Original Article

High fish consumption in French Polynesia and prenatal exposure to metals and nutrients

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French Polynesians consume high quantities of fish and are therefore exposed to seafood-related contaminants such as mercury (Hg) or lead (Pb) and nutrients such as iodine, selenium and long chain polyunsaturated fatty acids (LC-PUFAs). As the developing foetus is sensitive to contaminants and nutrients, a cross-sectional study was conducted in French Polynesia in 2005-2006 to assess prenatal exposure to contaminants and nutrients through fish consumption. Two hundred and forty one (241) delivering women originating from all islands of French Polynesia were recruited and agreed to answer questions on fish consumption and gave permission to collect umbilical cord blood for metals and nutrients analyses. All parameters were found in high concentrations in cord blood samples except for lead. Mercury concentrations averaged 64.6 nmol/L (or 13 µg/L) with values ranging from 0.25 to 240 nmol/L. Of the sample, 82.5% had Hg concentrations above the US-EPA blood guideline of 5.8 µg/L. Tuna was the fish species which contributed the most to Hg exposure. High selenium and LC-PUFAs may counterbalance the potential risk of prenatal exposure to Hg in French Polynesia. Due to the high fish consumption of mothers, Polynesian newborns are prenatally exposed to high doses of mercury. Although selenium and omega–3 fatty acids may counteract mercury toxicity, informing pregnant women on both the mercury and nutrient content of local fish species is important.

Key Words: mercury, n–3 fatty acids, iodine, selenium, lead, newborns

INTRODUCTION

Polynesians, as other remote maritime populations, are intimately connected to the oceanic environment which nourishes their daily life and culture. They still rely on marine foods and are among the highest fish consuming nations in the world. Among the small developing island states in the Pacific, Indian Ocean and the Caribbean, several countries have a per capita fish consumption over 50 kg a year, compared to 16 kg a year for the world average. Indeed, with 54 kg/year, French Polynesia is listed among the 23 countries where people consume more than 50 kg of fish per annum.[1] While providing nutrients, the consumption of high amounts of fish, particularly for pregnant women, raises the issue of potential exposure to harmful natural and anthropogenic contaminants[2-4] such as methylmercury (MeHg) and lead (Pb). Balancing the risks and benefits from seafood consumption is a burning debate not only for urban individuals but certainly more for subsistence-based communities.

Numerous studies have reported that MeHg in predator fish species represents a potential health threat for the developing foetus. As this seafood borne contaminant affects the development of the cerebral architecture by perturbing the neural cell division and migration, the developing nervous system is recognized as the main target,[5,6] Several prospective cohort studies have reported effects of prenatal exposure to MeHg on different domains of cognition (attention, memory, visuo-spatial performances and language) as well as gross and fine motor development, of which some persist well beyond the first years of life.[7-9] In contrast, a large epidemiological study from the Seychelles Islands did not find any effect of chronic *in utero* exposure to MeHg on infant neurodevelopment.[10,11] Several explanations have been proposed to explain this discrepancy such as chronic versus episodic exposure, age at neurobehavioral assessment, differential confounders adjustment, etc.[12]

Lead (Pb) exposure is especially toxic for the foetus and young child.[13,14] Many studies have reported the deleterious effects of lead exposure during early childhood on cognitive and motor functions.[15-17] More recently, behavioural deficits such as hyperactivity, impulsivity and aggressive behaviour have been shown.[18] Moreover, Pb exposure during pregnancy has been linked with premature births[19,20] as well as low birth weight[21] and an increase in growth retardation.[22]

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Meanwhile those populations also receive key nutrients through fish consumption which may counterbalance mercury toxicity[23] and provide nutritional benefits. Several health organisations recommend eating fish twice a week for the general population.[24,25] Fish consumption is largely recognised as beneficial for brain development[26] and protective against cardiovascular diseases[27,28] mental disorders[29,30] and various inflammatory conditions such as bowel diseases, asthma, and arthritis.[31] Interestingly, populations consuming a lot of fish have generally high birth weight babies.[32,33] Also, maritime populations have generally high intakes of long chain polyunsaturated fatty acids (PUFAs), the most important compounds being eicosapentanoic acid (EPA) and docosahexanoic acid (DHA). During pregnancy, fish consumption provides DHA to the mother and the foetus which helps brain and retina development.[2,34] In addition, fish and seafood are a very good natural source of selenium (Se) and iodine (I).[35,36] Concentrations of these two elements in food also depend on the local geological composition. It has been proposed that selenium may exert an antagonistic effect on mercury toxicity,[37] whereas iodine is needed for thyroid hormone synthesis which in turn is essential for brain development.[38] A deficit in iodine has been associated with severe mental retardation (cretinism).[39]

