Applied nutritional investigation

Fatty acid status and antioxidant defense system in mothers and their newborns after salmon intake during late pregnancy

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ABSTRACT

Objective: The aim of the present study was to assess the maternal and newborn status of erythrocyte fatty acids and the antioxidant defense system after the intake of two portions of salmon per week during late pregnancy.
Methods: Pregnant women (N = 123) were randomly assigned to continue their habitual diet, which was low in oily fish (control group, n = 61) or to consume two 150-g salmon portions per week (salmon group, n = 62) beginning at 20 wk of gestation and lasting until delivery. Fatty acids, selenium, and glutathione concentrations and antioxidant defense enzyme activities were measured in maternal erythrocytes at 20, 34, and 38 wk of pregnancy, and in cord erythrocytes collected at birth. Plasma concentrations of antioxidant molecules were measured.
Results: Compared with the control group, consuming salmon had little effect on erythrocyte fatty acids in either mothers or newborns. Components of the antioxidant defense system did not differ between groups. Glutathione peroxidase activity and the concentrations of tocopherols, retinol, and coenzyme Q10 were significantly lower in cord blood compared with maternal blood at week 38 in both groups.
Conclusion: Maternal and newborn erythrocyte fatty acids are not strongly affected by the intake of two portions of salmon per week during the second half of pregnancy, although erythrocyte docosahexaenoic acid might be increased in newborns. Maternal and newborn antioxidant defense systems are not impaired by intake of salmon from 20 wk gestation.

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Introduction

The requirements for the long-chain polyunsaturated fatty acids (LC-PUFA) arachidonic acid (AA, C20:4 ω-6) and docosahexaenoic acid (DHA, C22:6 ω-3) are especially high during the last trimester of pregnancy and the first weeks of extrauterine life because of their accretion into the growing brain and other tissues [1,2]. AA and DHA can be formed by elongation and desaturation of the essential precursors linoleic acid (LA; C18:2 ω-6) and α-linolenic acid (ALA; C18:3 ω-3), respectively, but fetal fatty acid-desaturase enzymes are unable to supply sufficient LC-PUFA until 16 wk after birth [3]. Therefore, fetal LC-PUFA must be supplied from the maternal circulation and so are ultimately derived from the maternal diet.

The increased fetal demand for LC-PUFA is indicated by a concomitant decrease in the relative concentrations of DHA and AA in the maternal plasma as pregnancy progresses [4,5]. Fish oils rich in ω-3 LC-PUFA, DHA and eicosapentaenoic acid (EPA; 20:5 ω-3), may enhance maternal, fetal, and neonatal PUFA status. Findings from several studies have shown that dietary intakes of ω-3 LC-PUFA of ≥2.6 g/d significantly increase the ω-3 LC-PUFA status in both pregnant women and their newborns [6–8]. Nonetheless, this increase may be accompanied by a reduction of ω-6 LC-PUFA toward the end of pregnancy [8–11], and this is not desirable.

The UK government recommends that pregnant women consume one or two portions of oily fish each week as a source of ω-3 LC-PUFA [10]. It is not clear whether consumption of fish as a whole food delivering ω-3 LC-PUFA affects the ω-3 LC-PUFA status of mothers and their newborns. In this regard, one study observed higher EPA and DHA status and lower AA status in mothers with high dietary intake of oily fish in relation to those with lower consumption, with similar findings in newborns [11]. To our knowledge, no intervention studies apart from Salmon in Pregnancy Study (SiPS) [12] have investigated the effect of higher oily fish intake in pregnant women whose consumption of oily fish was normally low. In SiPS, the intake of two portions of salmon per week (equivalent to a daily intake of about 500 mg EPA + DHA) resulted in an enhanced plasma EPA and DHA status in pregnant women, and a higher EPA and DHA status in the umbilical cord blood plasma than seen in the control group [12].

