Birthweight in a fishing community: significance of essential fatty acids and marine food contaminants

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Abstract

Background Marine food provides essential fatty acids that are important during pregnancy, but the benefits may be limited at high intakes and by seafood contaminants.

Methods In the fishing community of the Faroe Islands, 182 pregnant women with spontaneous singleton births were consecutively recruited for a cohort in 1994-1995. Concentrations of fatty acids and seafood contaminants in blood samples were analyzed as predictors of gestational length and birth weight.

Results Serum concentrations of eicosapentaenoic acid (EPA) increased with maternal marine food intake, while the tendency was less clear for docosahexaenoic acid (DHA). An increase in the relative concentration of DHA in cord serum phospholipids by 1% was associated with an increased duration of gestation by 1.5 days (95% CI: 0.7-2.2). However, birth weight adjusted for gestational length decreased by 246 g (95% CI: 16-476) for each increase by 1% of the EPA concentration in cord serum. Concentrations of the seafood pollutants mercury and polychlorinated biphenyls (PCBs) were associated with fatty acids levels, but the contaminants did not appear to affect any of the outcome parameters.

Conclusion An increased intake of marine fats appears to prolong the duration of gestation, but birth weight adjusted for gestational age may decrease at high intake levels. This effect does not seem to be due to increased exposures to seafood contaminants.

Keywords Birth weight eicosapentaenoic acid diet docosahexaenoic acid fish oil gestational age n-3 polyunsaturated fatty acids pregnancy

Key messages

- An epidemiological study in a fishing community confirms that a high intake of essential fatty acids from seafood is associated with a longer duration of pregnancy
- However, increased cord-serum concentrations of eicosapentaenoic acid, a main component of fish oil, are associated with a decreased birth weight adjusted for gestational age
- This association is apparently not due to adverse effects of seafood contaminants, such as mercury and polychlorinated biphenyls
- While beneficial effects of fish oil on pregnancy outcome have been documented at low intake levels, they do not extend into the high-intake range

Introduction

Seafood contains n-3 polyunsaturated fatty acids (PUFAs), mainly eicosapentaenoic acid (EPA, 20:5n-3) and docosahexaenoic acid (DHA, 22:6n-3),[1,2] that have important functions during gestation. Thus, a randomized controlled trial using a small daily supplement of 2.7 g fish oil during pregnancy showed prolonged gestation and increased birth weight.[3] In the fishing community of the Faroe Islands, a similar overall tendency was also observed, but birth weight and placenta weight decreased at the highest frequencies of seafood dinners.[4] The latter observation is supported by experimental evidence in rats where high doses of fish oil caused a decreased birth weight despite an increased gestational length.[5,6] Seafood and fish oil may also contain toxic contaminants, including polychlorinated biphenyls (PCBs),[7] that have been associated with decreased birth weight[8-10] and decreased birth length in boys,[11] although no effect was encountered in other studies.[12,13] Methylmercury, another seafood contaminant, has been linked with lower birth weights in Greenland populations,[14] while Cree Indian[15] and Faroese[16] birth weights showed an increase at higher maternal exposures to mercury.

The health implications of a maternal seafood diet during pregnancy are likely to represent a balance between beneficial effects of essential nutrients and adverse effects caused by toxicants or by possible oversupplies of nutrients.[17] However, studies of essential fatty acids did not consider the potential toxicity due to contaminants, and vice versa. Thus, current evidence does not allow an evaluation of the relative importance of and possible interactions between these seafood components.

We have therefore examined these issues in a birth cohort from the Faroe Islands, a community of 42 000 inhabitants located between Shetland and Iceland. In addition to large-scale fishing, the Faroese conduct occasional subsistence whaling which provides pilot whale meat and blubber for local distribution. In this homogeneous community, dietary habits depend on local availability and personal preferences, rather than socioeconomic factors. A questionnaire study of Faroese adults showed an average daily consumption of 72 g fish, 12 g whale muscle and 7 g of blubber, with fish and pilot whale meat constituting 44% and 9.5% of dinner meals, respectively.[18] While the concentration of essential fatty acids may be lower in whale blubber than in fish oil, PCB concentrations in blubber average up to 30 μg/g.[19] The lean whale muscle contains mercury concentrations at about 2 μg/g.[20] Fish is an important dietary source also of selenium[1] which may offer some protection against mercury toxicity.[17] Given the occurrence of high exposures to both beneficial and potentially toxic components of marine food, this population would seem useful to examine the implications of seafood diet for pregnancy outcome.