In 2004, we conducted a preliminary study among Polynesian adults living in the Tahiti and Moorea Islands, who participated in a follow-up study on Ciguatera disease.[40] MeHg, Se and omega–3 PUFAs were measured as potential confounding factors (as they come from seafood and are neuro-active). Total Hg concentrations in the blood of participants were found to be high (108.4 nmol/L), around 20-fold the background mercury concentrations found in the USA and Canada (5 nmol/L). Moreover, 85% of the blood Hg was in the form of MeHg for which the major known source of exposure is fish consumption.[41] It is also important to note that among the 39 female participants of childbearing age (18-45 yrs), the mean mercury concentration was 65.4 nmol/L compared to the 108.4 nmol/L arithmetic mean for the entire group. In addition, polychlorinated biphenyls (PCBs) concentrations measured in blood samples were very low.[40]

The main goal of this study was to determine the exact balance of risks and benefits from seafood consumption in French Polynesia. More importantly, this study wanted to confirm the existence of high levels of exposure to mercury during the prenatal life as well as assess exposure to lead, another toxic metal. Biomarkers for nutrient intake (Se, I, omega–3 PUFA) were also measured in umbilical cord blood samples collected among French Polynesian neonates from all archipelagos.

METHODS

Population

French Polynesia is located in the South Pacific. The total population is estimated to be 275 000 scattered over 68 inhabited islands (among the 118 existing ones). Tahiti, the main island, comprises more than 70% of the total French Polynesian population (Figure 1). The study population was all pregnant women born and living in French Polynesia for at least 5 years and their neonates. Participating women delivered between October 2005 and February 2006. During this 5-month period, 241 mothers were recruited and answered a short questionnaire by face-to-face interview on lifestyle habits, socio-demographic characteristics and fish consumption. The sampling protocol had to take into consideration administrative, geographic (remoteness, geology) and lifestyle differences expected in the different archipelagos. For example, high volcanic islands such as the Marquises and some the Australes Islands differ in many aspects to low atoll islands such as the Tuamotu and the Gambier archi-

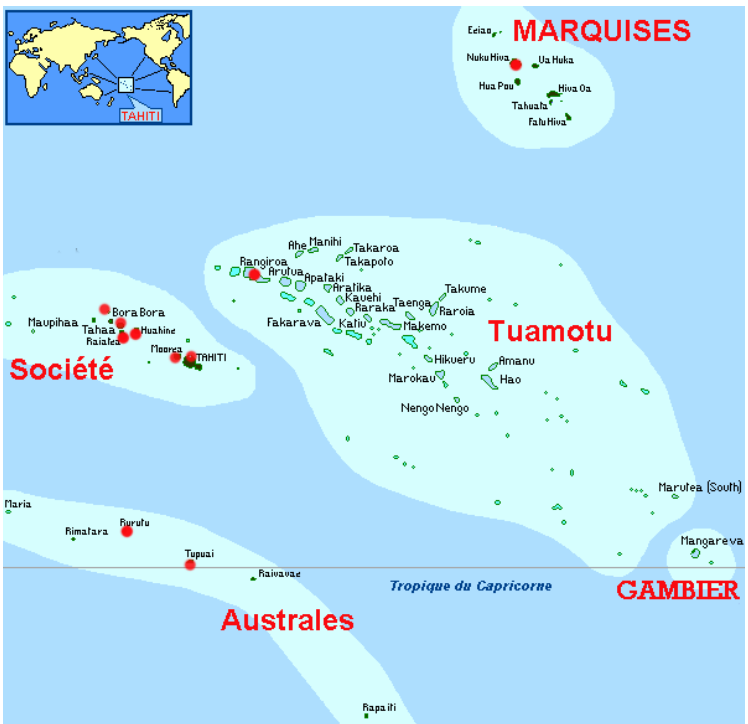

Figure 1. Location of French Polynesia and its archipelagos.