It is known that LC-PUFAs are good substrates for lipid peroxidation, and so a diet high in ω-3 LC-PUFA could contribute to oxidative stress [13]. However, several mechanisms exist to protect against peroxidative damage. These mechanisms involve exogenous vitamins and trace elements as well as endogenous enzyme systems [14]. In SiPS, maternal oxidative stress markers remained unaffected after consumption of two portions of salmon per week [15]. Furthermore, maternal retinol and selenium (Se) levels were significantly higher in the group supplemented with salmon than in the control group [16]. To our knowledge, there are no studies on the effect of increased maternal oily fish intake on the antioxidant defense system in newborns.

Therefore, the aims of the present study, as part of SiPS, were to examine the effect of increased salmon consumption beginning in week 20 of pregnancy through delivery (1) on erythrocyte fatty acids in pregnant women and their newborns and (2) on the antioxidant defense system in the newborns' blood.

Materials and methods

The study design, characteristics of the pregnant women, aspects of their diet, and compliance have been described in detail elsewhere [12]. In brief, 123 pregnant women residing in or near Southampton, United Kingdom were enrolled in the study. The inclusion criteria were age 18 to 40 y; <19 wk gestation; healthy, uncomplicated, singleton pregnancy; having a baby at risk for atopy; consuming less than two portions of oily fish per month, excluding tinned tuna; and not taking fish oil supplements either currently or in the previous 3 mo. The Southampton and South West Hampshire Research Ethics Committee (07/Q1704/43) approved all procedures. The study was conducted according to the principles of the Declaration of Helsinki, and all the women provided written informed consent. SiPS is registered at www.clinicaltrials.gov (NCT00801502).

Study design

We randomly assigned the women to one of two groups. Women in the control group (n = 61) were asked to continue their habitual diet, whereas those in the salmon group (n = 62) were asked to incorporate two portions of farmed salmon per week (150 g/portion) into their diet from study entry (20 wk of pregnancy) until delivery. SiPS was powered according to an anticipated increase in maternal plasma phosphatidylcholine EPA content. It was calculated that a sample size of 50 women per group would have 93% power to detect a 50% higher plasma phosphatidylcholine EPA content in the salmon group than in the control group [12]. The farmed salmon used in the SiPS were raised at Skretting Aquaculture Research Centre (Stavanger, Norway), using dietary ingredients selected to contain low levels of contaminants. Each 150-g salmon portion contained (on average) 30.5 g protein, 16.4 g fat, 0.57 g EPA, 0.35 g docosapentaenoic acid (DPA, C22:5 ω-3), 1.16 g DHA, 3.56 g total ω-3 PUFA, 4.1 mg α-tocopherol, 1.6 mg γ-tocopherol, 6 μg vitamin A, 14 μg vitamin D₃, and 43 μg selenium. The full fatty acid composition of the salmon is shown in Table 1. Contaminants constituted <12.5% of the Food and Agriculture Organization/World Health Organization provisional tolerable weekly intake for dioxin and dioxin-like polychlorobiphenyls, <11.5% for arsenic, <0.00000008% for cadmium, 0.0000025% for mercury, and <0.00000002% for lead [12].

Fifteen women were unable to complete the study as a result of preterm delivery, withdrawal due to fatigue, a busy schedule, or an unspecified injury, leaving 54 women in each group at the end of the study; 101 blood samples were collected at birth (50 from the control group and 51 from the salmon group) [12].

Analytical procedures

Fasting maternal venous blood samples were collected for analysis at 20 wk of gestation (before the intervention started), at 34 wk, and at 38 wk. Blood samples were obtained from the umbilical vein after cord clamping, immediately after delivery. All samples were added to heparin and centrifuged. Plasma and washed erythrocytes were immediately frozen and stored at −80°C.

Erythrocyte fatty acid profile

Erythrocyte fatty acids were transmethylated using acetyl chloride [17]. Hexane-resuspended methylated fatty acids were injected into a Hewlett Packard HP5890 Series II chromatograph (Hewlett Packard, Palo Alto, CA, USA), with a capillary column (60 m × 32 mm inner diameter; 20 μm film thickness) impregnated with SP2330 FS (Supelco, Bellefonte, CA, USA). Running conditions were as described elsewhere [18]. Fatty acid methyl esters were identified by comparison of retention times with those of authentic standards run previously.

