Infant plasma *trans*, n−6, and n−3 fatty acids and conjugated linoleic acids are related to maternal plasma fatty acids, length of gestation, and birth weight and length[1–3]

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See corresponding editorial on page 671.

ABSTRACT

Background: Arachidonic acid (AA) and docosahexaenoic acid (DHA) are important for growth and neural development. *trans* Fatty acids (TFAs) may inhibit desaturation of linoleic acid (LA) and α-linolenic acid (ALA) to AA and DHA, respectively. Conjugated linoleic acids (CLAs) also alter lipid metabolism and body fat.

Objective: We determined the associations of birth outcome with maternal and infant plasma concentrations of TFAs, CLAs, AA, and DHA.

Design: In healthy women, we sampled maternal blood at 35 wk gestation (n = 58) and umbilical cord blood at birth (n = 70).

Results: Mean (± SEM) TFA concentrations (% by wt) in infant plasma were as follows: triacylglycerol, 2.83 ± 0.19 (range: 0.63–12.79); phospholipid, 0.67 ± 0.03 (0.11–1.33); and cholesteryl ester, 2.04 ± 0.01 (0.86–4.24). LA, AA, DHA, TFA, and CLA concentrations in infant phospholipids correlated with the same fatty acid in maternal plasma phospholipids (n = 44; $P <$ 0.05). Infant plasma cholesteryl ester and triacylglycerol TFAs and cholesteryl ester CLAs (r = −0.33, −0.42, and –0.49, respectively) were significantly inversely related to length of gestation. Triacylglycerol and cholesteryl ester AA were positively related to length of gestation (r = 0.41 and 0.37, respectively) and birth weight (r = 0.27 and 0.23, respectively). Inverse correlations occurred between infant plasma TFA and DHA concentrations in triacylglycerols (r = –0.33) and between TFA and AA concentrations in cholesteryl esters (r = –0.23).

Conclusion: The results suggest possible important effects of TFAs and of AA on fetal growth and length of gestation. *Am J Clin Nutr* 2001;73:807–14.

KEY WORDS Conjugated linoleic acid, *trans* fatty acids, arachidonic acid, docosahexaenoic acid, maternal nutrition, fetal growth, birth outcome, infant, pregnancy, pregnant women, linoleic acid, α-linolenic acid, cholesteryl ester, triacylglycerol, phospholipid

INTRODUCTION

Arachidonic acid (AA; 20:4n−6) and docosahexaenoic acid (DHA; 22:6n−3) are critically important in fetal and infant growth and central nervous system development (1). AA is found in cell membrane phospholipids and is important in second messenger and cell signaling pathways, in cell division, and as an eicosanoid precursor. There is clinical evidence supporting a relation between blood lipid AA and infant growth (2, 3) and experimental evidence showing that dietary AA reverses the growth failure that results from deficiency of essential fatty acids (4). DHA concentrations are high in retinal and brain membrane phospholipids. DHA is involved in visual and neural function and neurotransmitter metabolism (1, 5–8).

It has been suggested that the *trans* isomers of oleic acid (18:1) and linoleic acid (LA; 18:2n−6), which are formed during hydrogenation of unsaturated vegetable oils, have adverse effects on growth and development through inhibition of the desaturation of LA and α-linolenic acid (ALA; 18:3n−3) to AA and DHA, respectively (9–14). These *trans* fatty acids (TFAs) are present in partially hydrogenated vegetable oils used in margarines and shortenings and in foods containing these fats, such as cookies, crackers, breads, and processed and prepared foods (15–17). Current estimates suggest that average daily dietary intakes of TFAs are in the range of 2.5 to 5.3 g/person in North America (18–20). Inverse associations between TFAs and AA and DHA in umbilical cord plasma cholesteryl esters and between plasma cholesteryl ester *trans* 18:1 and the birth weight of premature infants (21) have been reported. Inverse associations between plasma phospholipid TFAs and AA and DHA were also found in children aged 1–15 y (22). Furthermore, the n−6 and n−3 fatty acid status of infants at birth is an important determinant of the postnatal changes in AA and DHA in both breast-fed and formula-fed infants (23, 24). Thus, fetal n−6 and n−3 fatty acid accretion and exposure to TFAs derived from the maternal diet may be important to the growth and development of not only the fetus but also the older infant.