Subjects and Methods

Study Population

A cohort of 182 singleton term births was generated from consecutive spontaneous births during a 12-month period in 1994-1995 at the National Hospital in Tórshavn.[21] To obtain the widest possible range of contaminant exposures, the cohort was based on the primary catchment area away from the capital area of Tórshavn, i.e. the central and northwestern villages where access to fish and whale is the easiest. This cohort represents 64% of the 293 births occurring during this period; only few women did not consent to participate, and incomplete sampling was mainly due to surgical intervention or logistic problems in the busy ward. In addition, four children were excluded because of birth before the 36th week of gestation, and two children because they had congenital neurological disease. Low birth weight was not used as an exclusion criterion, but none was below 2500 g. Taking into account the exclusions, the overall participation rate is only slightly below the one obtained in a previous Faroese cohort.[16]

Obstetric and nutritional data

Relevant obstetric data were obtained by standardized procedures. Estimated gestational length took into account day of last menstruation, ultrasound examination conducted approximately at week 22 of pregnancy, and clinical impression; disagreements were resolved by the Dubowitz score.[22] Birth weight and placental weight were measured by the midwife. Two weeks after parturition, a brief nutrition questionnaire comparable to the previous study[4,23] was administered to all mothers to record frequencies of main meals with fish (number per week), whale meat, and whale blubber (both as number per month) during pregnancy (Table 1). Information on fish species or portion sizes was not obtained.

Blood analyses

Maternal serum was obtained from 175 of the women in connection with the last antenatal consultation at week 34. Blood from the umbilical cord was taken by the midwife in heparinized syringes with teflon-lined pistons; whole-blood and serum for analysis were available from 163 and 179 births.

Both maternal serum and cord serum were analyzed for phospholipid fatty acids.[24,25] A human control serum stored at -80^{o}C was used to monitor analytical performance, and day to day precision for each fatty acid was generally within 5% (coefficient of variation). Results were computed as relative weight % for essential n-3 PUFAs from fish oil (EPA and DHA), arachidonic acid (AA, 20:4n-6) as an essential n-6 PUFA, and the most relevant elongation and desaturation products, i.e., eicosatrienoic acid (ETA, 20:3n-9), docosatetraenoic acid (DTA, 22:4n-6) and docosapentaenoic acid (DPA, 22:5n-6).

Maternal serum was analyzed for persistent organochlorine contaminants, including 28 PCB congeners.[21,26] When expressed in relation to the serum lipid concentration, PCB concentrations are similar in maternal and cord serum.[21] Because of collinearity between the lipophilic contaminants, ∑PCB was calculated as the sum of all detectable PCB congeners and was used as indicator of long-term exposure to persistent organochlorine compounds.

Whole blood from the cord was analyzed for mercury[27,28] and selenium.[29]

Statistical analyses

Contaminant concentrations were logarithmically transformed because of skewed distributions. Parametric methods were applied throughout, except when questionnaire data required the use of Spearman's correlation coefficient (r_s). Multiple regression analysis was used to determine the relative importance of relevant predictors of the outcome parameters. Potential confounders were identified on the basis of previous studies[16,30] and included maternal height, maternal weight, smoking during pregnancy, diabetes, parity, gestational length, and sex of the child. Covariates were kept in the final regression equation if statistically significant ($p < 0.1$) after backward elimination.

Results

Half of the women reported that they had fish for dinner at least three times per week during pregnancy; about 60% had whale meat, and slightly more than one-half had whale blubber, for dinner at least once per month (Table 1). Most women (147; 82.6%) had not changed their dietary habits in this regard during the pregnancy. Average birth weight was high (Table 2), only 12 (6.6%) being below 3000 g.