Table 1. Geographical origin of participants

	Number of births in 2002	Sample size (n)
Île du Vent		
Tahiti	3 332	91
Moorea	264	21
Iles sous le vent	599	50
Marquises	162	22
Australes	92	8
Tuamotu-Gambier	306	38
Unspecified islands		11
Total	4 755	241

pelagos. These characteristics may influence for example the local fish consumption (pelagic vs reef fish). A blood sample was taken from the umbilical cord of neonates after severing. In 2004, 4 432 births were registered in French Polynesia and 85% occurred in Papeete, with 50% at the public territorial hospital and half in the two major private clinics. The other 15% occurred in the Moorea, Taravao and Marquesas health centres. Table 1 presents the geographical origin (residence) of delivering women who participated in the study. The project was reviewed and approved by the French Polynesia Ethical Committee (No 24/CEPF-1 September 2005).

Laboratory analyses

Hg, Pb, Se and I concentrations were determined in whole cord blood samples from individual participants at the Centre de toxicologie du Québec, Canada. They were analysed by inductively coupled plasma mass spectrometry (ICP-MS) which allows the simultaneous determinations of several metals in elementary form in various matrices. Blood samples were diluted in ammonium hydroxide and metals were brought to their elementary form by passing through argon plasma before being identified by mass spectrometry. All samples were analysed on a Perkin Elmer Sciex Elan 6000 ICP-MS (DRC II for Hg) instrument. Detection limits were 0.001 µmol/L for Pb and 0.49 nmol/L for Hg. Concentrations of Hg were also determined in hair samples of 12 participating women. Five segments of 1 cm were analysed per participant. Hair Hg was determined by cold vapour atomic absorption spectrometry on a Mercury Monitor Model 100 from Pharmacia. Each hair segment was chopped and microwave-digested using nitric acid. An aliquot was used for the analysis. The detection limit for this method was 0.41 nmol/g. Accuracy and precision were determined using reference materials from the Toxicology laboratory's Interlaboratory Comparison Program. Also, external comparisons were performed in the framework of the "Programme de comparaison interlaboratoire du mercure dans les cheveux, Santé Canada, Ottawa".

The fatty acid composition of red cell membrane phospholipids was measured after total lipid extraction with a chloroform/methanol mixture, phospholipid separation by thin layer chromatography and methylation of fatty acids,[42] followed by capillary gas-liquid chromatography using a DB-23 column (39m x 0.25 mm ID x 0.25 um thickness) or a column SP-2500 column (for trans fatty acids, 100m x 0.25 mm ID x 0.20 um thickness) in a HP-Packard GC chromatograph. This standard method is currently used at the Québec Lipid Research Centre. These analyses were available for only 116 participants.

Table 2. Number of meals/month of lagoon and pelagic fish among French Polynesian pregnant women

	Fish intake (meals/month)			
	Lagoon fish		Pelagic fish	
Archipelagos	*n*	Arithmetic mean (SD†)	*n*	Arithmetic mean (SD†)
Îles du vent				
Tahiti	80	15.9 (25.2)	91	12.4 (13.9)
Moorea	19	20.1 (21.1)	18	11.4 (10.1)
Îles sous le vent	39	19.5 (40.7)	42	9.5 (12.8)
Marquises	19	17.3 (15.7)	22	17.5 (15.1)
Australes	7	18.2 (11.5)	6	6.3 (5.4)
Tuamotu-Gambier	38	38.1 (31.5)	33	8.1 (7.2)
All	207	21.3 (30.0)	211	11.5 (12.7)

†Standard deviation

Statistical analysis

Results on metal and nutrient concentrations are presented as arithmetic and geometric means with 95% confidence intervals as well as minimum and maximum values. We performed Pearson correlations to quantify the linear relationship of Hg with frequency of fish consumption and nutrient concentrations. Data were analysed using SAS 9.1 version (SAS Institute Cary, NC) and the statistical significance was set at $\alpha=0.05$.