Conjugated linoleic acids (CLAs) is a collective term for a group of geometric (*trans*) and positional isomers of all *cis* LA in which the double bonds are conjugated. CLAs are present in

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dairy products and ruminant meats as a result of biohydrogenation of fatty acids in the cow rumen. The average concentration of CLAs in these foods is ≈5 mg/g fat (25). CLAs have been shown to inhibit tumor cell growth, adipocyte proliferation and differentiation (26–28), and adipocyte lipoprotein lipase activity and to reduce body fat in animals (29, 30). This suggests that the biological activity of CLAs may differ from that of other TFAs. It is not known whether CLAs cross the placenta or whether the concentrations of maternal or newborn infant TFAs derived from hydrogenated vegetable oils or CLAs are related to n−6 and n−3 fatty acids or birth outcome in term infants.

This study was designed to test 2 hypotheses: *1*) maternal plasma TFAs, CLAs, and n−6 and n−3 fatty acids are significantly related to concentrations of the same fatty acids in the newborn infant, and *2*) in healthy pregnant women, maternal TFA intakes from unrestricted diets do not adversely affect their birth outcomes or the concentrations of AA or DHA in their newborn infants.

SUBJECTS AND METHODS

Subjects

Sixty pregnant women at 22–24 wk gestation were recruited from predelivery registration records and were followed up longitudinally until delivery. Another 24 women were recruited on admission to the low-risk delivery unit of the British Columbia Women's Hospital. Women who had medical or surgical problems that were likely to influence lipid metabolism or fetal growth or who had a communicable disease were not eligible to participate. The women who were not eligible included those with more than one fetus, hyperemesis, psychological or social problems, illicit drug or alcohol use, cardiac or renal disease, diabetes, epilepsy, respiratory or rheumatoid conditions, cholestasis, history of high blood cholesterol or triacylglycerol concentrations before pregnancy, HIV infection or AIDS, hepatitis, or tuberculosis. The study protocol was approved by the University of British Columbia's Clinical Screening Committee for Research and Other Studies Involving Human Subjects and the British Columbia Women's Hospital Research Coordinating Committee. All the participants provided written, informed consent.

Experimental procedures

Infant cord arterial blood samples were collected immediately after delivery of the infant, after clamping of the cord. Maternal blood samples were not collected at delivery because of the many variables in labor that might alter plasma lipids. Instead, maternal venous blood samples were collected at 35 wk gestation from the women who enrolled at 22–24 wk gestation. The subjects provided these samples at our hospital outpatient laboratory. The blood was collected into tubes containing EDTA as the anticoagulant. Length of gestation and infant sex, weight, length, and head circumference were recorded at birth.

Plasma lipids were extracted (31), lipid classes were separated by thin-layer chromatography (32), and the fatty acids were separated by using the methods of Ratnayake and Chen (33). We analyzed the fatty acid methyl esters with a Varian 3400 gas-liquid chromatograph (Varian Inc, Walnut Creek, CA) equipped with a 100 m × 0.25 mm nonbond fused silica SP2560 column (Supelco, Bellefonte, PA). The oven temperature was programmed to begin at 100°C for 2 min and then to increase to 150°C by 5°C/min. After 20 min, the temperature increased to 225°C by 1°C/min. This temperature was held for 2 min and then was increased to 245°C, which was maintained for 25 min. The injector and detector were kept at 250°C. The chromatography peaks were integrated by using a Varian Star Chromatography system (Varian Inc). Geometric and positional isomers of fatty acids were identified on the basis of comparisons of retention times with those of authentic standards (Sigma, St Louis) and analysis of partially hydrogenated and nonhydrogenated fats and oils and dairy fats. The CLAs identified were *cis*-9, *trans*-11; *trans*-9, *cis*-11; *cis*-10, *trans*-12; and *trans*-12, *cis*-10 18:2.

Molecular weights of the fatty acids were confirmed by using a Varian Saturn gas chromatograph ion-trap mass spectrometer (Varian Inc). This allows determination of molecular weights but does not allow confirmation of specific positional or geometric isomers of unsaturated fatty acids. For the purposes of this article, individual isomeric *trans* 16:1, 18:1, 18:2, and 18:3, other than those identified as CLAs, were summed and classified as TFAs. Our chromatographic conditions resulted in overlap of *trans*-12 to *trans*-16 18:1 with *cis* 18:1 (34). However, the most common 18:1 isomers in hydrogenated vegetable oils, foods containing these oils, and milk are the *trans*-6 to *trans*-11 isomers (34–36).