{Tables 1 and 2 here}

Fatty acid concentrations in maternal serum averaged about 3-fold higher than in cord serum (Table 3), but the relative concentrations of ETA, AA, EPA, and DPA were higher in cord serum than maternal serum. At the same time, the strongest associations ($p < 0.001$; $n = 151$) between relative concentrations in paired samples of maternal serum and cord serum were observed for AA ($r = 0.49$), EPA ($r = 0.35$), and DPA ($r = 0.44$).

{Table 3 here}

Although seafood contaminant concentrations were increased, selenium occurred in an approximate 10-fold molar excess above mercury (Table 3). As expected from the sources of dietary exposures, the frequencies of blubber, whale meat and fish dinners during pregnancy were the best predictors for the concentrations of PCBs, mercury, and selenium, respectively.

Table 4 shows associations of fatty acid concentrations in cord serum with indicators of a maternal diet rich in marine fats. EPA increased at high intake levels, while ETA, DTA and DPA decreased. Similar, though less marked, tendencies were observed for maternal serum concentrations. The PCB concentration showed much the same associations with the PUFA concentrations, except that it showed a negative association with AA (Table 4). Mercury showed similar, though weaker associations in the same direction.

{Table 4 here}

The statistical significance of potential predictors of the obstetric outcome variables was assessed for identification of covariates to be included in the regression equations. Table 5 shows the averages for the adjusted outcome variables in tertile groups of fatty acid concentrations and contaminant concentrations.

{Table 5 here}

The duration of pregnancy was 5.7 days shorter in the 11 mothers who had diabetes mellitus or signs of gestational diabetes (p = 0.04), while other covariates were only weakly associated with gestational length. Calculations were therefore restricted to non-diabetic pregnancies. Gestational length showed a strong positive association with cord serum DHA concentration. When all fatty acids were entered as independent variables in a regression analyses, DHA was clearly the best predictor. An increase in the relative concentration by 1% was associated with an increase by 1.5 days (95% CI, 0.7-2.2). The slight tendency of association with PCB all but disappeared when adjusted for DHA.

For birth weight, the significant covariates were gestational length, parity, maternal height, smoking, and gender of child. Birth weight showed a positive correlation with cord serum concentrations of ETA and DPA and a negative association with EPA (Fig. 1). An increase in the relative EPA concentration in phospholipids by 1% was associated with a decrease in birth weight by 246 g (95% CI: 16-476). Birth weight also seemed to decline slightly at increased PCB concentrations. This parameter was therefore added to the full regression model along with the EPA concentration as the most relevant fatty acid (Table 6). Although the tendency for PCB remained, it was far from significant and much less important than EPA and the known predictors of birth weight.

{Table 6 here}

Placental weight increased with both parity and gestational age, but the latter was not significant after adjustment for parity. Placental weight was less clearly associated with the serum parameters, though ETA was a significant predictor. The ratio between birth weight and placental weight appeared not to be affected by the fatty acid or contaminant concentrations.

Maternal serum PUFA concentrations showed weaker associations in the same directions as seen with the cord serum concentrations. However, selenium concentrations showed no clear associations with the obstetric outcomes, and the same applied to the dietary questionnaire results concerning seafood dinner frequencies.

Discussion

The Faroese averages for n-3 PUFA concentrations in serum are higher than most previously published values.[31-37] For example, the average concentration of DHA in Faroese cord serum is about twice as high as comparable data from the Netherlands.[36,37] These increases in serum concentrations of the n-3 PUFAs were associated with seafood intake, and concurrent decreases were seen in desaturation levels, as indicated by ETA, DTA and DPA. The associations observed are in agreement with previous results from Norway using the same analytical method.[32,33] While no effect of seafood diets on AA would be expected,[32-34] a significant decrease in AA concentrations at high PCB levels deserves attention in future studies.