Table 1
Fatty acid composition of the salmon

Fatty acid	Percentage of salmon fatty acids
Myristic acid (14:0)	2.25 ± 0.09
Palmitic acid (16:0)	12.25 ± 0.27
Palmitoleic acid (16:1 ω-7)	2.52 ± 0.08
Stearic acid (18:0)	3.32 ± 0.11
Oleic acid (18:1 ω-9)	33.01 ± 0.36
Vaccenic acid (18:1 ω-7)	2.70 ± 0.01
Linoleic acid (18:2 ω-6)	11.60 ± 0.15
α-Linolenic acid (18:3 ω-3)	7.37 ± 0.32
Eicosenoic acid (20:1 ω-9)	2.79 ± 0.13
Docosadienoic acid (20:2 ω-6)	1.15 ± 0.2
AA (20:4 ω-6)	1.30 ± 0.05
EPA (20:5 n-3)	3.53 ± 0.16
Nervonic acid (24:1 ω-9)	0.36 ± 0.01
DPA (22:5 ω-3)	2.09 ± 0.04
DHA (22:6 ω-3)	7.11 ± 0.11
Others	6.65 ± 0.04

AA, arachidonic acid; DHA, docosahexaenoic acid; DPA, docosapentaenoic acid; EPA, eicosapentaenoic acid

Enzymatic antioxidants

Hemoglobin (Hb) concentration in the blood samples was determined by the colorimetric cyanmethemoglobin method. Erythrocyte catalase (CAT), erythrocyte superoxide dismutase (SOD), erythrocyte glutathione reductase (GR), and erythrocyte glutathione peroxidase (GPx) activities were assayed as previously described [19–22].

Nonenzymatic antioxidants

Plasma concentrations of α- and γ-tocopherol, retinol, and coenzyme Q10 (CoQ10) were determined by high-pressure liquid chromatography coupled to an electrochemical detector (HPLC-EC) [23], after extraction with 1-propanol. β-carotene also was determined after extraction with 1-propanol in an HPLC system attached to a multiwave-length ultraviolet detector set at 450 nm. We identified all compounds by predetermining the retention times of individual standards.

Erythrocyte selenium and glutathione

Erythrocyte Se was determined by inductively coupled plasma mass spectrometry [24] on an Agilent 7500 ICPMS. Se concentration was calculated using an external standard. Erythrocyte glutathione content was measured by HPLC with fluorescence detection at 420 nm, as described previously [25].

Statistical analysis

Values are presented as mean ± SEM. Before statistical analysis, we checked all variables for normality using the Kolmogorov–Smirnov test. The homogeneity of the variances was estimated using Levene's test. In pregnant women, a general linear model of variance for repeated measures was performed to assess differences among times and between groups and the interactions between group and time. When Mauchly's test indicated that the assumption of sphericity was violated, the Greenhouse–Geisser correction was applied for univariate analysis. When the Greenhouse–Geisser correction was <0.05, we used multivariate analysis of variance (ANOVA) tests, which do not depend on the assumption of sphericity. A one-way ANOVA was applied to evaluate the effects of time (20, 34, and 38 wk) within each group, and a posteriori Bonferroni tests were used for the comparison among multiple means. To evaluate differences between two groups, Student's *t* test was performed. Correlations between parameters were estimated by computing Pearson's and Spearman ρ correlation coefficients. *P* values <0.05 were considered statistically significant. All statistical analyses were performed with SPSS 15.0 for Windows.

Results

As reported previously [12], the two groups did not differ in maternal age, height, or weight, or in infant birth weights or skin prick test positivity. Additionally, the percentages of EPA and DHA in plasma phospholipids decreased during pregnancy in the control group [12]. This decline did not occur in the salmon group; indeed, the percentages of EPA and DHA increased so that both were higher in the salmon group than in the control group at weeks 34 and 38 [12].