Dietary analysis

Maternal dietary intakes of energy, fat, and fatty acids were estimated by using a food-frequency questionnaire specifically designed to collect data on amounts and sources of fat, methods of food preparation, brand names, and places of food purchase. In addition, we purchased ≈400 foods available locally and nationally and analyzed their fat contents and fat compositions. These foods included individual foods, prepared meals, and fast foods. The fat and fatty acid data were entered into a nutrient database (FOOD PROCESSOR II, version 7; ESHA Research, Salem, OR) and the software was then used to analyze the dietary records.

Statistical analysis

Data were analyzed with SPSS (version 9.0 for WINDOWS; SPSS Inc, Chicago). Differences between maternal and infant fatty acid concentrations in plasma lipids were compared with Student's *t* tests when data were available for both the mother and the infant (n = 44). Regression analysis was used with results for mother-infant pairs (n = 44) to assess relations between maternal and infant fatty acid concentrations, between TFA concentrations and both n−6 and n−3 fatty acid concentrations, and between fatty acid concentrations and birth outcome measures. The statistical results did not change when we controlled for the concentrations of TFAs in analyses of the relations between birth outcome and individual n−6 and n−3 fatty acids and CLAs. $P < 0.05$ was considered statistically significant. All values are presented as means ± SEMs unless otherwise noted.

RESULTS

Birth measures and length of gestation

The mean infant birth weight was 3500 ± 56 g (range: 2035–4810 g) (n = 84) and the mean length of gestation was 40.0 ± 0.1 wk (range: 36–42 wk) (n = 83; the value was missing for one infant). Of the 83 infants for whom length of gestation

TABLE 1
Fatty acid composition of maternal plasma lipids at 35 wk gestation and of umbilical cord plasma lipids[1]

	Maternal plasma (n = 58)			Infant plasma (n = 70)		
Fatty acid	Triacylglycerol	Phospholipid	Cholesteryl ester	Triacylglycerol	Phospholipid	Cholesteryl ester
			% by wt of total fatty acids			
trans	3.99 ± 0.21	2.37 ± 0.10	1.57 ± 0.10	2.83 ± 0.19	0.67 ± 0.03	2.04 ± 0.01
	(1.26–7.90)	(1.12–4.47)	(0.64–3.70)	(0.63–12.79)	(0.11–1.33)	(0.86–4.24)
CLA	0.59 ± 0.03	0.32 ± 0.01	0.61 ± 0.06	1.29 ± 0.16	0.25 ± 0.01	0.69 ± 0.08
	(0.23–1.41)	(0.10–0.58)	(0.12–1.82)	(0.05–4.46)	(0.09–0.36)	(0.05–2.73)
LA (18:2n−6)	13.75 ± 0.49	20.8 ± 0.40	42.4 ± 0.69	10.1 ± 0.35	7.49 ± 0.15	15.6 ± 0.41
	(7.75–26.2)	(13.6–27.2)	(33.2–56.7)	(2.89–16.9)	(5.04–10.7)	(9.02–22.7)
ALA (18:3n−3)	1.21 ± 0.08	0.36 ± 0.02	1.02 ± 0.05	0.48 ± 0.02	0.05 ± 0.00	0.15 ± 0.01
	(0.42–3.75)	(0.17–0.75)	(0.05–2.62)	(0.15–0.96)	(0.02–0.18)	(0.00–0.47)
AA (20:4n−6)	0.88 ± 0.04	8.72 ± 0.17	5.31 ± 0.14	3.55 ± 0.16	17.7 ± 0.24	11.8 ± 0.36
	(0.47–2.12)	(5.55–11.8)	(2.48–8.37)	(0.99–7.26)	(13.8–23.0)	(2.1–17.4)
EPA (20:5n−3)	0.10 ± 0.01	0.52 ± 0.03	0.58 ± 0.05	0.31 ± 0.02	0.37 ± 0.02	0.33 ± 0.03
	(0.02–0.42)	(0.11–1.64)	(0.13–1.64)	(0.03–1.31)	(0.06–1.46)	(0.09–1.44)
DHA (22:6n−3)	0.52 ± 0.03	5.03 ± 0.17	0.69 ± 0.04	2.75 ± 0.15	7.62 ± 0.20	1.42 ± 0.06
	(0.23–1.40)	(2.84–8.11)	(0.05–1.31)	(0.47–5.90)	(4.35–11.7)	(0.49–3.09)

[1] $\bar{x}$ ± SEM; range in parentheses. CLA, conjugated linoleic acids; LA, linoleic acid; ALA, α-linolenic acid; AA, arachidonic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.

was known, 81 were born between 37 and 42 wk gestation and 2 were born at 36 wk gestation. The birth length of one infant was not recorded.

