), it can be concluded that there is high
28 26 variability in the mean fish consumption in different
29 27 countries across Europe, and such variation in food
30 28 consumption could result in exposures that vary by a factor of
31 29 10. In addition, the weighted mean contamination, which was
32 30 based on all data for the mercury concentration in fish and
33 31 seafood products submitted by the Member States, was 109 ± 845
34 32 µg/kg; the high standard deviation reflects the wide
35 33 variations in the mercury contents.

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3 1 In numerous studies high mercury contents in fish have been
4 reported (Bosnir et al., 1999). One of the fish species with
5 2 higher mercury contents was tuna, though mercury contents
6 3 depended also on their origin. For instance, *Thunnus thynnus*
7 4 from the Eastern Mediterranean had mean total mercury contents
8 5 of 1.18 mg kg⁻¹ (maximum 2.59 mg kg⁻¹), whereas in the Atlantic
9 6 Ocean the mean content was 0.485 mg kg⁻¹ (maximum 0.76 mg kg⁻¹)
10 7 (Storelli et al., 2002). More recently, Yamashita et al.
11 8 (2005) reported a methylmercury content of 0.49 ± 0.31 mg kg⁻¹
12 9 (maximum 0.90 mg kg⁻¹) (Pacific Ocean) vs. 0.29 ± 0.04 mg kg⁻¹
13 10 (maximum 0.34 mg kg⁻¹) (Atlantic Ocean) for this species.
14 11

15 12 The opinion of the Scientific Panel on Contaminants in the
16 13 Food Chain (EFSA, 2004) is that the consumption of large
17 14 predatory fish, which are at the top of the food chain, such
18 15 as swordfish and tuna, and which all contain higher levels of
19 16 methylmercury, may be significantly greater in countries in
20 17 southern Europe.
21 18

22 19 The importance of fish consumption in Spain, its
23 20 nutritional value, and the risk associated with mercury
24 21 contamination in this kind of product explain our interest in
25 22 determining mercury in fish commercially available in Spain.
26 23

27 24 A total diet study carried out in the Basque Country
28 25 (Spain), revealed a mean and maximum daily mercury intake of
29 26 12 and 18 µg day⁻¹ was found, fish being the main dietary
30 27 source of mercury (Urieta et al. 1996). The study did not
31 28 include the speciation of mercury. Laterly, Sanzo et al.
32 29 (2001) estimated mercury intake due to fish consumption among
33 30 individuals from Gipuzkoa participating in the European
34 31 Prospective Investigation into Cancer (EPIC), and found an
35 32 average intake of 48.3 µg week⁻¹. Recently, an estimation of
36 33 the daily intake of mercury from the consumption of marine
37 34 species has been made in Catalonia (Spain): mercury intakes
38 ranging from 5.6 (female children) to 9.89 (male adults) µg
39 day⁻¹ have been reported.

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3 1 The techniques most frequently used to release mercury
4 species from solid samples are acid leaching (Hardisson et
5 2 al., 1999; Ortiz et al., 2002; Storelli et al., 2002, Cabañero
6 3 et al., 2004) or alkaline digestion (Slaets et al., 1999),
7 4 with the option of applying ultrasonic (Río and Bendicho,
8 5 1999) or microwave energy (Gebersmann et al., 1997; Berzas et
9 6 al., 2005) to assist in the procedure. In alkaline media
10 7 methylmercury appears to be more stable than in acid media,
11 8 the proteins being easily hydrolyzed (Hintelman et al., 1997).
12 9 To detect organomercurial compounds, selective techniques such
13 10 as atomic absorption spectrometry (AAS), atomic fluorescence
14 11 spectrometry (AFS)(Jókai et al, 2005), microwave-induced
15 12 plasma atomic emission spectrometry (MIP-AES) and inductively
16 13 coupled plasma mass spectrometry (ICP-MS) (Cai et al., 2000)
17 14 and electron capture detection (ECD) coupled to GC methods
18 15 have been used. However, such advanced instrumentation is not
19 16 always available in the laboratories of some countries with
20 17 important fish catches, as for instance some African and South
21 18 American countries. This is the reason why a simple device was
22 19 used in the determination of organic mercury in this study.
23 20 With the ultimate aim of estimating the contribution of fish
24 21 and seafood to mercury intake, mercury content was measured in
25 22 fish and seafood products usually consumed in Spain,
26 23 differentiating between inorganic and organic mercury, by
27 24 applying a simple method comprising cold vapor and AAS,
28 25 previously used and validated in our laboratory (Ubillús et
29 26 al., 2000).