Maternal erythrocyte fatty acids

During pregnancy, there was a significant increase in the proportion of palmitic acid in erythrocytes in both groups and of AA, lignoceric acid, and DHA ($P = 0.005$ to $P < 0.001$) in the control group. The proportion of ALA decreased in both groups, whereas LA and DPA decreased only in the salmon group ($P = 0.012$ to $P < 0.001$) (Table 2). There were no changes in other fatty acids during pregnancy. The percentage of maternal erythrocyte fatty acids did not differ between the two groups at any time point.

Umbilical erythrocyte fatty acids

Erythrocytes from newborns in the salmon group had a significantly lower proportion of lignoceric acid than did erythrocytes from their mothers ($P = 0.020$), whereas the proportions of ALA, EPA, DHA, ω-3 PUFA, and ω-3 LC-PUFA were significantly higher in newborns than in their mothers ($P = 0.036$ to $P = 0.005$) (Table 2).

Relationships between maternal and newborn erythrocyte fatty acid

We observed negative correlations between maternal and newborn erythrocyte ω-6 PUFA in both control ($r = -0.391$; $P = 0.025$) and salmon ($r = -0.516$; $P = 0.003$) groups. Both DHA and saturated fatty acid (SFA) proportions were positively correlated between maternal and newborn erythrocytes in the salmon group ($r = 0.384$; $P = 0.030$ and $r = 0.356$; $P = 0.045$, respectively) while monounsaturated fatty acid (MUFA) and total PUFA were negatively correlated only in the control group ($r = -0.350$; $P = 0.046$ and $r = -0.488$; $P = 0.004$, respectively).

Maternal and newborn enzymatic antioxidant defense system

Table 3 shows the antioxidant enzyme activities in both groups. GPx activity was significantly lower in cord blood from newborns than in their mothers in both groups ($P < 0.001$).

Maternal and newborn nonenzymatic antioxidant defense system

There were no significant differences between the two groups or between maternal blood at 38 wk and newborn blood for Se, oxidized glutathione (GSSG), reduced glutathione (GSH), or total glutathione concentrations (data not shown). There were no significant differences between the two groups for maternal blood at 38 wk or for newborn blood α-tocopherol, γ-tocopherol, or CoQ10 concentrations (data not shown). The concentration of retinol was significantly higher in mothers in the salmon group than in those in the control group ($P = 0.002$). Compared with maternal blood, cord blood from newborns had significantly lower concentrations of tocopherols, retinol, and CoQ10 in both the control ($P = 0.035$ to $P < 0.001$) and the salmon ($P = 0.014$ to $P < 0.001$) groups.

Relationship between maternal and newborn antioxidant defense system

Combining data for both groups, SOD activity and Se concentration correlated positively and significantly between mothers and newborns ($r = 0.697$, $P < 0.001$, n = 69 and $r = 0.603$, $P < 0.001$, n = 55, respectively). No correlations were found for CAT, GR, GPx, α-tocopherol, γ-tocopherol, β-carotene, retinol, CoQ10, or GSH. In contrast, mothers' concentrations of γ-tocopherol, β-carotene, and CoQ10 correlated negatively with SOD activity in newborns ($r = -0.439$, $P < 0.001$, n = 70; $r = -0.291$, $P = 0.014$, n = 71; and $r = -0.296$, $P = 0.014$, n = 69, respectively). When separating data according to group, significant positive correlations were observed between maternal and newborn for Se concentration and SOD activity in both control ($r = 0.469$, $P = 0.010$, n = 29; $r = 0.706$, $P < 0.001$, n = 34, respectively) and salmon ($r = 0.622$, $P = 0.001$, n = 26; $r = 0.689$, $P < 0.001$, n = 35) groups. Additionally, levels of α-tocopherol were positively correlated between mother and newborn in the salmon group ($r = 0.516$, $P = 0.005$, n = 28).