Blood sample collection

Cord blood samples were collected from all 24 infants born to the women recruited on admission to the low-risk delivery unit and from 46 of the 60 infants born to the women recruited at 22–24 wk gestation. Samples were not collected from the remaining 14 subjects because the medical staff did not identify the women as study participants or did not obtain a blood sample during deliveries that occurred when the research staff were not available.

Maternal diet

Maternal fat intake during pregnancy averaged 28.3 ± 0.7% (n = 60) and 27.5 ± 0.7% (n = 57) of total energy intake at 28 and 35 wk gestation, respectively. Also at 28 and 35 wk gestation, respectively, mean daily maternal intakes of fatty acids were 3.8 ± 0.3 and 3.4 ± 0.3 g TFAs, 29.7 ± 1.6 and 26.3 ± 1.3 g saturated fatty acids, 31.5 ± 1.8 and 26.4 ± 1.3 g monounsaturated fatty acids, and 13.6 ± 0.9 and 12.2 ± 0.6 g polyunsaturated fatty acids. Dietary intake of TFAs adjusted for total energy intake at 35 wk gestation was significantly related to the concentrations of TFAs in maternal plasma phospholipids (r = 0.39), triacylglycerol (r = 0.33), and cholesteryl esters (r = 0.34) ($P < 0.05$ for all).

Maternal and newborn infant plasma lipid fatty acids

The concentrations of TFAs, CLAs, and the major n−6 and n−3 fatty acids [LA, ALA, AA, eicosapentaenoic acid (EPA; 20:5n−3), and DHA] in maternal and infant plasma triacylglycerols, phospholipids, and cholesteryl esters are shown in **Table 1**. Mean TFAs accounted for 3.99 ± 0.21%, 2.37 ± 0.10%, and 1.57 ± 0.10% by wt of total fatty acids in maternal and 2.83 ± 0.19%, 0.67 ± 0.03%, and 2.04 ± 0.01% by wt of total fatty acids in infant plasma triacylglycerols, phospholipids, and cholesterol esters, respectively. However, the range of TFA concentrations was wide, with values as high as 7.90% and 12.79% in maternal and infant plasma triacylglycerols, respectively. The concentrations of TFAs, CLAs, LA, ALA, AA, EPA, and DHA in infant plasma lipids were all significantly different from the corresponding concentrations in maternal plasma lipids (**Table 2**, n = 44). Despite this, the concentrations of TFAs, CLAs, LA, ALA, AA, EPA, and DHA in maternal plasma phospholipids (**Figure 1**) were each significantly related to the concentration of the same fatty acid in infant plasma; the regression analyses were performed on matched mother-infant blood samples (n = 44). The maternal plasma triacylglycerol concentrations of AA, EPA, and DHA, but not TFAs or CLAs, were also each significantly related to the concentration of the same fatty acid in the infant plasma triacylglycerols ($P < 0.05$; n = 44; data not shown).

The TFA concentrations were significantly higher in the maternal than in the infant plasma triacylglycerols and phospholipids. However, the TFA concentrations in the plasma cholesteryl esters were higher in the infants than in their mothers ($P < 0.05$; n = 44). In contrast with TFAs, the mean concentration of CLAs in infant plasma triacylglycerols was 2-fold higher than the mean maternal value ($P < 0.05$). The mean concentration of AA was ≥2-fold higher in the infant plasma phospholipids, cholesteryl esters, and triacylglycerols than in the corresponding maternal plasma lipids ($P < 0.05$). Similarly, the mean concentration of DHA was consistently and significantly higher (1.5–5-fold) in the infant than in the maternal plasma lipids (Tables 1 and 2). In contrast, the LA and ALA concentrations were consistently lower in the infant than in the maternal plasma triacylglycerols, phospholipids, and cholesteryl esters ($P < 0.05$).

