

Medical and psychometric examinations of conscripts born to mothers with a high intake of fish contaminated with persistent organochlorines

by Lars Rylander, DrMed Sc,¹ Lars Hagmar, MD¹

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Objectives The present study aimed to investigate whether boys who had been pre- and postnatally exposed to persistent organochlorine compounds through the consumption of contaminated fatty fish from the Baltic Sea (on the east coast of Sweden) had medical or psychometric impairments in the compulsory conscript examination at 18 years of age.

Methods Boys born in 1973 to 1975 to fishermen's wives and fishermen's sisters from the Swedish east coast were examined at 18 years of age. For relevant comparisons a corresponding group from the Swedish west coast, where the fish are less contaminated, were used. In addition, comparisons were made with expected values based on conscript examination data for the general population in the same geographic areas.

Results The boys in the 2 cohorts did not, during the conscript testing, significantly differ in the results of the psychometric tests. On the other hand, the boys from the eastcoast cohort were somewhat shorter and had more visual and hearing impairments than the boys from the west coast. However, the eastcoast boys did not differ from the regional reference population with respect to visual and hearing ability.

Conclusions Although no individual exposure data were available, the present results do not support any harmful long-term impact of pre- and postnatal exposure to persistent organochlorine compounds from mothers' fish consumption on the psychometric functions of boys in their conscript examinations.

Key terms polychlorinated biphenyls, polychlorinated dibenzofurans, polychlorinated dibenzo-p-dioxins.

In Sweden, the main exposure route for persistent organochlorine compounds, such as polychlorinated biphenyls (PCB) and polychlorinated dibenzo-p-dioxins and dibenzofurans, is through the consumption of fatty fish from the Baltic Sea (1–3). Swedish fishermen have been shown to eat almost twice as much fish as men from the general Swedish population (2). This difference was reflected by at least 2 times higher concentrations of persistent organochlorine compounds in plasma among east-coast fishermen as compared with fishermen from the Swedish west coast, where the fish are less contaminated (4). The concentration of persistent organochlorine compounds in plasma among westcoast fishermen was, however, approximately the same as among men from the local general population. The general populations on the Swedish east and west coasts had very similar concentrations of persistent organochlorine compounds in plasma.

Accidental exposure to extremely high levels of persistent organochlorine compounds for women through the consumption of contaminated rice oil (Yusho and Yucheng) have caused long-standing developmental disturbances in children (5). Substantially lower exposure to persistent organochlorine compounds has also been associated with reduced birthweight and negative effects on neonatal behavioral performance tests (6–17). Prenatal exposure to PCB from contaminated fish from Lake Michigan also seems to have a negative long-term impact on intellectual functions (18). The most highly prenatally exposed children were, at 11 years of age, about 3 times as likely to have low average intelligence scores and about 2 times as likely to be at least 2 years behind in reading comprehension, than less-exposed children. Whether pre- and postnatal dietary exposure to persistent organochlorine compounds may cause even more prolonged long-term effects is, however, unknown.

¹ Department of Occupational and Environmental Medicine, Institute of Laboratory Medicine, University Hospital, Lund, Sweden.

Reprint requests to: Dr Lars Rylander, Department of Occupational and Environmental Medicine, Institute of Laboratory Medicine, University Hospital, SE-221 85 Lund, Sweden. [E-mail: lars.rylander@ymed.lu.se]

Moreover, animal data show harmful effects of PCB exposure on hearing ability (19–21), but no such effects have been reported for humans.

It is known that the wives and sisters of Swedish fishermen eat more fish than women from the general population (14, 17, 22). Moreover, fishermen's wives from the Swedish east coast (on the Baltic Sea) have been shown to have an average of about 30% higher PCB levels in plasma than women from the general population (23, 24). Accordingly, infants born to fishermen's wives and fishermen's sisters from the Swedish east coast were considered as a suitable pre- and postnatally exposed group for the study of long-term effects. The present study aimed to investigate whether boys from this eastcoast group had increased risks for growth retardation, vision defects, or hearing disability or low psychometric scores at the time of the compulsory conscript examination at 18 years of age. For relevant comparisons, we used a similar cohort of boys from fishermen's families from the Swedish west coast, where the contamination of the fish has been considerably lower (4). In addition, comparisons were made with expected values based on conscript examination data for the general population in the same geographic areas during the corresponding calendar-year period.

Table 1. Live-born boys (1973 to 1975) of the east- and westcoast cohorts and those of them with data from the Military Service Enrolment Register (MSER) during the period 1991 to 1994. The number of conscripts with a low birthweight, being small for gestational age, or with major malformation are given.