50 28

51 29 **Materials and methods**

52 30 *Instrumentation*

53 31 For mercury determination by cold vapor generation atomic
54 32 absorption spectrometry, a Perkin-Elmer (PE) 2380 atomic
55 33 absorption spectrophotometer equipped with a quartz absorption

1
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3 1 cell (19 mm long, 17 mm i.d. with quartz windows), a System 2
4
5 2 Electrodeless Discharge Lamp (PE) and a discharge mercury lamp
6
7 3 (PE) were used. A hydride generation vessel (25 ml capacity)
8
9 4 and a small fish tank air pump were also used. A Heraeus model
10 5 D-6450 Hanau forced air oven was used to dry samples.
11
12 6

13 14 7 *Samples and sample preparation*

15
16 8 The analyzed samples were species of fish and seafood most
17
18 9 frequently consumed in Spain, and arbitrarily selected from
19
20 10 local markets. Overall 25 different fish and seafood products,
21
22 11 mainly in the fresh state, were analyzed. Two different
23
24 12 samples of each fish species (with the exception of chucla
25
26 13 (Blotched picarel, *Spicara maena*), serrano and pagre (Common
27
28 14 sea bream, *Pagrus pagrus* (Linné 1758), from which only one
29
30 15 sample could be obtained), bought in different stores or in
31
32 16 the case of fresh fish on different days were analyzed. Among
33
34 17 the available canned products, the most frequently consumed
35
36 18 were selected, and from each of them two samples from two
37
38 19 different batches were analyzed. In all cases, three aliquots
39
40 20 of each sample were analyzed.

41
42 21 Fish samples were prepared by dissection of the edible
43
44 22 parts, which were dried at 80°C for 24 h and homogenized by
45
46 23 grinding in a glass mortar.

47
48 24 The preparation of the samples was based on the method for
49
50 25 mercury speciation proposed by Oda et al. (1981), adapted to
51
52 26 the conditions of our laboratory (Ubillús et al., 2000).
53
54 27

55 28 *Mercury determination*

56
57 29 Inorganic and organic mercury contents were measured by cold
58
59 30 vapor atomic absorption spectrometry (CV-AAS). The
60
31 instrumental conditions applied are: 253.7 nm of wavelength,
32 0.7 nm of spectral bandwidth; for measurement a discharge

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3 1 mercury lamp at 170 mA with a deuterium lamp as background
4 correction, and the peak height mode were used.
5 2

6 3 Calibration curves with inorganic and methylmercury
7 standards, in the range from 0 to 40 ng ml⁻¹, were plotted; the
8 standard addition method was applied.
9 4
10 5
11 6

12 7 *Analytical Quality Assurance*

13 8 Matrix interference was checked by comparing the slopes of the
14 calibration curves obtained with standards in aqueous solution
15 and added to a tuna digest (standard addition method).
16 9
17 10

18 11 The suitability of the method was evaluated by determining
19 the analytical parameters (limit of detection, limit of
20 quantification, precision and accuracy).
21 12
22 13

23 14 The limits of detection (LOD) and quantification (LOQ)
24 defined as the mercury concentration corresponding to three or
25 ten times the standard deviation of blanks, respectively, and
26 were determined with nine reagent blanks.
27 15
28 16
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30 18 The precision of the method was estimated from the values
31 obtained in the independent analysis of 9 aliquots of tuna
32 fish. The values were expressed as percentage of the relative
33 standard deviation (RSD %).
34 19
35 20
36 21

37 22 Eight aliquots (0.10-0.20g) of Tuna Certified Reference
38 Material (CRM 463, BCR) were analyzed by the method, and
39 measured values of mercury were compared with certified
40 values.
41 23
42 24
43 25
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46 28 **Results and discussion**

47 29 *Analytical Quality Assurance*

48 30 The application of the standard addition method revealed
49 matrix interferences: the values of the slopes obtained for
50 inorganic and methylmercury standards in aqueous solution were
51 0.00147 and 0.00225, respectively, while in tuna digest were
52 0.00106 and 0.00144 for inorganic mercury and methylmercury,
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1
2
3 1 respectively. The slopes obtained in aqueous and digested
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5 2 media were significantly different ($p < 0.05$); therefore, the
6
7 3 standard addition method was used in all determinations.

