

Mercury in Human Hair and Fish: is there a Hong Kong Male Subfertility Connection?

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Hair is a useful indicator of a person's exposure to mercury. For this reason, hair samples from 94 fertile and 117 subfertile Hong Kong residents were compared over four separate age groups. A typical 30 year old Hong Kong male had a hair mercury concentration of approximately 3.3 mg/kg mercury while a 60 year old Hong Kong subfertile male had a hair mercury concentration of about 7.5 mg/kg. Most of this mercury comes from seafood consumption. Individuals consuming four or more meals of fish per week had a hair mercury of 4.07 mg/kg dry weight of hair while those consuming fish less frequently had significantly lower levels (2.56 mg/kg). Hong Kong residents that consumed no fish had only 1.21 mg/kg hair mercury. The relative risks of males with moderate and high levels of mercury in their hair were significant ($p = 0.062$). Age corrected estimates of risk indicated that compared with men with low levels of mercury in their hair, men with higher levels were twice as likely to be subfertile (relative risk, 1.95) and there was a dose-response trend that was highly significant ($p < 0.0005$). In light of these risks we concluded that the maximum permitted mercury level in food sold in Hong Kong should be lowered from 0.5 mg/kg wet weight to a level to be determined by risk analysis. In Japan, where fish mercury levels and fish consumption rates are lower than those in Hong Kong, the maximum amount of mercury permitted in food for human consumption is 0.3 mg/kg wet weight. © 1999 Elsevier Science Ltd. All rights reserved.

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For many years now, it has been recognized that most animals are able to regulate the amount of heavy metals in their body by excreting these metals when their concentrations exceed the needs of the organism (Underwood, 1997). However, there is an upper limit to the rate that each metal can be excreted and when the amount of a heavy metal consumed exceeds its excretion rate, the metal accumulates in the organisms' body (Bryan, 1976). The present study examined the levels of mercury in Hong Kong residents of varying age to determine if mercury accumulated to higher concentrations in older individuals.

The purpose of the present study was to examine the relationship between human male fertility and mercury in seafood. We examined 200 people, 117 Hong Kong subfertile males, 67 fertile males and females and 45 fertile vegetarians of both sexes. The vegetarians had eaten no fish, shellfish or other meat during the last 5 or more years. We also examined mercury levels in Hong Kong store-bought fish and in fish that we captured in Hong Kong waters in order to answer the following questions:

1. Do Hong Kong residents accumulate mercury at a rate faster than they can excrete it?
2. Is there any evidence to suggest that individuals with high concentrations of mercury in their hair might be at risk?

Methods

About 5 g dry wt of hair from individuals who did not use hair dyes or shampoos containing heavy metals was collected from 117 subfertile males between the ages of 24 and 72. In addition, 67 fertile males and females between the ages of 24 and 75 as well as 45 vegetarians between the ages of 26 and 61 were sampled. Each hair sample was washed to remove any adsorbed or external contaminants and then dissolved in high purity grade

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TABLE 1
Mean mercury level (mg/kg) in the hair of fertile and subfertile males.

Age	Fertile (<i>n</i> = 94)	Subfertile (<i>n</i> = 117)	<i>t</i> -test (<i>p</i> -value)
17–29	2.445 (4)	3.128 (4)	0.626
30–39	3.462 (37)	3.867 (86)	0.320
40–49	2.985 (6)	5.313 (24)	0.268
50–72	3.762 (2)	7.563 (3)	0.417
All	3.3329	4.2332	0.057*

* *p*-value adjusted for exact age by ANOVA (*F* test value = 0.062).

nitric acid. Samples were analysed for mercury using an ICP operated by Doctor's Data (170 W. Roosevelt Rd., West Chicago, IL, 60185 USA). All glasswares were acid washed after first soaking in Alconox solution for 24 h. After acid washing, the glassware was rinsed in three separate washes of deionized water. The hair was left in the acid at 80°C until the solution was clear and all the hair was in solution using standard microwave digestion procedures (Tyler, 1993). The ICP-MS detection limits for most of the 29 elements were in the parts per trillion range. The mercury analyses are the only ones reported here as only mercury was correlated with subfertility.