	West coast		East coast	
	N	%	N	%
Born 1973–1975	556		287	
Conscripts 1991–1994	510	91.7	268	93.4
Birth weight				
< 2500 g	13	2.5	8	3.0
< 3000 g	45	8.8	35	13.1
Small for gestational age	12	2.4	9	3.4
Major malformation	7	1.4	6	2.2

Subjects and methods

Cohorts

Cohorts of fishermen's wives and fishermen's sisters from the Swedish east and west coasts have previously been established (14, 17). By linkage to the Swedish Medical Birth Register infants born to these women from 1973 and onwards were identified. The register includes almost every infant born in Sweden since 1973, and it is based on copies of record forms for maternity health care, deliveries, and pediatric examinations of newborn (25). During the period 1973 to 1975, 287 boys were born live in the eastcoast cohort (table 1). The corresponding figure for the westcoast cohort was 556 boys. By linkage to the Military Service Enrolment Register (MSER), data from the conscript examinations in 1991 to 1994 were obtained for 268 (93.4%) of the eastcoast boys and 510 (91.7%) of the westcoast boys. A somewhat larger fraction of the boys in the eastcoast cohort than in the westcoast cohort had had a birthweight of less than 3000 grams (13.1% versus 8.8%).

Outcome variables

The Military Service Enrolment Register includes data from both the medical and psychometric examinations of conscripts. In our study the following outcome variables were studied: body height, bodyweight, and body mass index (BMI, kg/m²). In addition the vision accuracy, scored on a scale from 1 to 9, where 9 is full vision (1.0) of both eyes was included, along with color vision, presented as a dichotomized variable (any defect versus no defect). Hearing ability, classified into 5 categories, defined in table 2, was also included, as was psychometric function. Psychometric function comprised 2 variables, measuring the ability to act under pressure and general intelligence (26); these variables were classified into 9 categories, where 9 was optimal ability.

For the different outcome variables the fraction of missing values varied between 4% and 7%, and there were no obvious differences between the cohorts.

Table 2. Hearing ability of the east- and westcoast cohorts. The expected distributions (%) based on data for the regional reference populations are also given.

	West coast			East coast		
	N ^a	%	Expected ^b	N ^a	%	Expected ^c
Average hearing loss in better ear at 500, 1000, and 2000 Hz between 40–60 dB	0	0	0	0	0	0
Average hearing loss in better ear at 500, 1000, and 2000 Hz between 20–40 dB	8	1.7	1.2	3	1.2	1.4
Hears 20 dB at 500, 1000, and 2000 Hz in best ear and loss of 20–40 dB in worse ear	6	1.2	1.4	6	2.3	1.5
Hears 20 dB at 500, 1000, 2000, and 3000 Hz with both ears	41	8.5	9.1	36	14.0	13.1
Hears 20 dB at 500, 1000, 2000, 3000, 4000, and 6000 Hz with both ears	429	88.6	88.3	213	82.6	83.9

^a Direct comparison between the eastcoast- and westcoast-cohort distributions ($P=0.02$).

^b Comparison between the observed and expected distributions of the westcoast cohort ($P>0.2$).

^c Comparison between the observed and expected distributions of the eastcoast cohort ($P>0.2$).

Statistics

The observed distributions were compared with the expected distributions, which were based on data from the Military Service Enrolment Register for the regional reference populations (ie, all boys from the Swedish east- and westcoast counties). The results for the dichotomized outcome variables are presented as the ratio between the observed (O) and expected (E) numbers with the 95% confidence interval (95% CI) calculated by treating the observed number as a Poisson variable. Moreover, direct comparisons were performed between the east- and westcoast cohorts. The results for the dichotomized variables were then presented as odds ratios (OR) with their confidence intervals. For the statistical testing we used a t-test for the continuous variables and the Mann-Whitney test for the ordinal data. All the tests were 2-tailed.

Results

Body height, bodyweight and body mass index

At the conscript examination, the boys in the eastcoast cohort were somewhat shorter than the boys in the westcoast cohort (means 178.8 and 180.1 cm, respectively, $P=0.01$) (table 3), whereas no significant differences were found between the cohorts regarding bodyweight or BMI. The boys in the eastcoast cohort had an increased BMI when compared with that of their regional reference population (22.6 kg/m² and 22.1 kg/m², respectively, $P=0.04$), which was mainly explained by the fact that the eastcoast cohort tended to be somewhat shorter (178.8 and 179.5 cm, respectively, $P=0.08$). The boys in the westcoast cohort had an increased BMI as compared with that of their regional reference population (22.6 kg/m² and 22.0 kg/m², respectively, $P<0.001$). The reason for this difference was that the westcoast cohort was heavier than the regional reference population (73.4 kg and 71.4 kg, respectively, $P<0.001$).