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9 4 The values obtained for the limit of detection, precision
10
11 5 and accuracy are reported in Table I. There is good agreement
12
13 6 between the certified and measured values, so the method is
14
15 7 accurate. The precision for inorganic mercury was not
16
17 8 evaluated because in the analyzed samples the inorganic
18
19 9 mercury contents were lower than the limit of detection of the
20
21 10 method.

22
23 11 The analytical parameters obtained confirm the usefulness
24
25 12 of the method in relation to the study objective.

26 13 27 14 *Mercury determination*

28
29 15 The methylmercury contents referred on a dry and wet matter
30
31 16 basis are reported in Tables II and III, corresponding to
32
33 17 fresh and frozen fish and to canned products, respectively.
34
35 18 Total mercury contents in fish analyzed in this study did not
36
37 19 exceed the maximum levels established by the European Union
38
39 20 (reported above).

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41 21 In all analyzed samples inorganic mercury contents were
42
43 22 lower than the limit of detection. In this respect, a study on
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45 23 total mercury and methylmercury determination in different
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47 24 seafood characterized as frequently consumed species in Spain
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49 25 concluded that methylmercury content is the major mercury
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51 26 species in seafood samples (Gomez-Ariza et al., 2004). In the
52
53 27 same sense, mercury was present almost completely in the
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55 28 methylated form in the muscle of hake and striped mullet from
56
57 29 the Mediterranean (Storelli et al., 2005).

58
59 30 There was broad variability not only among the mercury
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31 levels of different fish species, but also among different
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33 samples of the same species. A mean value of total mercury
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concentration in fish and seafood products of $109 \pm 845 \mu\text{g kg}^{-1}$
food was reported by the Member States by scientific co-

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3 1 operation (SCOOP) task 3.2.11.; the high standard deviation of
4 2 the mean reflects the variability of mercury contents in fish
5 3 (EFSA, 2004). Mercury speciation is not performed routinely by
6 4 national control laboratories.

7 5 In the study carried out, the highest mercury levels
8 6 corresponded to predatory fish species located at the highest
9 7 level of the food chain (tuna, swordfish), these being the
10 8 species for which the European Union allows the highest
11 9 mercury contents. In the case of mollera (Poor cod,
12 10 *Trisopterus minutus*) and pagre (Common sea bream, *Pagrus*
13 11 *pagrus*), despite their small size compared to tuna, salmon and
14 12 swordfish, they came from Valencian coastal waters at the
15 13 mouth of the Albufera lake - a fact that could explain their
16 14 relatively high mercury contents.

17 15 Values found for methylmercury contents are in the upper
18 16 level of the ranges reported in the literature.

19 17 The comparison of methylmercury contents in fresh and
20 18 canned tuna show a mean difference of 17%. In samples of the
21 19 same brand of canned tuna, differences between batches,
22 20 perhaps ascribable to differences in the origin of the tuna
23 21 were found. The most surprising observation corresponded to
24 22 tuna in vegetal oil brand B, where in one of batches (a) the
25 23 mercury content was lower than the limit of detection of the
26 24 method, while in the other total MeHg was $> 400 \mu\text{g kg}^{-1}$ wet
27 25 weight.

28 26 Differences in mercury contents depending on tuna origin
29 27 have been reported. Accordingly, bluefin tuna (*Thunnus*
30 28 *thynnus*) caught in the Mediterranean had 4- to 5-fold higher
31 29 mercury contents than tuna from the same species caught in the
32 30 Atlantic (Storelli et al., 2002). Tuna migration and the fact
33 31 that the Mediterranean Sea is part of the Circumpacific-
34 32 Mediterranean-Himalayan mercuriferous belt, which contains
35 33 mercury ferrous rocks, could explain this difference
36 34 (Bernhard, 1988 and EEA, 1999)

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3 1 In addition, the variation in mercury levels among tuna
4 2 samples may be largely dependent on both species and body
5 3 size, and the mercury levels found in the muscle of cultured
6 4 tuna in the Mediterranean were higher than the average levels
7 5 in the muscle of wild tuna. This may be due to mercury intake
8 6 from large predatory fish species, such as mackerels, used as
9 7 feed in tuna aquaculture (Yamashita, Omura and Okazi, 2005).