Male subfertility criteria

Two semen analyses were taken two weeks apart for each patient. Semen analyses by Computer-assisted Semen Analysis (Cellsoft CASA) included sperm count, morphology, motility, velocity and linearity. Abnormal seminal parameters were defined by WHO as having a semen volume < 2 ml, sperm count < 20 million/ml, sperm motility < 50% and normal sperm morphology < 30%. Azoospermic patients were excluded as they are infertile rather than subfertile and many of them have etiologies distinct from subfertile men.

Because vegetarians and subfertile males were relatively rare, the authors asked for volunteers from the Hong Kong Vegetarian Society and from the In vitro-fertilization Clinic in Hong Kong. The mean age of the 230 volunteers was about 40 years. Volunteers were asked a series of standard questions such as fish preferences and fish and shellfish consumption frequency, number of cigarettes smoked per day, number of tooth amalgam fillings, intake of Chinese herbal remedies (some contain mercury), types of perms and hair colouring agents used (if any). If an individual's hair was artificially coloured or permed, it was not used in this study as some hair dyes and perm lotions contain heavy metals that do not wash out. Volunteers also answered questions about how long they had lived in Hong Kong. We selected those who had lived in Hong Kong for a minimum of 5 years (most participants had lived in Hong Kong for 15 years or more).

Results

Hair samples from 94 fertile and 117 subfertile males were compared for four separate age groups (Table 1).

TABLE 2
Mercury in the hair of 16 Hong Kong vegetarians.

	No.	Mean Hg	s.d.	Stand. error
Hong Kong vegetarians	45	1.21	0.49	0.115

Hair from 45 vegetarians ages 22–61 years of age was sampled and analysed (Table 2).

Discussion

Most of our body's retained mercury comes from the consumption of fish and shellfish (Harriss and Hohenemser, 1978; WHO, 1990; Clarkson, 1992) and relatively little comes from dental amalgams, shampoos, hair dyes, herbal medicines, the water we drink, the food that we eat (other than sea food) and/or the air that we breathe (Camner *et al.*, 1979). Clarkson concluded that sea food consumption was the main cause of mercury accumulation in humans and suggested that mercury intake in humans could be controlled by limiting the intake of mercury contaminated fish and shellfish (Clarkson, 1992).

Consumption studies

Although few consumption studies have been carried out in Hong Kong (Shaw, 1995), it would appear from our limited questionnaire (*n* = 230) that Hong Kong Asians consume fish about three to four times per week, while in Finland and Europe (Salonen *et al.*, 1995), fish consumption frequencies are much lower. According to the Hong Kong Government's Annual Report for 1997 (Tables 3 and 4) about 800 tonnes of fish are consumed each day by the 6.5 million people living in Hong Kong (Howlett, 1997).

Forty seven percent of this 191,750 tonnes (Tables 3 and 4) was exported from Hong Kong to mainland China and other countries. In 1996, the total catch of marine fish available for local consumption was 84,180 tonnes. An additional 150,312 tonnes of fish were imported into Hong Kong for local consumption for a total of about 234,500 tonnes (Howlett, 1997). Assuming, that approximately 90% of this was actually consumed, the rest being scales, bones etc or loss to spoilage, then 210,050 tonnes of fresh fish were con-

TABLE 3
Hong Kong Government's annual report for 1997 (Howlett, 1997).

Metric tonnes of fish imported into Hong Kong	1994	1995	1996
Fresh fish, chilled fish and frozen fish (fw + marine)	174,971	157,150	150,312
Freshwater species only	—	—	43,670
Dried fish, smoked and salted fish	14,386	17,582	17,023
Crustaceans and molluscs (fresh, frozen, salted and dried)	110,415	111,586	104,468
Fish products and preparations	8796	8116	8929
Crustacean and mollusc products and preparations	6109	4776	5585
Oil and fats (crude and refined)	746	1813	3700
Fish meals used as animal feeds	12,871	13,372	15,061

TABLE 4
Hong Kong Government's annual report for 1997 (Howlett, 1997).