Vision

The vision tests showed lower scores for visual accuracy for the eastcoast cohort ($P=0.04$) (table 4) than for the westcoast cohort. The odds ratio for the vision scores below 7, where corrective lenses are needed, was 1.4 (95% CI 0.9–2.0). Moreover, more boys in the east than in the west had impaired color vision (OR 1.6, 95% CI 0.9–2.7). When comparisons were made with the regional reference populations, an increased number of boys on the west coast had full vision ($P=0.003$), while no difference in vision ability was seen for the eastcoast cohort, when they were compared with their reference population.

Hearing

Table 2 shows the results of the hearing tests. Some hearing loss was found in 17.4% of the eastcoast cohort as compared with 11.4% of the westcoast cohort, corresponding to an odds ratio of 1.6 (95% CI 1.0–2.6). However, none of the cohorts differed from their regional reference population with respect to hearing.

Psychometric scoring

There were no significant differences between the cohorts regarding the psychometric scores ($P=0.09$ and $P>0.2$).

Table 3. Body height, bodyweight, and body mass index (BMI) at the time of the conscript examination of the east- and westcoast cohorts. The expected values (mean) based on data for the regional reference populations are also given.

	West coast			East coast		
	Mean ^a	SD	Expected ^b	Mean ^a	SD	Expected ^c
Height (cm)	180.1	6.6	180	178.8	6.2	179.5
Weight (kg)	73.4	11.7	71.4	72.2	13.0	71.2
BMI (kg/m ²)	22.6	3.2	22	22.6	3.8	22.1

^a Direct comparisons between the east- and westcoast cohorts: height $P=0.01$, weight $P=0.2$, BMI $P>0.2$.

^b Comparisons between the observed and the expected distributions of the westcoast cohort: height $P>0.2$, weight $P<0.001$, BMI $P<0.001$.

^c Comparisons between the observed and expected distributions of the eastcoast cohort: height $P=0.08$, weight $P>0.2$, BMI $P=0.04$.

Table 4. Visual accuracy and color vision of the east- and westcoast cohorts. The expected distributions (%) based on data for the regional reference populations are also given. (OR = odds ratio, 95% CI = 95% confidence interval)

	West coast			East coast		
	N	%	Expected	N	%	Expected
Visual accuracy ^{a, b, c}						
1	-	0	0	1	0.4	0
2	-	0	0	-	0	0
3	1	0.2	0.1	-	0	0.1
4	3	0.6	0.6	3	1.2	0.5
5	7	1.4	1.2	5	1.9	1.2
6	70	14.4	22.4	47	18.1	23.1
7	32	6.6	7.3	27	10.4	7.8
8	30	6.2	6.6	11	4.2	4.4
9	342	70.5	61.8	165	63.7	62.8
Color vision ^{d, e, f}						
Any defect	35	7.2	6.5	28	10.9	7.7
No defect	450	92.8	93.5	230	89.1	92.3

^a Direct comparison between the eastcoast- and westcoast-cohort distributions: $P=0.04$.

^b Comparisons between the observed and the expected distributions for the westcoast cohort: $P=0.003$.

^c Comparisons between the observed and the expected distributions for the eastcoast cohort: $P>0.2$.

^d Any defect in the eastcoast cohort as compared with the defects in the westcoast cohort: OR 1.6, 95% CI 0.9–2.7.

^e Number of boys with any defect in the westcoast cohort (O) as compared with the expected number (E): O/E 1.1, 95% CI 0.8–1.5.

^f Number of boys with any defect in the eastcoast cohort (O) as compared with the expected number (E): O/E 1.4, 95% CI 0.9–2.0.

Table 5. Results of the psychometric tests of the east- and westcoast cohorts. The expected distributions (%) based on data for the regional reference populations are also given.

Score	West coast			East coast		
	N ^a	%	Expected ^b	N ^a	%	Expected ^c
Ability to act under pressure						
1 — low	16	3.4	1.7	5	2.0	2.4
2	33	7.0	7.0	19	7.6	6.2
3	57	12.0	11.6	33	13.1	10.7
4	103	21.7	20.6	48	19.1	15.2
5	109	23.0	21.4	45	17.9	21.6
6	91	19.2	19.8	46	18.3	18.8
7	44	9.3	13.1	27	10.8	16.5
8	20	4.2	4.1	24	9.6	6.9
9 — high	1	0.2	0.7	4	1.6	1.7
General intelligence						
1 — low	14	2.9	2.8	11	4.3	2.9
2	60	12.3	6.9	24	9.3	7.5
3	71	14.6	11.0	53	20.5	10.9
4	87	17.9	15.4	39	15.1	15.6
5	126	25.9	24.6	63	24.4	23.9
6	62	12.8	16.7	31	12.0	16.4
7	38	7.8	12.1	18	7.0	11.9
8	22	4.5	6.7	10	3.9	7.1
9 — high	6	1.2	3.8	9	3.5	3.9

^a Direct comparison between the eastcoast- and westcoast-cohort distributions: ability to act under pressure $P=0.09$, general intelligence $P>0.2$.