Discussion

In normal pregnancies, there is a physiological insulin resistance during the last trimester that promotes maternal lipolysis, to ensure the provision of fatty acids to the fetus [26]. Among

Table 2
Fatty acid profile of erythrocyte membranes in newborns and their mothers consuming their habitual diet (control group) or including salmon twice per week (salmon group) beginning at week 20 of gestation

	Group							
	Control (n = 33)				Salmon (n = 32)			
	20 wk	34 wk	38 wk	Newborn	20 wk	34 wk	38 wk	Newborn
%								
Palmitic acid (16:0)	24.02 ± 0.32^a	25.96 ± 0.51^b	25.00 ± 0.58^{ab}	25.24 ± 0.63	23.35 ± 0.33^a	25.68 ± 0.51^b	26.00 ± 0.59^b	24.78 ± 0.39
Stearic acid (18:0)	16.50 ± 1.24	15.01 ± 0.26	14.86 ± 0.74	14.74 ± 0.28	16.50 ± 1.26	15.37 ± 0.27	16.04 ± 0.75	15.01 ± 0.30
Oleic acid (18:1 ω-9)	14.37 ± 0.48	14.40 ± 0.34	14.42 ± 0.40	15.34 ± 0.32	13.71 ± 0.48	14.10 ± 0.34	13.95 ± 0.41	14.75 ± 0.33
Linoleic acid (18:2 ω-6)	8.35 ± 0.38	7.49 ± 0.34	7.27 ± 0.44	7.33 ± 0.51	8.15 ± 0.39^a	7.21 ± 0.35^{ab}	6.73 ± 0.45^b	6.87 ± 0.47
α–Linolenic acid (18:3 ω-3)	0.26 ± 0.03^{ab}	0.29 ± 0.02^a	0.21 ± 0.02^b	0.24 ± 0.03	0.24 ± 0.03^{ab}	0.30 ± 0.02^a	0.19 ± 0.02^b	$0.27 \pm 0.03*$
AA (20:4 ω-6)	10.65 ± 0.51^a	10.58 ± 0.61^a	12.94 ± 0.62^b	12.57 ± 0.55	11.45 ± 0.52	11.33 ± 0.63	12.44 ± 0.63	13.29 ± 0.39
EPA (20:5 ω-3)	0.49 ± 0.06	0.47 ± 0.04	0.50 ± 0.04	0.41 ± 0.04	0.49 ± 0.06	0.51 ± 0.04	0.36 ± 0.04	$0.49 \pm 0.05*$
Lignoceric acid (24:0)	2.92 ± 0.16^a	3.95 ± 0.19^b	3.53 ± 0.17^b	3.29 ± 0.14	3.08 ± 0.16^a	3.72 ± 0.20^b	3.58 ± 0.17^{ab}	$3.05 \pm 0.12*$
Nervonic acid (24:1 ω-9)	6.62 ± 0.29	6.68 ± 0.23	6.57 ± 0.23	6.53 ± 0.18	7.20 ± 0.30	6.55 ± 0.23	6.63 ± 0.24	6.02 ± 0.19
DPA (22:5 ω-3)	1.69 ± 0.11	1.57 ± 0.12	1.59 ± 0.14	1.55 ± 0.14	1.92 ± 0.11^a	1.52 ± 0.12^b	1.47 ± 0.14^b	1.69 ± 0.14
DHA (22:6 ω-3)	3.58 ± 0.29^a	4.57 ± 0.35^a	5.26 ± 0.34^b	5.30 ± 0.32	4.33 ± 0.29	4.74 ± 0.36	5.02 ± 0.34	$6.10 \pm 0.28*$
SFA	39.23 ± 0.78	41.75 ± 0.99	39.81 ± 1.29	37.86 ± 1.46	38.31 ± 0.79	40.20 ± 1.00	38.78 ± 1.31	38.32 ± 1.34
MUFA	24.00 ± 0.99	22.76 ± 0.26	22.22 ± 0.56	22.07 ± 0.29	24.45 ± 1.01	23.07 ± 0.26	23.44 ± 0.57	21.90 ± 0.35
PUFA	30.53 ± 1.04	30.54 ± 0.59	31.02 ± 0.81	31.67 ± 0.76	30.54 ± 1.06	30.08 ± 0.60	29.47 ± 0.82	31.84 ± 0.83
ω-6 PUFA	24.77 ± 0.85	23.93 ± 0.53	23.67 ± 0.69	24.41 ± 0.64	23.80 ± 0.86	23.31 ± 0.54	22.62 ± 0.70	23.56 ± 0.69
ω-3 PUFA	5.76 ± 0.40	6.61 ± 0.45	7.35 ± 0.42	7.26 ± 0.41	6.74 ± 0.41	6.77 ± 0.45	6.85 ± 0.43	$8.28 \pm 0.39*$
ω-6 LC-PUFA	1.63 ± 0.10	1.44 ± 0.10	1.58 ± 0.12	1.34 ± 0.08	1.50 ± 0.10	1.45 ± 0.10	1.53 ± 0.12	1.51 ± 0.09
ω-3 LC-PUFA	5.76 ± 0.40	6.61 ± 0.46	7.35 ± 0.42	7.26 ± 0.41	6.74 ± 0.41	6.77 ± 0.45	6.85 ± 0.43	$8.28 \pm 0.39*$