RESULTS

Participating mothers were aged 15 to 44 years old (mean = 26 years) and their distribution according to their archipelago is presented in Table 1. Seven percent of women were under 18 years of age, whereas 12.6% were over 35 years old. Thirty-five percent of participating women declared smoking before pregnancy. This percentage dropped during pregnancy, as only 23.5% were still smoking, with an average consumption of 5 cigarettes/ day. Many participants had a college degree (37.8%) and 77.2% had a monthly income below 1,800.00 USD. The average gestational age of newborns was 39.2 weeks (range 27.0 – 42.1 weeks) with a mean birth weight of 3.3 kg (range 1.0 – 4.8 kg). Five percent of neonates had less than 37 weeks of gestation, whereas 5% weighed less than 2.5 kg. The monthly fish consumption of participants is presented in Table 2 and little variation was observed between archipelagos for overall fish consumption mean: 33 meals/month corresponding to 21.3 and 11.5 meals/ months respectively for reef and pelagic fish. As expected, the mother from the Tuamotu-Gambier has the highest reef fish consumption (38 meals/month) and pelagic fish consumption was the highest (17.5 meals/month) among women from the Marquises archipelago.

Table 3 shows the average umbilical cord blood Hg concentration found in French Polynesian newborns. The

Table 3. Cord blood concentrations of mercury (nmol/L) among French Polynesian newborns

		Mercury (nmol/L)					
Archipelagos	n	Arithmetic mean	Arithmetic 95% CI†	Geometric mean	Geometric 95% CI†	Minimum	Maximum
Îles du vent							
Tahiti	89	73.6	(63.1-84.5)	61.5	(54.2-69.6)	14.00	240.0
Moorea	20	44.2	(29.8-58.7)	34.8	(24.6-49.2)	6.50	120.0
Îles sous le vent	48	57.5	(46.3-68.8)	43.0	(32.2-57.5)	0.25	170.0
Marquises	20	64.7	(51.9-77.4)	58.0	(45.5-73.8)	19.00	110.0
Australes	8	78.9	(34.6-123.1)	62.7	(33.4-117.6)	21.00	150.0
Tuamotu-Gambier	38	63.1	(51.3-74.9)	52.6	(42.3-65.6)	6.40	170.0
All	234	64.6	(59.1-70.1)	52.0	(47.3-57.2)	0.25	240.0

†95% CI: 95% Confident interval

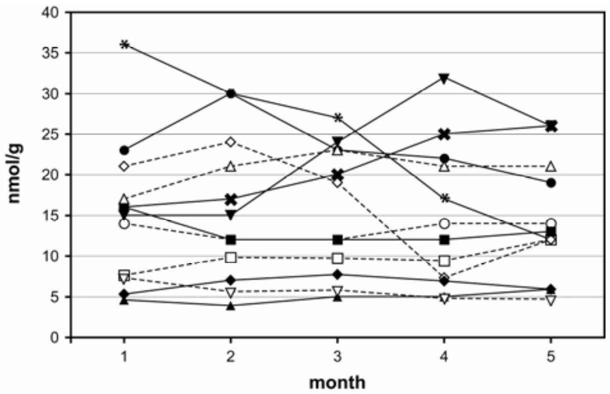

Figure 2. Temporal evolution of mercury concentrations in hair of 12 Polynesian mothers

mean concentration of Hg for the whole sample was 64.6 nmol/l, two thirds of the average concentration previously found in adults.[40] Some variations were observed between archipelagos but surprisingly Tahiti, the main island, where fish consumption was expected to be lower than in remote archipelagos showed relatively high concentrations. Almost 39% of newborns had an Hg corresponding blood concentration exceeding the tolerable daily intake (0.23 µg/kg body weight/day) proposed by the WHO, which corresponds approximately to a blood concentration of 67 nmol/L of Hg. If we apply the EPA guidelines, 82% of newborns had a blood Hg concentration above 30 nmol/L, corresponding to a tolerable daily intake of 0.1 µg/kg body weight/day. Also, Hg concentrations in maternal hair were determined in separate hair fragments (0-2, 3-4, 4-6, 6-9 et 9-12 cm) in order to evaluate the temporal evolution of the exposure over a 5-month period (Figure 2). Results show that overall, the Hg exposure for this period was fairly constant for most mothers.