Fatty acid concentrations in serum are a result of a dynamic interaction between absorption, degradation and, for some of them, catabolism, as well as changes in transplacental passage.[31,38] The fact that concentrations of individual fatty acids correlated well in the paired samples and that maternal dietary habits were reflected in cord serum concentrations is in agreement with the passage of PUFAs across the placental barrier.[39] Although some PUFAs showed a relative accumulation on the fetal side, the cord serum concentrations were much below maternal levels. These results corroborate previous findings at lower concentrations.[34-38]

Cord serum concentrations showed clearer associations with the outcome variables than did maternal levels. Although the maternal serum samples were obtained at a standardized time, the cord serum concentrations at birth may more accurately reflect the availability of PUFAs to the fetus. Physiological changes during pregnancy and the time interval between collection of the paired samples must be taken into account, but PUFA concentrations in cord serum seem to change only little during the last few weeks of normal gestation.[36,38]

The results obtained support the notion that increased intakes of DHA may prolong gestation, as documented in a randomized controlled trial in a population with low seafood intakes.[40] However, erythrocyte concentrations of n-3 PUFAs were found to be associated with gestational length only at low average seafood consumption and not in a high-intake group of Faroese women.[41] Thus, the major benefit of n-3 supplements may occur within the low range of intakes.

The fatty acids that prolong the gestational period may not necessarily augment fetal growth. The high average birth weight in the present study is similar to previously reported results.[4,16] However, at increasing levels of seafood intake, birth weight first seemed to increase and then to diminish.[4] In the present study, birth weight showed a negative correlation with EPA concentrations. Likewise, higher levels of desaturation products were associated with both lower birth weight and higher placental weight. While increases in concentrations of desaturation products occur when supplies of essential fatty acids are insufficient,[42] the concentrations seen in this study are much below those reported from other locations.[35-37] These findings therefore suggest that both essential fatty acid intake and desaturation activity affect the degree of relative sufficiency or excess, and that they could conceivably affect fetal growth even within serum concentration ranges otherwise considered optimal.

Experimental evidence also suggests that a high intake of n-3 PUFAs may cause decreased intrauterine growth.[5,6] Although the mechanism is unknown, excess prenatal exposure to PUFAs may well lead to augmented lipid peroxidation,[43] which may be particularly harmful during development.[44] However, antioxidant selenium also occurs in seafood[45] and could potentially counter this possible risk at high seafood intakes. Serum selenium concentrations increase with the duration of the pregnancy,[23,46] but this element showed no clear association with gestational length or birth weight in the present study.

While the findings of the present study are in agreement with a fish-oil induced prolongation of gestation, the possible stresses induced by excess intakes therefore deserve attention. Fish oil supplements during pregnancy may be indicated only for prolongation of the gestational period when n-3 PUFA status is low.

Seafood contaminants also deserve consideration, although the major concern may relate to neurotoxicity,[9,21] rather than intrauterine growth retardation. The increased concentrations of PCBs and mercury in the present study are comparable to previously published levels from the Faroes,[23,28,47] but the average PCB concentration is about 3-fold higher in the Netherlands.[9,21] The mercury average is similar to results from Greenland[14] but about one order of magnitude higher than those reported from populations not relying on seafood.[29] However, despite previous reports on possible adverse effects on birth weight,[8-11,14] the present study of a wide exposure interval provides no evidence of an exposure-associated decrease in birth weight. While a small effect could possibly be hidden by the much greater impact of the associated n-3 PUFAs, increased contaminant exposure seems not to be the explanation of the decrease in birth weight associated with high EPA concentrations.

Conclusion

The duration of gestation is prolonged at increased intakes of marine lipids and associated serum concentrations of PUFAs. However, birth weight adjusted for gestational age may decrease at high intake levels. This effect is apparently not due to seafood contaminants. After adjustment for PUFAs and other covariates, mercury and PCB were poorly associated with birth weight.

Acknowledgments

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Figure legend:

Figure 1 Relative concentration of eicosapentaenoic acid (%) in cord serum phospholipids in relation to birth weight adjusted to non-smoking nullipara term birth of male baby in 182 spontaneous singleton births in Tórshavn, Faroe Islands.