Analyses of potential relations in infant plasma between concentrations of TFAs and the n−6 and n−3 fatty acids measured showed that TFAs were inversely related to LA and DHA in triacylglycerols ($P < 0.001$ and $P < 0.05$, respectively) and to LA ($P < 0.01$) and AA ($P < 0.05$) in cholesteryl esters (**Table 3**). In contrast, in maternal plasma, concentrations of TFAs were inversely related to LA and ALA in triacylglycerols and to LA, ALA, AA, and DHA in cholesteryl esters.

Plasma lipid fatty acids and birth outcome

The infant plasma cholesteryl ester TFAs and CLAs and triacylglycerol CLA concentrations were all significantly and inversely related to the length of gestation (**Table 4**). The plasma

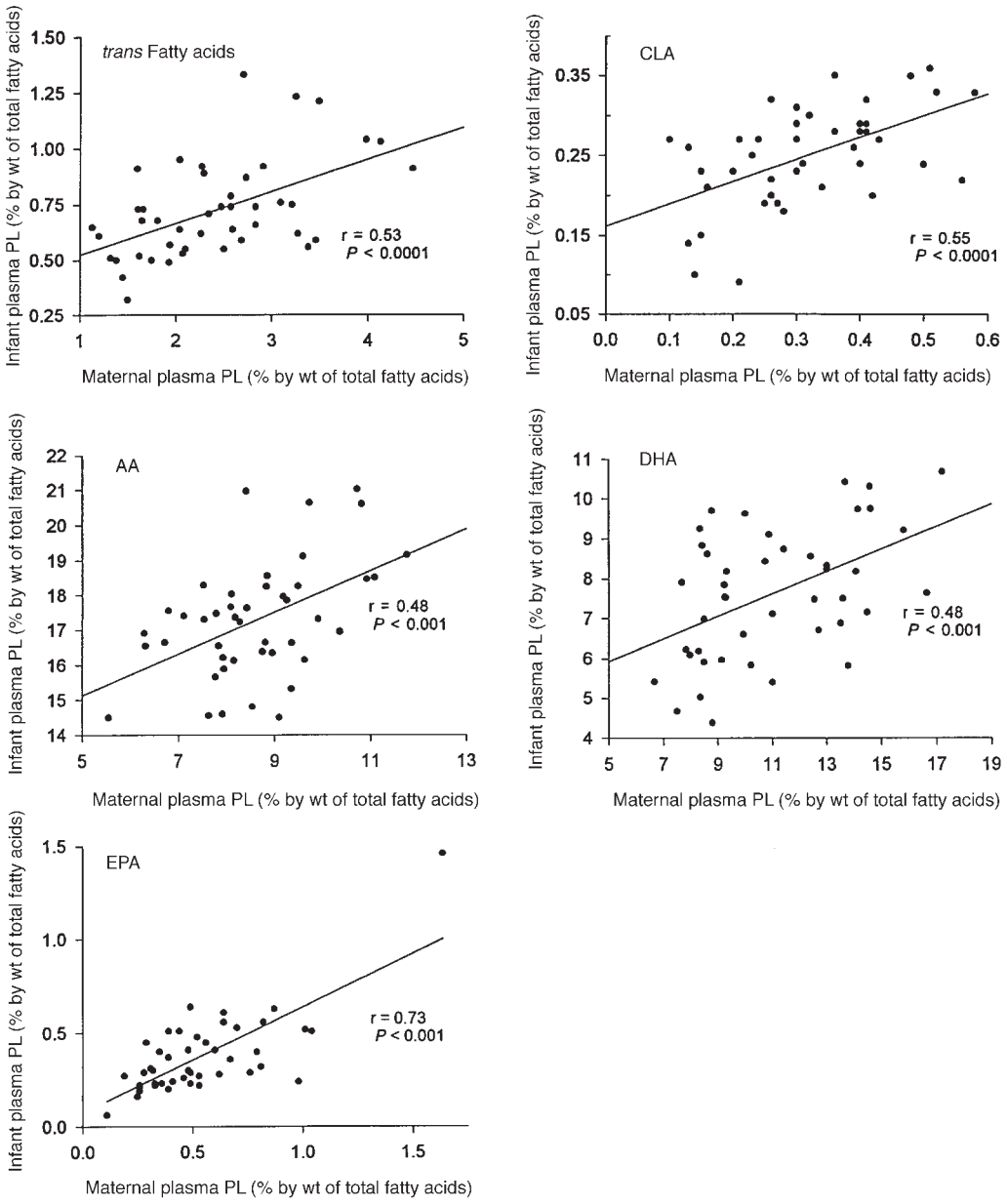

FIGURE 1. Relations between maternal and umbilical cord plasma phospholipid (PL) arachidonic acid (AA; 20:4n−6), eicosapentaenoic acid (EPA; 20:5n−3), docosahexaenoic acid (DHA; 22:6n−3), *trans* fatty acids, and conjugated linoleic acids (CLAs); $n = 44$ matched mother-infant pairs.

concentration of infant cholesteryl ester CLAs, but not TFAs, was also inversely related to infant birth weight and birth length. In contrast, the infant plasma triacylglycerol and cholesteryl ester AA concentrations were significantly and positively related to the length of gestation. Significant, positive relations were also found between infant plasma cholesteryl ester AA and infant birth weight and between triacylglycerol AA and infant birth weight and length (Table 4). No significant relations were found between infant plasma lipid EPA concentrations and length of gestation or infant birth length. Maternal plasma triacylglycerol AA, but not phospholipid or cholesteryl ester AA, was positively related to length of gestation, infant birth weight, and infant birth length ($P < 0.01$; results not shown). No significant relations were found between maternal plasma TFAs, CLAs, or the other n–3 and n–6 fatty acids that we measured and the length of gestation or infant birth weight or length.