The dietary questionnaire allowed us to identify the most common fish species consumed. By far, tuna was the most consumed fish with nearly 75 % of all pelagic fish consumed (6.9 among 9.6 meals/month), followed by bonito and mahi-mahi (0.9 meal/ month). Blood Hg concentrations were moderately correlated with pelagic fish consumption (meals/month) (r = 0.21, p = 0.003) and tuna consumption (r = 0.16, p = 0.02) but not with frequency of lagoon fish consumption (r = 0.06, p = 0.41).

Mean umbilical iodine cord blood concentrations by archipelago are presented in Table 4. Newborns from Iles Sous le Vent (ISV) have the highest exposure to iodine with an average of 2.60 µmol/L whereas newborns form the Australes archipelago had the lowest mean concentration (0.46 µmol/L). The mean cord blood selenium concentration was 2.0 µmol/L for the whole sample. The highest mean concentration was measured in the Marquesas archipelago (2.7 µmol/L) and the lowest in Moorea and Australes (table 5). Umbilical cord blood concentrations of selenium were highly correlated with Hg concentrations (r = 0.39, p< 0.001), and with n–3 PUFA levels (r = 0.20, p = 0.002).

The mean concentration of n–3 PUFAs measured in red cell membrane phospholipids was 3.52 %. Eicosapentanoic acid and DHA represented 87 % of all n–3 PUFAS, but EPA was almost absent (0.01%) compared to DHA. No major differences were observed between archipelagos (data not shown).

The average cord blood concentration of lead was very low (0.06 µmol/L or 12.5µg/L). Very few variations were observed between archipelagos. None of the mothers had cord blood concentrations of lead above the 0.48 µmol/L (100 µg/L) guideline. Lead concentrations were significantly higher among smoking mothers (0.074 µmol/L) compared to non smokers (0.057 µmol/L; p = 0.002).

DISCUSSION

Risk due to mercury exposure

Although mercury has been recently associated with cardiovascular problems during the prenatal life,[43] its main health effect remains neurotoxicity. Indeed, the foetal brain appears to be particularly susceptible to Hg.[5] Consequently, most of the scientific literature about effects of prenatal exposure to Hg at background levels focussed on child neurobehavioral development,[6,44] Two well designed studies investigated the effects of prenatal exposure to MeHg on child neurodevelopment. In the Seychelles Child Development Study, results from 46 neurobehavioral endpoints were reported in children from 6 to 108 months of age and no adverse association with prenatal mercury exposure was shown.[45-48] By contrast, in the Faroe Island cohort, prenatal mercury exposure was significantly associated with a decrease in neurologic opti-

Table 4. Cord blood iodine concentration in French Polynesian newborns

Archipelagos	Iodine (µmol/L)						
	n	Arithmetic mean	Arithmetic 95% CI[†]	Geometric mean	Geometric 95% CI[†]	Minimum	Maximum
Îles du vent							
Tahiti	89	1.02	(0.69-1.35)	0.62	(0.52-0.74)	0.16	10.00
Moorea	20	0.62	(0.40-0.84)	0.50	(0.37-0.67)	0.20	1.80
Îles sous le vent	48	2.60	(0.77-4.44)	0.99	(0.70-1.39)	0.16	41.00
Marquises	20	1.06	(0.12-2.00)	0.61	(0.41-0.91)	0.20	9.40
Australes	8	0.46	(0.36-0.55)	0.44	(0.37-0.55)	0.29	0.59
Tuamotu-Gambier	38	1.27	(0.67-1.86)	0.72	(0.53-1.00)	0.23	10.00
All	234	1.35	(0.93-1.76)	0.68	(0.60-0.77)	0.16	41.00

[†]95% CI : 95% Confident interval

Table 5. Mean cord blood selenium concentration in French Polynesian newborns

Archipelagos	Selenium (µmol/L)						
	n	Arithmetic mean	Arithmetic 95% CI[†]	Geometric mean	Geometric 95% CI[†]	Minimum	Maximum
Îles du vent							
Tahiti	89	1.95	(1.86-2.04)	1.91	(1.83-1.99)	1.3	3.8
Moorea	20	1.83	(1.66-2.00)	1.80	(1.65-1.97)	1.4	2.6
Îles sous le vent	48	1.89	(1.76-2.03)	1.84	(1.73-1.97)	1.2	4.0
Marquises	20	2.71	(2.30-3.11)	2.59	(2.26-2.97)	1.5	4.9
Australes	8	1.83	(1.52-2.13)	1.79	(1.51-2.12)	1.3	2.4
Tuamotu-Gambi er	38	2.06	(1.90-2.23)	2.00	(1.87-2.16)	1.4	3.9
All	234	2.01	(1.94-2.08)	1.95	(1.90-2.01)	1.2	4.9