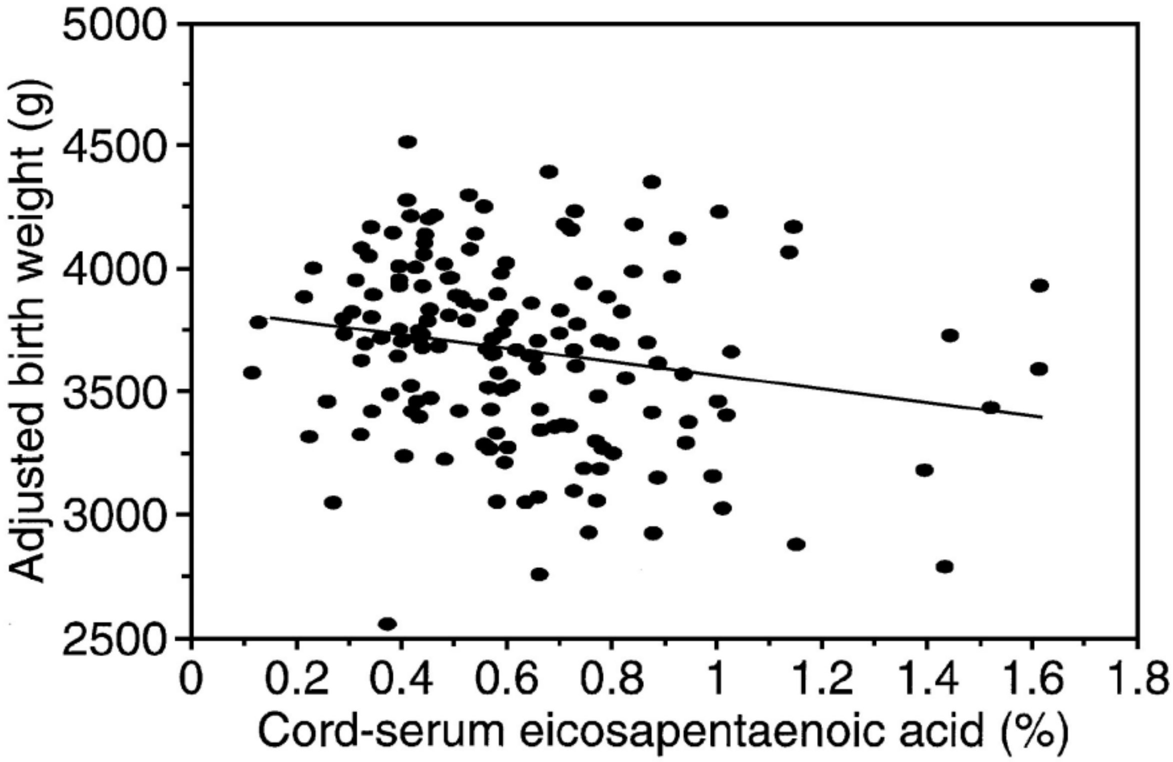

Table 1 Demographic and risk factor characteristics of 182 Faroese mothers, 1994-1995.

Mean age ± SD[a] (years)	28.0 ± 5.8
Mean height ± SD (cm)	163.7 ± 5.7
Mean prepregnancy weight ± SD (kg)	62.0 ± 10.5
Parity n (%)	
0	54 (29.7)
1	53 (29.1)
≥ 2	75 (41.2)
Smoking during pregnancy n (%)	57 (31.3)
Alcohol consumption during pregnancy n (%)	23 (12.6)
Fish dinners per week n (%)[a]	
0	2 (1.1)
1	34 (19.1)
2	52 (29.2)
≥ 3	90 (50.6)
Whale meat dinners per month n (%)[a]	
0	71 (39.9)
1	45 (25.3)
≥ 2	62 (34.8)
Whale blubber dinners per month n (%)[a]	
0	84 (47.2)
1-2	63 (35.4)
> 2	31 (17.4)

[a] Four mothers were not interviewed.

Table 2 Obstetric outcome variables of 182 Faroese babies, 1994-1995.

	Boys (n = 93)	Girls (n = 89)
Mean gestational age ± SD[a] (days)	280.9 ± 7.8	279.4 ± 8.7
Mean birth weight ± SD (g)	3801 ± 469	3537 ± 463
Mean placental weight ± SD (g)	687 ± 128	673 ± 133

[a]Standard deviation.

Table 3 Exposure characteristics of 182 Faroese babies, 1994-1995.