AA, arachidonic acid; DHA, docosahexaenoic acid; DPA, docosapentaenoic acid; EPA, eicosapentaenoic acid; LC-PUFA, long-chain polyunsaturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; SFA, saturated fatty acids
Values are presented as mean weight % of total fatty acids $\pm$ SEM. Values for maternal erythrocyte not sharing a common superscript letter (a, b) are significantly different (within a group). There were no significant differences between groups
* Significantly different from mothers at 38 wk gestation, $P < 0.05$.

these fatty acids, ω-3 LC-PUFA are the most important because they are essential for normal fetal brain development [1] and for visual acuity [2]. Additionally, adequate levels of ω-6 LC-PUFA are necessary during early development [27,28]. In the present study, erythrocyte AA proportions increased during pregnancy and percentages in either maternal or newborn erythrocytes did not differ between groups. This suggests that the provision and incorporation of AA is not being limited by the increased intake of ω-3 LC-PUFA in the salmon group.

Decreased AA and increased DHA proportions in both plasma and erythrocytes have been reported in some studies toward the end of pregnancy in women receiving ω-3 LC-PUFA supplements [8–11]. However, other studies showed no effect of DHA supplementation [29,30]. One likely reason for these discrepancies is the quantity of DHA used in those studies. Regarding SiPS, the ω-3 LC-PUFA provided was equivalent to a daily intake of about 500 mg EPA plus DHA, and levels of both DHA and AA increased in erythrocytes during pregnancy. Results from another study

[31] suggested that a dose of 500 mg/d ω-3 LC-PUFA during pregnancy significantly increased neonatal ω-3 LC-PUFA status without affecting ω-6 LC-PUFA. Similarly, supplementation of pregnant women with 570 mg/d DHA significantly increased plasma and erythrocyte DHA levels in newborns without a reduction in ω-6 LC-PUFA [32]. The observations made in the present study are consistent with the findings made in pregnant women taking supplements providing about 500 mg/d DHA.

Additionally, we observed that maternal erythrocyte and plasma phospholipid, EPA and DHA appear to respond differently during pregnancy. In particular, in the control group, DHA declined in plasma phospholipids but increased in erythrocytes, whereas EPA declined in plasma phospholipids and did not change in erythrocytes. This may be because plasma phospholipids are more metabolically active and are involved in the processes of preferential transfer of ω-3 LC-PUFA to the developing fetus [33]. Conversely, an enhanced status of plasma phospholipid EPA and DHA was detected in mothers and their newborns in the salmon group in SiPS [12]. Additionally, percentages of EPA and DHA along with total ω-3 PUFA and ω-3 LC-PUFA in cord erythrocytes in the salmon group were significantly higher compared with mothers' erythrocytes at 38 wk of gestation.