^b Comparison between the observed and expected distributions of the westcoast cohort: ability to act under pressure $P=0.11$, general intelligence $P<0.001$.

^c Comparison between the observed and expected distributions of the eastcoast cohort: ability to act under pressure $P>0.2$, general intelligence $P<0.001$.

(table 5). Neither cohort differed from its regional reference population regarding the ability to act under pressure, whereas both cohorts had a decreased fraction of boys with high general intelligence.

Discussion

The main finding of the present study was that the boys in the east- and westcoast cohorts did not, at the time of the conscript testing, significantly differ in the psychometric tests. However, both cohorts included a decreased fraction of boys with high general intelligence. A reasonable explanation for this finding may be differences in parental educational level or other socioeconomic factors, as compared with the parental educational level of the general population. This possibility underlines the importance of supplementing general population comparisons with a socioeconomically more comparable group.

In the Lake Michigan area, prenatal exposure to persistent organochlorine compounds through contaminated fish have been associated with a negative long-term impact on intellectual function, at least until 11 years of age (18). But, to our knowledge, infants exposed prenatally to persistent organochlorine compounds through fish consumption have not been followed for any longer

periods. In Sweden, the conscript examination is compulsory for all 18-year-old boys. Moreover, the Medical Birth Register covers almost all newborns (27). This situation, taken together with the unique personal identification code assigned to all individuals in Sweden, makes long-term follow-up studies, as the present one, possible. Data in the Military Service Enrolment Register was obtained for 91.7% and 93.4% of the live-born west- and eastcoast cohorts, respectively. These figures are in agreement with those from previous studies on the general Swedish population (27, 28). We therefore do not believe that selection bias is an issue of concern.

Unfortunately no individual exposure data were available in the present study. There is, however, circumstantial evidence that some of the boys in the eastcoast cohort had not only been substantially exposed to persistent organochlorine compounds prenatally, but also postnatally through breast feeding. The concentrations of persistent organochlorine compounds in fatty fish from the Baltic Sea are higher than in fatty fish caught on the Swedish west coast (4). Consequently, fishermen from the Swedish east coast have been found to have at least twice the plasma concentrations of these pollutants as compared with westcoast fishermen (2). In addition, it is known that both the wives and sisters of Swedish fishermen have a relatively high intake of locally caught fish (14, 17) and that in the 1970s, when the boys in the present study were born, the fish from the Baltic Sea contained much higher concentrations of persistent organochlorine compounds than today (29).

Validity controls have shown that the birthweight information in the Medical Birth Register is good (25). Even after adjustment for potential confounders, such as parity, maternal age, gender, and smoking habits, fishermen's wives and sisters from the Swedish east coast have been shown to have an increased risk of having an infant with a low birthweight (14, 17). In addition, a nested case-referent study within the cohort of eastcoast fishermen's wives indicated an increased risk of low birthweight for infants born to mothers who reported a relatively high current intake of fish from the Baltic Sea, as well as for infants born to mothers with a relatively high concentration of 2,2',4,4',5,5'-hexachlorobiphenyl (CB-153) in plasma (15, 16). Thus we had clear indications that dietary exposure to persistent organochlorine compounds had contributed to slight intrauterine growth retardation among highly exposed infants. This finding justifies the present evaluation of persistent long-term effects.

Although, in our study, height at 18 years of age differed significantly between the cohorts, the absolute difference must be considered to be of little consequence. The boys in the eastcoast cohort showed impaired visual accuracy as compared with those in the westcoast cohort, whereas no difference was observed when the compari-

son was made with the regional reference population. The reason for a larger fraction of boys in the westcoast cohort with full vision as compared with the regional reference population is unknown. Developmental exposure of rats to PCB has caused hearing loss (19–21), but no such effects have been reported in human studies. In our study, the eastcoast cohort did not differ in hearing ability as compared with their regional reference population. An unexpected finding was that the background distributions for the hearing test differed between the coastal areas, the westcoast population having a larger fraction of boys with full hearing. The reason for this finding is not known. The test instruments used at the different conscript examination centers are calibrated yearly (Gunnel Sandegård, personal communication), and therefore the risk for systematic differences in diagnostic accuracy between the 2 coastal areas was minimal.

To sum up, the present results do not support any negative long-term impact of prenatal or postnatal exposure to persistent organochlorine compounds from mothers' fish consumption on the psychometric function of boys at 18 years of age. A caveat is of course that the lack of individual exposure data may have resulted in an exposure misclassification that diluted a true risk increase for those most highly exposed.

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