10 8 No significant differences have been reported in mercury
11 9 levels in canned tuna packed in oil compared to water.
12 10 Inorganic mercury was below limit of detection and about 90%
13 11 of the mercury in fish was methylmercury (Burger and Gochfeld,
14 12 2004). In the present study, in canned natural tuna
15 13 methylmercury contents were, in the two analyzed batches,
16 14 higher than those found in tuna in vegetal oil. The
17 15 differences can not be ascribed to the brine, considering the
18 16 high variability in methylmercury content in the same fish
19 17 species, the possibility that the difference could be due to
20 18 the fish origin can not be ruled out. However, the fact that
21 19 the lower content corresponded to tuna in oil (with values
22 20 even lower than those corresponding to the analyzed fresh
23 21 tuna) could also be explained by partial dissolution of
24 22 organic mercury in the oil.

25 23

26 24 *Intake estimation*

27 25 To evaluate the contribution of fish consumption to mercury
28 26 intake, data from the Spanish *Ministerio de Agricultura, Pesca*
29 27 *y Alimentación* (MAPA) (Martín, 2002) were used. The dietary
30 28 intake (DI) of methylmercury was modeled as:

$$31 29 \quad DI = \sum I_{sw}C_s$$

32 30 where I_{sw} was the daily intake (in kg) of fish in weight w of
33 31 species s , and C_s was the methylmercury content ($\mu\text{g kg}^{-1}$) in
34 32 species. In Table IV, estimated seafood consumption and its
35 33 contribution to mercury intakes in Spain are reported.

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3 1 Contributions of fish to mercury intake are represented in
4 2 Fig 1, where these values are compared to the provisional
5 3 tolerable weekly intake (PTWI) limits set by the JECFA and by
6 4 the NRC.
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10 5 Both PTWI were calculated with the absence of appreciable
11 6 adverse effects in children born of mothers with mercury hair
12 7 contents of 14 or 12 $\mu\text{g g}^{-1}$ hair, respectively. Estimation of
13 8 the methylmercury intake is complex, because it is based in
14 9 the conversion of biomarker data, such as hair levels, into
15 10 daily intake. To obtain the US-NRC limit a composite
16 11 uncertainty factor higher of 10 to take into account
17 12 interindividual variability and incompleteness of the data
18 13 base was applied, while in the estimation of JECFA PTWI the
19 14 uncertainty factor was 10. Imprecision in intake estimates
20 15 may lead to underestimation of the true mercury effect, and to
21 16 an overestimation of the benchmark dose level (EFSA, 2004).
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31 17 Considering the species analyzed in this study, their
32 18 daily contribution to the methylmercury intake of the Spanish
33 19 population was 6.6 μg . It has to be noted that only fish
34 20 products frequently consumed or with a potential contribution
35 21 to mercury intake have been analyzed. As shown in Figure 1, a
36 22 Spanish individual with body weight ≤ 60 kg could have mercury
37 23 dietary intakes in excess of the U.S.-NRC limit. This is the
38 24 case of children, who consume more fish than adults, when
39 25 intake is expressed on a body weight basis (EFSA, 2004; Crépet
40 26 et al., 2005).
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49 27 Therefore, the probability of exceeding the methylmercury
50 28 limit is much higher in small children. On the other hand,
51 29 considering that intrauterine exposure is believed to
52 30 represent the critical period for methylmercury
53 31 neurodevelopmental toxicity, pregnant women must also control
54 32 methylmercury, and therefore our advice is to limit the intake
55 33 of large predators, as they are the real main sources of
56 34 methyl mercury.
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3 1 In agreement with the literature, population groups with
4 2 frequent consumption of large predatory fish such as tuna or
5 3 swordfish are at risk of high methylmercury intake.

6 4 Data from the SCOOP report indicate that in some countries
7 5 the average mercury intake from fish and seafood products may
8 6 be at the US-NRC limit, and some average intake levels may
9 7 exceed this limit (EFSA, 2004).

10 8 In 1999, taking into account the mean annual per capita
11 9 fish consumption of the Spanish population, it was estimated
12 10 that the mean weekly mercury intake from fish would be 49.8 μg
13 11 (of which 45 μg corresponds to organic mercury) (Bosnir et
14 12 al., 1999). The estimation of the present study was 46.2
15 13 $\mu\text{g}/\text{week}$. However, it must be noted that the sum of fish
16 14 intakes reported in Table IV is about 52 g per individual,
17 15 while daily fish and seafood consumption by the Spanish
18 16 population was 73 g (Martin, 2002); as a result, the estimated
19 17 weekly methylmercury intake could be slightly underestimated.
20 18 In addition, the contribution of locally consumed fish species
21 19 such as chucla, mollera, llisa, etc. - some of them with
22 20 relevant methylmercury contents - was not considered, because
23 21 their consumption is unknown.