To our knowledge, no studies have directly investigated the effect of ω-3 fatty acids from oily fish on the newborns' antioxidant defenses. It is well known that birth is a situation of increased stress and free radical generation [34] in which the newborn is highly exposed to oxygen, which may be difficult to control [35]. However, endogenous antioxidant enzymes, as well as vitamins and trace elements, are responsible for the detoxification of deleterious oxygen radicals [14]. Some studies have shown that cord plasma contains significantly lower levels of antioxidant vitamins and soluble factors than maternal plasma [34–36], which may be due to lower amount of lipids present in the cord blood that limit the ability to transport such factors [34].

Table 3
Enzymatic antioxidant activities in newborns and their mothers consuming their habitual diet (control group) or including salmon twice per week (salmon group) beginning at week 20 of gestation

	Group			
	Control (n = 34)		Salmon (n = 35)	
	38 wk	Newborn	38 wk	Newborn
CAT (nmol•L•g Hb)	2.93 ± 0.14	3.36 ± 0.64	3.00 ± 0.16	2.84 ± 0.12
SOD (U/mg Hb)	1.52 ± 0.14	1.72 ± 0.15	1.43 ± 0.13	1.47 ± 0.14
GR (U/g Hb)	3.44 ± 0.27	3.59 ± 0.15	3.46 ± 0.29	3.75 ± 0.18
GPx (U/g Hb)	519 ± 38	$332 \pm 16*$	604 ± 42	$382 \pm 20*,†$

CAT, catalase; GPx, glutathione peroxidase; GR, glutathione reductase; Hb, hemoglobin; SOD, superoxide dismutase
Values are mean $\pm$ SEM
* Significantly different from mothers at 38 wk gestation.
† Significantly different from control group.

In the present study, although cord blood and maternal GSSG and GSH concentrations were similar in both groups, the enzyme GPx showed lower activity in cord rather than mothers' erythrocytes. Between group comparisons determined that antioxidant enzyme activities in cord blood were not different; additionally, concentrations of vitamins and soluble factors were similar in both groups of newborns. Hence, salmon consumption (twice per week) seems not to affect these molecules in the newborn.

We observed a significant negative correlation for ω-6 PUFA between maternal and newborn erythrocytes in both groups, the same results were seen in supplemented [7,37] and unsupplemented [38,39] women. Moreover, this negative relationship was evident for MUFA and PUFA in the control group. In contrast, there was a positive correlation for SFA and DHA in the salmon group. Likewise, significant correlations were observed between maternal and umbilical cord blood for SOD activity and Se concentration. Additionally, associations of plasma α- and γ-tocopherol concentrations between mothers and their newborns were observed, these correlations are in accordance with those observed in previous studies [34–36].

It is important to highlight that there are external factors that may have affected the results obtained in the present study. Different changes during pregnancy in each woman, changes associated with the evolution of pregnancy, the previous nutritional status of the mother, and the characteristics of the fetus (growth, weight, etc.) are aspects that could affect the influence of ω-3 LC-PUFA, and these factors cannot be controlled. The precise nutrient composition of salmon also could affect the results; this composition depends on the diet fed to the salmon and may differ between each salmon. Also, the exact way that women incorporated salmon into their diet and what the salmon replaced could vary and this may influence the results obtained.

Conclusions

Limited attention has been given to the antioxidant defense system of the fetus in relation to maternal LC-PUFA exposure and, probably never before, when the source of ω-3 LC PUFA is oily fish. The present study demonstrated that the consumption of farmed salmon twice a week from week 20 of pregnancy until delivery (providing about 500 mg/wk of EPA + DHA) did not impair the antioxidant defense system and did not alter erythrocyte fatty acid composition in newborns or their mothers.

Acknowledgments

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