[†] 95% CI : 95% Confident interval

mality score at 2 weeks of age,[9] neuropsychological dysfunctions in the domains of language, attention and mem ory at 7 years of age,[7] longer reaction time on a continued performance task as well as deficits in cued naming at 14 years of age.[8] Many hypotheses have been proposed to explain discrepancies between these two well designed cohorts: peaks (Faroe) vs. stable Hg exposure (Seychelles), high Se (Seychelles) vs. moderate Se levels (Faroe), PCB effects (Faroe), fatty acid profiles, etc.[12]

Recently, FAO/WHO[49] reviewed their international guidelines of the Provisional Tolerable Weekly Intake (PTWI) of 0.23 µg/kg/bw/day for pregnant women of methylmercury (MeHg). In the USA, the National Health and Nutrition Study (NHANES) found in 1999-2002 that blood Hg levels in young US children and women of childbearing age were usually below levels of concern (the US-EPA level is of 5.8 µg/L and correspond to a maternal intake of 0.1 µg Hg/kg/bw/day, more than 2 times lower than the 0.23 µg/kg/bw/day FAO/WHO guideline for pregnant women).[50] Only 6% of women of childbearing-age had levels at or above a reference dose which corresponds to an estimated level assumed to be without appreciable harm ($\geq$5.8 μg/L). However, 16% of adult female participants who self-identified as Asian, Pacific Islander, Native American or multiracial had blood mercury levels ≥5.8 µg/L. In French Polynesia, the geometric mean Hg concentration in cord blood was 64.6 nmol/L (13.3 µg/L). Consequently, 82.5% of samples had Hg concentrations above the US-EPA guideline. This concentration is much higher than that reported in Hawaii[51] were Hg was measured in cord blood samples collected in 2004 and 2005 from 308 mothers. The mean cord blood Hg concentration was 4.82 µg/L (or 23 nmol/L), three time less than in French Polynesia but 5 times the US average of 1.02 µg/L measured among women of childbearing age.[41]

In the Nunavik Inuit population (Arctic Quebec, Canada), cord blood levels of Hg were 18.5 µg/L,[52] a little less than that observed in the Faroe Islands (24.2 µg/L)[53] and also lower than in the Seychelles Islands cohorts.[54] Therefore, Polynesian newborns are exposed to similar doses of Hg compared to Inuit, Faeroe's or Seychellois neonates. Furthermore, as shown in Figure 2, even though we observed some temporal variations, Hg concentrations measured in hair samples of delivering mothers were mostly stable over the 5-month period. As the Seychelles and Faroe Islands studies found contradictory results concerning the neurodevelopmental effect of prenatal exposure to MeHg and considering that the pattern of exposure is similar to the one observed in the Seychelles Islands (stable exposure to mercury over the year with little seasonal patterns, high selenium intake), it is possible that the reassuring negative results from this study could also apply to the French Polynesian community.

Data from a health and nutrition survey conducted in 1995 in French Polynesia reports that the average total tuna and bonito consumption was 8.6 kg (for a total of 44 kg of other fish and shellfish) per year for women.[55] From 2001 to 2004, the Polynesian Government also measured Hg in pelagic fish species for the export market and concentrations for tuna and bonito (*Thunnus alalung, Thunnus albacares*, *Thunnus obesus* and *Katsuwonus pelamis*) were all found to be around 0.3 µg/g.[56] Therefore from a mean blood concentration of 64.6 nmol/L (13.3 µg/L) of Hg measured in this study, we can estimate an average daily intake of approximately 13 µg/day or 4700 µg per year of Hg for pregnant Polynesian women. Considering the Hg content of tuna and bonito, we can estimate that alone they represent around 50% of the yearly intake, tuna being the major source of Hg exposure. The remaining exposure probably originates from other species with a low Hg content that are frequently consumed such as mahi mahi (0.1 µg/g) and lagoon fish (<0.1 µg/g, personal data) and species with high Hg concentrations but infrequently consumed such as swordfish (0.8 µg/g), marlin (1.7 µg/g) and shark (2.2 µg/g).[56] It is possible that even the overall fish consumption is lower in Tahiti compared to other archipelagos; the relative proportion of pelagic fish (tuna) is probably higher since lagoon fish is more consumed in remote islands. That may explain why Tahitian newborns are exposed to comparable Hg levels compared to newborns from remote islands.