DISCUSSION

The physiologic significance of TFAs in the maternal diet with regard to placental transfer or fetal metabolism of n−6 and n−3 fatty acids is uncertain. However, it is known that the infant's AA status and DHA status at birth are important predictors of later postnatal changes in AA and DHA in both breast-fed

TABLE 2
Fatty acid composition of maternal plasma lipids at 35 wk gestation and of umbilical cord plasma lipids at birth for the mother-infant pairs[1]

	Maternal plasma (n = 44)			Infant plasma (n = 44)		
Fatty acid	Triacylglycerol	Phospholipid	Cholesteryl ester	Triacylglycerol	Phospholipid	Cholesteryl ester
	% by wt of total fatty acids					
trans	4.03 ± 0.26	2.41 ± 0.12	1.61 ± 0.12	3.00 ± 0.16[2]	0.73 ± 0.03[2]	2.26 ± 0.13[2]
	(1.26–7.90)	(1.13–4.47)	(0.64–3.70)	(0.63–5.18)	(0.32–1.33)	(0.86–4.24)
CLA	0.57 ± 7.90	0.32 ± 0.02	0.58 ± 0.07	1.30 ± 0.17[2]	0.25 ± 0.01[2]	0.70 ± 0.083[2]
	(0.23–1.40)	(0.10–0.58)	(0.12–1.82)	(0.05–4.46)	(0.09–0.36)	(0.05–2.73)
LA (18:2n−6)	13.7 ± 0.60	20.9 ± 0.49	42.6 ± 0.83	9.36 ± 0.45[2]	7.27 ± 0.18[2]	14.9 ± 0.47[2]
	(7.75–26.2)	(13.6–27.2)	(33.2–56.7)	(2.89–16.9)	(5.36–9.57)	(8.70–22.62)
ALA (18:3n−3)	1.26 ± 0.10	0.37 ± 0.02	1.03 ± 0.06	0.45 ± 0.03[2]	0.04 ± 0.00[2]	0.14 ± 0.02[2]
	(0.61–3.75)	(0.17–0.75)	(0.05–2.62)	(0.15–0.88)	(0.02–0.18)	(0.00–0.47)
AA (20:4n−6)	0.87 ± 0.05	8.62 ± 0.26	5.24 ± 0.17	3.71 ± 0.21[2]	17.29 ± 0.25[2]	11.3 ± 0.46[2]
	(0.47–2.12)	(5.55–11.8)	(2.48–8.37)	(0.99–6.22)	(14.5–21.0)	(3.73–17.2)
EPA (20:5n−3)	0.09 ± 0.01	0.53 ± 0.04	0.60 ± 0.06	0.33 ± 0.04[2]	0.38 ± 0.03[2]	0.36 ± 0.04[2]
	(0.02–0.42)	(0.11–1.64)	(0.16–1.64)	(0.03–1.31)	(0.06–1.46)	(0.09–1.44)
DHA (22:6n−3)	0.54 ± 0.05	5.02 ± 0.21	0.67 ± 0.04	2.67 ± 0.20[2]	7.67 ± 0.25[2]	1.51 ± 0.09[2]
	(0.23–1.40)	(2.84–8.11)	(0.05–1.37)	(0.47–5.90)	(4.38–10.71)	(0.49–3.09)