Metric tonnes of fish captured by Hong Kong vessels	1994	1995	1996
Marine fresh fish, chilled fish and frozen fish	157,750	154,800	147,600
Freshwater fish (fresh), chilled and frozen	5500	5250	5100
Marine dried fish, smoked and salted fish	220	280	490
Crustaceans and molluscs (fresh, frozen, salted and dried)	26,720	22,290	21,940
Fish products and preparations	400	250	100
Crustacean and mollusc products and preparations	210	70	140
Fish meals used as animal feeds	25,710	16,330	16,380
Total for 1996			191,750

sumed in 1996 by approximately 6.2 million people = 34 kg of fresh fish per person during the year. According to the Consumer Asia Report, 58 kg of seafood are consumed per capita each year in Hong Kong. Thus, about 24 kg of dry fish, smoked fish, salted fish and dry or fresh prawns, shrimp, crabs, bivalves, jelly fish, sea cucumbers, sea urchins, and lobsters were consumed per person in 1995 in Hong Kong (Consumer Asia, 1997). Based on the Consumer Asia study, Hong Kong ranks third in total seafood consumption out of eight countries surveyed (Fig. 1).

Hair mercury

Human blood gives no indication of the cumulative levels of heavy metals (Underwood, 1997; Houtman, 1978). Petering *et al.* (1973) concluded that blood samples were inappropriate for trace element studies where

cumulative effects were critical. Unlike blood, hair is an inert and chemically homogenous substance. It consists of a fibrous alpha keratin protein set in a matrix containing slightly higher levels of cystein (Petering *et al.*, 1973). The structure of the hair is permanent and once a heavy metal atom is incorporated into it, the atom is permanently fixed there (Laker, 1982). As a result, hair provides a better assessment of normal trace element concentrations than does blood because short-term variations are averaged out.

The levels of mercury in the hair of Hong Kong residents was considerably higher than hair from residents of Finland, Europe or the United States (Fig. 2). The average concentration of mercury in the hair of the 67 fertile, non-vegetarians tested from Hong Kong was 3.3 mg/kg while in Finland it was 2.1 mg/kg and in Europe, where people generally eat fish less frequently than they

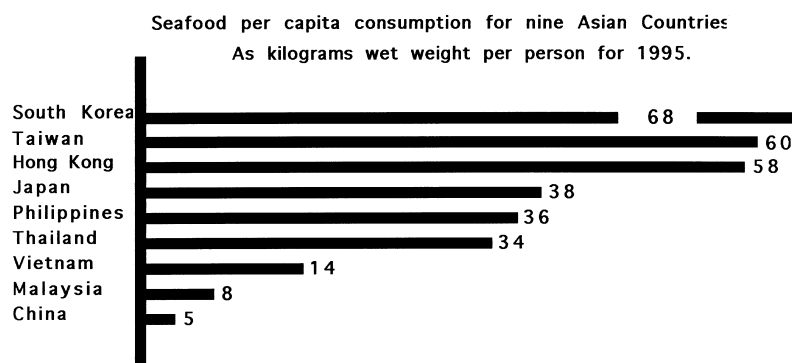


Fig. 1 Seafood consumption in kg per person in 1995 for nine Asian countries (Consumer Asia, 1997 and Japanese Dept. of Fisheries).

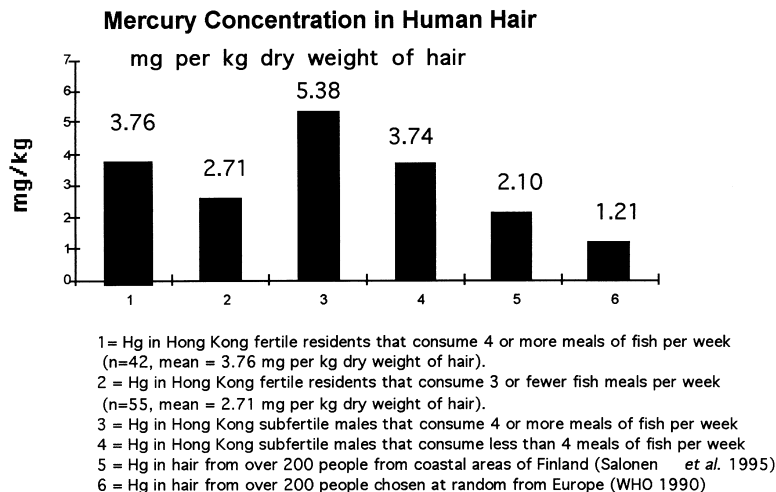


Fig. 2 Mercury concentrations in the hair of European, Scandinavian and Hong Kong residents. Vertical bars represent 1 standard deviation about the mean.