Benefits from nutrients

Iodine status is usually based on urine measurements. Blood iodine concentrations found in cord blood samples from French Polynesia suggest that the dietary intake is adequate (i.e. 1.35 µmol/L corresponding to 170 µg/L). The concentrations measured in newborns were higher than blood levels observed in adults from non endemic goitre areas (50-80 µg/L).[57]

The mean blood selenium concentration found in French Polynesian was high (2 µmol/L), but much lower than concentrations found in adult blood observed in the pilot study (mean: 4.7 µmol/L).[40] However, all cord blood Se concentrations in this study were below 560 µg/L (7 µmol/L), a concentration corresponding to the individual daily maximum safe intake suggested by Yang et al. (1989).[58] The mean cord blood Se level in Nunavik Inuit was also reported to be high (3.7 µmol/L)[52] compared to other populations even considering that these measures were performed on serum: 2.6 times higher than in the Faroe Island child cohort[53] and 9 times higher than in Greenlanders.[59] Selenium is usually measured in plasma or serum. However, whole blood determinations are sometimes reported, especially for highly exposed populations. In general populations, a ratio of Se-blood/ Se-plasma is usually 1.1-1.2.[60]

It is less clear why French Polynesian newborns have high concentrations of blood selenium (2 µmol/L or 160 µg/L) compared to the French population, as imported foods come from France, New Zealand, Australia (to our knowledge, no cord blood measures were reported for France). In fact, cord blood concentrations measured in French Polynesia are almost 2 times higher than serum Se concentrations reported among French women (1.09 µmol/L)[61] even considering a whole blood/plasma ratio of 1.2. In comparison, a mean value for serum Se in seven European Union countries was calculated to be 1 µmol/L and the optimum level of serum Se is estimated to be 1.27 µmol/L.[62] For the general North American population, selenium mainly comes from wheat used in bread and cereals and from meat, poultry and fish.[63] The mean selenium intake level in Canada is known to be one of the highest in the world with Japan and Venezuela.[64] In French Polynesia, we hypothesized that a high selenium intake comes from fish consumption as Se was so strongly correlated with mercury and n–3 PUFA. Furthermore, since tropical fish contain Se concentrations around 0.5 µg/g (0.63 on average for tuna),[3] a yearly consumption of 54 kg provides a daily Se intake of 60 µg which could easily explain this high Se body burden. The significance of the protective effect of a high selenium exposure on mercury toxicity might be of great public health importance in French Polynesia. Among other effects, selenium is known to be a preventive factor for prostate cancer.[65] Interestingly, the standardized incidence ratio for prostate cancer between 1988 and 1992 was 0.68 compared to Hawaiians from Hawaii and 0.69 compared to Maoris from New Zealand ($p<0.01$).[66,67]

French Polynesian newborns have relatively high concentrations of omega–3 fatty acids in their red cell membrane phospholipids considering the low fat content of tropical pelagic fishes. In a previous paper[68] we reported that the normal consumption of tropical fish species contributes sufficient quantities of omega–3 fatty acids to meet adequate intakes. In fact, French Polynesians and Inuit have similar PUFA concentrations,[33] but fatty acids profiles differ between these populations. It is interesting to note that the mean EPA concentration was extremely low in this population (0.01%). As previously mentioned, data from the food frequency questionnaire suggest that fresh tuna is the most consumed pelagic fish. Fear of ciguatera poisoning is probably the most important factor that limits lagoon fish consumption in French Polynesia. Tuna oil differs from other fish oils in the ratio of EPA to DHA with a ratio of approximately 1:4 in tuna oil and 1:0.6 in menhaden oil (FDA. 2002). Indeed, while menhaden oil contains respectively 14 and 8% of EPA and DHA, tuna oil contains very little EPA (6%) and much more DHA (26.5%). Also, sources of fat are quite different in tropical pelagic fish compared to cold water fish as fat is located in the gut.[68] These fat deposits make up for the relatively low levels of fat in the flesh of tropical fish. A second phenomenon is that the fat content varies considerably according to seasons. These differences between cold water and tropical pelagic fish could possibly explain the surprising PUFA profile seen among Polynesian newborns compared to the Inuit profile. The high content of DHA in tuna oil may be another important protective factor against the neurotoxic effects of MeHg as DHA is essential for brain and retina function, while EPA is known to be a cardio-protective and anti-inflammatory fatty acid.[69]