[1] $\bar{x}$ ± SEM; range in parentheses. CLA, conjugated linoleic acids; LA, linoleic acid; ALA, α-linolenic acid; AA, arachidonic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.
[2] Significantly different from respective value in maternal plasma, $P < 0.05$ (Student's t test).

and formula-fed infants (23, 24) and that AA and DHA are positively related to infant growth and visual and neural development (2, 3, 5). Previous studies noted significant correlations between concentrations of elaidic acid (*trans* 18:1n−9, the major TFA in partially hydrogenated vegetable oils) in maternal total plasma lipids and in umbilical cord plasma obtained by transabdominal puncture (37) and between concentrations in maternal plasma and in cord blood total lipids at birth (38). Our study showed that the concentrations of CLAs, as well as those of TFAs from hydrogenated vegetable oils, in infant plasma are significantly related to the concentrations in maternal plasma and that the distributions of TFAs and CLAs differ among the plasma lipids and between the mother and the infant.

Furthermore, our study showed that although the mean concentrations of TFAs in plasma triacylglycerols were relatively low, at 2.83% and 3.99% in infants and mothers, respectively, the range was wide, with values as high as 12.79% and 7.90% in infants and mothers, respectively. Analyses of dietary data collected in the second and third trimesters of pregnancy showed that fat accounted for ≈28% of total energy intake and included ≈26–30 g polyunsaturated fat and 3.4–3.8 g TFAs/person daily. This suggests that the dietary fat intakes of the women in our study were relatively stable. The stable fat intakes of the women probably explain the highly significant relations between maternal and infant plasma concentrations of TFAs, CLAs, and n−6 and n−3 fatty acids, even though the maternal measurements (dietary and plasma) and infant measurements (plasma) were taken 2–5 wk apart.

Previous studies that showed inverse relations between birth weight and cord plasma phospholipid and cholesteryl ester *trans* 18:1 in premature infants (21) raised concerns that TFAs may interfere with fetal growth and essential fatty acid metabolism. Our study found a significant inverse relation between the newborn infant plasma concentration of TFAs in cholesteryl esters and the length of gestation, but we did not find any association between the infant plasma concentrations of TFAs and birth weight, birth length, or head circumference. Whether this reflects differences between preterm and term infants, methodologic differences, or other variables is not known.

We separated CLAs from all *cis* 18:2n−6 and other TFAs because the biological activities of CLAs may differ from those of TFAs formed by industrial hydrogenation. Our study provided new data showing that CLAs cross the human placenta; the data suggest possible unique or different handling of CLAs by the placenta or fetus. In contrast with other TFAs, the CLA

TABLE 3
Relations between concentrations of *trans* fatty acids and n−6 and n−3 fatty acids in plasma lipids of infants and mothers[1]

	Maternal plasma (n = 58)			Infant plasma (n = 70)		
	Triacylglycerol	Phospholipid	Cholesteryl ester	Triacylglycerol	Phospholipid	Cholesteryl ester
LA (18:2n−6)	−0.48[2]	−0.18	−0.63[2]	−0.40[2]	−0.06	−0.31[3]
ALA (18:3n−3)	−0.43[2]	−0.14	0.33[3]	−0.14	0.24	0.08
AA (20:4n−6)	−0.08	0.03	−0.31[4]	−0.08	0.05	−0.23[4]
EPA (20:5n−3)	−0.16	−0.15	−0.11	−0.06	−0.16	−0.22
DHA (22:6n−3)	−0.21	−0.12	−0.37[4]	−0.33[4]	−0.11	−0.08

[1] Values are Pearson's product-moment correlation coefficients (r) for the relation between *trans* fatty acids and the fatty acid listed. LA, linoleic acid; ALA, α-linolenic acid; AA, arachidonic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.
[2] $P < 0.001$.
[3] $P < 0.01$.
[4] $P < 0.05$.