24 22 It should be noted that daily fish and seafood consumption
25 23 by the Spanish population is above the average fish
26 24 consumption range in the European Union - from 10 g per person
27 25 in The Netherlands to 80 g per person in Norway (EFSA, 2004).
28 26 Consequently, control of the methylmercury contents in fish is
29 27 required.

30 28 If total daily fish and seafood consumption by the Spanish
31 29 population of 73 g) (Martin, 2002) and the mean concentration
32 30 for mercury in fish and seafood products submitted by the
33 31 Member States of 109 $\mu\text{g kg}^{-1}$) (EFSA, 2004) are considered, then
34 32 dietary exposure to mercury should be 7.8 μg - this value
35 33 being higher than that estimated in the present study. It
36 34 should be taken into account that 109 $\mu\text{g kg}^{-1}$ corresponds to

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3 1 the mean total mercury content in fish, the variability in the
4 2 contents being very high. All this corroborates the need for
5 3 studies on real fish and seafood consumption (differentiating
6 4 among fish species) for different population groups, together
7 5 with routine estimation of methylmercury in products of this
8 6 kind - in order to obtain more reliable estimations of
9 7 methylmercury intakes.

10 8 As reported by the Scientific Panel Members (EFSA, 2004),
11 9 other possible sources of mercury for humans, such as might
12 10 arise from the consumption of meat products of animals fed
13 11 methylmercury-containing fishmeal, have not been considered
14 12 but would need to be taken into account in any comprehensive
15 13 evaluation of methylmercury intake.

16 14 In agreement with Sanzo et al. (2001), it can be concluded
17 15 that methylmercury in fish must continue to be monitored
18 16 closely in order to assess the risk for the population.

19 17 However, the mentioned beneficial effects of fish
20 18 consumption on coronary diseases derived from the presence of
21 19 ω -3 fatty acids, together with the low mercury contents in
22 20 some species (sardine and salmon) makes fish consumption
23 21 advisable.

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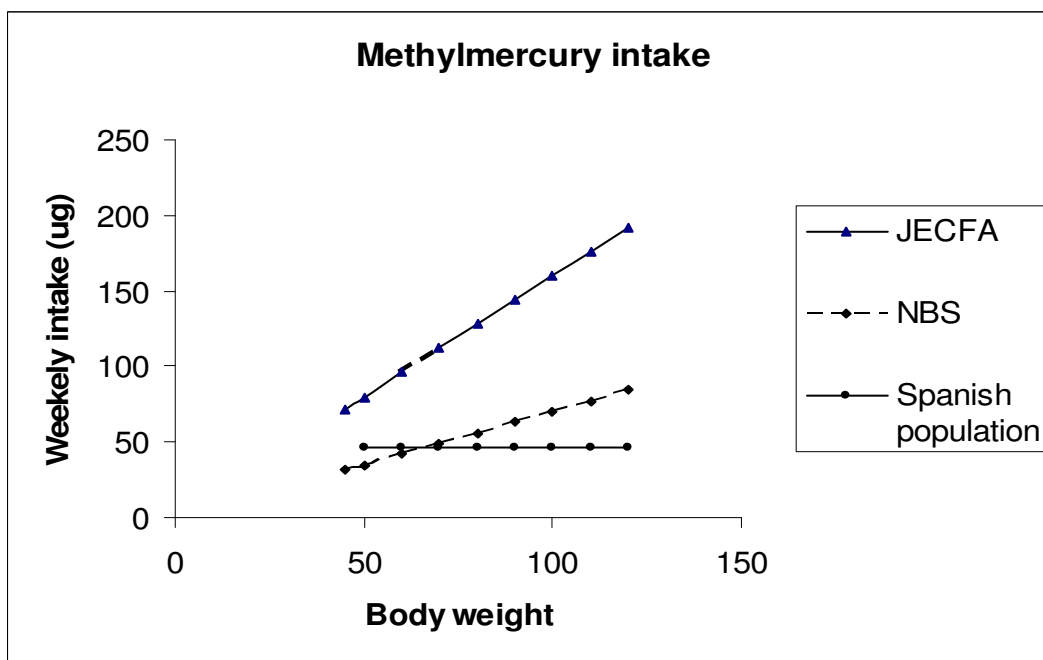
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3 Figure 1. Estimated weekly methylmercury intake compared
4 with provisional tolerable weekly intake (PTWI) limits set
5 by the JECFA in the European Union and by the NRC in the
6 United States.
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