do in Finland or Hong Kong, the level of hair mercury was only 1.2 mg/kg (Fig. 2).

Age related mercury accumulation

The youngest person in our study was 24 and the oldest was 75 years of age. The relationship between mercury concentration in human hair and age was statistically significant. Hair mercury concentrations in fertile males increased with age. When age was regressed against fertile male hair mercury, the slope of the regression line was 0.67. Fertile females had the lowest levels of mercury in their hair and the lowest rate of mercury accumulation as a function of age (slope = 0.60). The reverse was true for subfertile males (slope = 1.2).

Hair mercury as a function of rates of fish consumption

In both 1996 and 1997 over ten medical doctors from Hong Kong met to discuss symptoms displayed by their patients with elevated levels of hair mercury. Dr Kam, a dental surgeon, described dental foci and chronic musculo-skeletal pain for several of his patients with elevated hair mercury levels. Dr. Yeung, a Hong Kong orthopedic surgeon, recounted numerous instances of chronic pain associated with mercury toxicity in his patients with elevated hair mercury concentrations (Yeung, 1997) and Dr. Lai, a Hong Kong psychiatrist attributed a number of symptoms displayed by his patients to their elevated levels of hair mercury. Thus it would appear that in addition to a correlation between subfertility and elevated levels of hair mercury, there is evidence from psychiatrists, orthopedic surgeons and dental surgeons to corroborate our observations that chronic mercury intoxication is associated with elevated levels of hair mercury in Hong Kong residents (Lai, 1997; Leung, 1997; Kam, 1997; Yeung, 1997).

Long-term chronic responses to the frequent consumption of mercury tainted fish

Studies in Canada, Iraq and Japan have concentrated on relatively short-term (0.01–10 years) periods of ingestion of mercury-laden rice, fish and/or shellfish while studies reported here are concerned with longer term (25–75 years) consumption patterns of fish contaminated with low levels of mercury. The youngest person studied was 24 years and the oldest was 75 years of age. The shorter term studies (0–10 years) concluded that some adults with hair mercury levels of 50 mg/kg body weight displayed symptoms of mercury poisoning (Boichio et al., 1995). In Hong Kong, some males with only 5 mg/kg hair mercury displayed signs of subfertility.

In Japan, as in Hong Kong, fish meals are commonly taken three or more days per week (Shaw, 1995). The Japanese Government recommends that fish with mercury concentrations of 0.3 mg/kg or more should not be sold for human consumption. In Hong Kong, the World Health Organization (WHO) guideline which allows fish with 0.5 mg Hg/kg wet weight to be sold for human consumption.

Conclusions

Mercury levels were significantly higher in Hong Kong males than in Hong Kong females and increased with age (ages 25–72). Individuals that ate fish or shellfish more than four times per week had significantly higher mercury concentrations in their hair than those who ate fish and shellfish less frequently. Hong Kong vegetarians who consumed no seafood for the last five or more years had the lowest levels of mercury in their hair (1.21 versus 3.33 mg/kg hair for Hong Kong non-vegetarians).

The relative risks of males with moderate and high levels of mercury in their hair were significant ($p < 0.05$). Age corrected estimates of risk indicated that

compared with men with low levels of mercury in their hair, men with higher levels were twice as likely to be subfertile (relative risk, 1.95). In light of these risks we concluded that the maximum permitted mercury level in food sold in Hong Kong should be lowered from 0.5 mg/kg wet weight to a level to be determined by risk analysis. It is likely that a value approaching the 0.3 mg/kg wet weight level adopted in Japan would be appropriate for Hong Kong.

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