Parameter	Mean ± SD[a]
Maternal serum phospholipid fatty acids (mg/l)	1918 ± 283
Cord serum phospholipid fatty acids (mg/l)	632 ± 116
Geometric mean (interquartile range) maternal serum ΣPCBs (µg/g lipid)	0.86 (1.05)
Geometric mean (interquartile range) cord blood mercury (nmol/l)	101.7 (140.1)
Cord blood selenium (µmol/l)	1.31 ± 0.18

[a]Standard deviation

Table 4 Mean relative concentrations of fatty acids (%) in cord serum phospholipids, as related to approximate tertile groups of frequencies of maternal whale blubber dinners during pregnancy and concentrations of polychlorinated biphenyls (PCBs) in maternal serum.

		Number of blubber dinners per month				ΣPCB concentration in maternal serum (µg/g lipid)			
Fatty acid	Mean ± SD	0	1-2	>2	P value[a]	< 0.6	0.6-1.3	>1.3	P value
Eicosatrienoic acid	0.68 ± 0.30	0.77	0.60	0.60	0.004	0.70	0.70	0.65	0.27
Arachidonic acid	16.5 ± 1.63	16.5	16.3	16.5	0.55	17.1	16.3	16.0	<0.001
Eicosapentaenoic acid	0.63 ± 0.28	0.55	0.67	0.73	0.002	0.50	0.64	0.72	<0.001
Docosatetraenoic acid	0.77 ± 0.14	0.80	0.73	0.75	0.012	0.82	0.76	0.73	0.002
Docosapentaenoic acid	0.76 ± 0.26	0.83	0.70	0.68	<0.001	0.85	0.76	0.68	0.001
Docosahexaenoic acid	8.95 ± 1.65	8.86	8.82	9.56	0.55	8.76	8.82	9.22	0.11

[a] For association as determined by Spearman's correlation coefficient

Table 5 Mean values for obstetric outcome variables in tertile groups of cord serum concentrations of fatty acids (% of total phospholipids), ΣPCB concentration in maternal serum (ng/g lipid) and mercury in cord blood (nmol/l).

	Gestational length (days)[a]	P value[b]	Birth weight (g)[c]	P value	Placental weight (g)[d]	P value
Eicosatrienoic acid		0.47		0.001		0.019
<0.50	281.4		3539		602	
0.50-0.76	281.0		3689		657	
>0.76	280.7		3773		651	
Arachidonic acid		0.20		0.58		0.097
<15.7	279.9		3669		664	
15.7-17.1	280.8		3728		627	
>17.1	284.3		3607		615	
Eicosapentaenoic acid		0.41		0.015		0.43
<0.46	281.8		3761		647	
0.46-0.70	280.7		3664		632	
>0.70	280.6		3575		628	
Docosatetraenoic acid		0.004		0.79		0.30
<0.70	279.4		3616		641	
0.70-0.82	280.0		3717		661	
>0.82	283.7		3678		611	
Docosapentaenoic acid		0.092		0.002		0.24
<0.64	280.7		3557		624	
0.64-0.83	280.1		3670		632	
>0.83	282.2		3769		650	

Docosahexaenoic acid			<0.001		0.16		0.18
	<8.0	278.8		3719		659	
	8.0-9.6	280.6		3620		625	
	>9.6	283.6		3662		624	
ΣPCB			0.09		0.47		0.99
	<0.6	279.5		3691		650	
	0.6-1.3	281.3		3557		647	
	>1.3	281.1		3606		617	
Mercury			0.81		0.63		0.64
	<72.0	281.2		3643		624	
	72.0-165	280.1		3662		636	
	>165	280.8		3661		638	

[a]Non-diabetic pregnancies only.
[b]For regression coefficient (continuous variable).
[c]Adjusted to non-smoking average-height and nullipara mother with term birth of male baby
[d]Adjusted to nullipara birth

Table 6 Multiple linear regression results for independent predictors of birth weight in 182 births in Faroe Islands, 1994-1995.

Variable	β	SE	p
Gender = girl	-237	63	<0.001
Parity = 1	281	84	0.001
Parity = ≥2	498	81	<0.001
Gestational length ≤ 37 weeks	-702	173	<0.001
Gestational length = 38 weeks	-341	93	<0.001
Smoking	-154	66	0.021
Maternal height (cm)	23.4	5.4	<0.001
Cord serum EPA[a] concentration (%)	-246	117	0.037
Serum ΣPCB concentration (μg/g lipid)	-31.0	99.9	0.757

[a]Eicosapentaenoic acid