CONCLUSION

French Polynesians consume considerable amounts of fish, an important part of their culture. As a result, they are exposed to risks and benefits associated with the presence of a mixture of harmful contaminants and healthy nutrients in consumed fish. These preliminary data suggest that French Polynesian newborns are exposed to high doses of mercury similarly to other fish-eating populations such as those from the Seychelles Islands, Faroe

Islands and the Arctic. We believe that as the pattern of exposure (little seasonal variation, low PCB exposure) and the general dietary pattern are close to that observed in the Seychelles, the absence of effects reported from the Seychelles cohort study concerning neurotoxic effects of MeHg probably applies to the French Polynesian population. Furthermore, taboos against pelagic fish consumption have been reported for pregnant women (pers. com. Ms Hinano Murphy of the *Te pū átitiá* association, Moorea) which may also contribute to the decrease in mercury exposure of pregnant women compared to the general adult population.

In Polynesia, pelagic fish and particularly tuna consumption is probably the major source of Hg exposure, whereas tropical lagoon fish species also provide important nutrients such as fatty acids and selenium. Accordingly, analyses of lagoon and pelagic fish consumed in this population for Hg and Se content as well as for characterization of PUFA profiles are ongoing.

For pregnant women, considering the specific susceptibility of the foetus to mercury toxicity, it would be safe to promote less contaminated fish species. These preliminary results need to be complemented by another ongoing study aiming at measuring contaminants and nutrients in local fish species in order to inform and assist pregnant women in selecting less contaminated fish (mercury and ciguatera) for their daily fish consumption while maintaining the nutritional benefits of fish consumption.

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AUTHOR DISCLOSURES

Eric Dewailly, Édouard Suhas, Yolande Mou, Renée Dallaire, Ludivine Château-Degat and René Chansin, no conflicts of interest.

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Original Article

High fish consumption in French Polynesia and pre-natal exposure to metals and nutrients

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法屬玻里尼西亞魚的高攝取量與胎兒時期的金屬與營養素暴露

法屬玻里尼西亞人攝取高量的魚，因此會暴露到海鮮食物相關的汙染物如汞或鉛，及營養素如碘、硒，及長鏈多元不飽和脂酸。胎兒的發展過程中對於污染物及營養素是敏感的，因此 2005-2006 年在法屬玻理尼西亞做一個橫斷性的研究，去評估胎兒時期經由魚類攝取而暴露到汙染物及營養素的情形。被納入的 241 名產婦均來自於法屬玻里尼西亞群島，且同意回答有關於魚類的攝取，並允許收集臍帶血以供金屬與營養素分析。除了鉛以外，所有的參數都被發現在臍帶血中具有高濃度。汞濃度平均為 64.6 nmol/L (或 13 μg/L)，範圍為 0.25 到 240 nmol/L。在這些樣本中，有 82.5%血液汞的濃度超過 US-EPA 所訂的標準值 5.8 μg/L。鮪魚是魚類中提供汞暴露最多的。高量的硒及長鏈多元不飽和脂酸可能抵銷在法屬玻里尼西亞胎兒暴露到汞的潛在危險性。由於母親攝取高量的魚，玻里尼亞人的新生兒在胎兒時期即暴露到高劑量的汞。雖然硒及 omega–3 脂肪酸可能相抵汞的毒性，但是告知懷孕婦女當地魚種汞及營養素兩者的含量是重要的。

關鍵字：汞、n-3 脂肪酸、碘、硒、鉛、新生兒。