TABLE 4
Relations between umbilical cord plasma lipid fatty acids and length of gestation, birth weight, and birth length[1]

	Triacylglycerol		Phospholipid		Cholesteryl ester	
	r	*P*	*r*	*P*	*r*	*P*
Length of gestation						
trans Fatty acids	−0.14	NS	−0.09	NS	−0.33	0.006
CLA	−0.42	0.004	0.08	NS	−0.49	0.001
AA	0.41	<0.0001	0.06	NS	0.37	0.002
EPA	0.13	NS	−0.09	NS	−0.19	NS
DHA	0.13	NS	0.16	NS	0.17	NS
Birth weight						
trans Fatty acids	−0.06	NS	−0.06	NS	−0.19	NS
CLA	0.25	NS	0.15	NS	−0.30	0.04
AA	0.27	0.02	0.04	NS	0.23	0.05
EPA	0.12	NS	0.05	NS	−0.19	NS
DHA	0.07	NS	0.05	NS	0.10	NS
Birth length						
trans Fatty acids	−0.03	NS	−0.12	NS	−0.11	NS
CLA	−0.40	0.006	0.17	NS	−0.33	0.03
AA	0.51	<0.0001	0.03	NS	0.23	NS
EPA	0.24	NS	0.03	NS	−0.07	NS
DHA	0.27	NS	0.22	NS	0.31	0.04

[1] Values are Pearson's product-moment correlation coefficients (*r*). $n = 70$ for length of gestation and birth weight; $n = 46$ for birth length. CLA, conjugated linoleic acids; AA, arachidonic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.

concentration in infant plasma triacylglycerol was 2-fold higher than that in maternal plasma. We also found significant inverse relations between infant plasma triacylglycerol CLAs and both length of gestation and infant birth length, and between cholesteryl ester CLAs and length of gestation, infant birth weight, and infant birth length.

On the basis of our analyses, we predict that for every 1% increase in infant plasma triacylglycerol CLAs, length of gestation would decrease by only 0.5 d (95% CI: 0.2, 0.8) and birth length would decrease by 1 cm (95% CI: 0.3, 1.5) but that for every 1% increase in cholesteryl ester CLAs, birth weight would decrease by 310 g (95% CI: 19, 600). The newborn infant plasma cholesteryl ester CLA concentration ranged from 0.1% to 2.7% by wt of total fatty acids, suggesting the potential for clinically important effects of CLAs on fetal growth. When fed in relatively high amounts, CLAs reduce body fat gain in animals (29, 30). However, this effect on lipid accretion was attributed to the *trans*-10, *cis*-12 18:2 isoform (30) rather than to the *cis*-9, *trans*-11 18:2 isoform that makes up almost all of the CLAs in dairy fats (25). This suggests that other dietary or lifestyle factors associated with high intakes of dairy fats during pregnancy, rather than CLA intake itself, may explain the inverse relations found in our study between CLAs and infant birth length and weight. Further studies are needed to determine whether the different CLA isoforms have biological activity relevant to fetal growth and to explain the apparent preferential assimilation of CLAs into fetal compared with maternal plasma triacylglycerols.

Our findings confirm the results of Crawford et al (39), who reported preferential accumulation of AA and DHA, with low concentrations of LA and ALA, in fetal plasma phospholipid. Despite probable placental selectivity for certain fatty acids, our results show significant positive relations ($P < 0.001$) between maternal and infant plasma phospholipid LA, ALA, AA, and DHA concentrations and provide evidence that fetal assimilation of n−6 and n−3 fatty acids is determined in part by the n−6 and n−3 fatty acid concentrations in maternal plasma lipids.

Consumption of n−3 fatty acids, specifically EPA from fish, was associated with an increase in the length of gestation of ≈4 d in women consuming 10.3 g supplemental n−3 fatty acids/d (40, 41). The suggested mechanism is that n−3 fatty acids inhibit synthesis of eicosanoids from AA that are involved in parturition. In our study, we found no evidence of a relation between length of gestation and EPA in the maternal or newborn infant plasma. However, this might be explained by the relatively low EPA status of all the women in this study.

The positive associations between AA and length of gestation, infant birth weight, and infant birth length in our study are of considerable interest. Length of gestation was positively related to AA concentrations in maternal plasma triacylglycerols ($P < 0.01$) and infant plasma triaclyglycerols ($P < 0.01$) and cholesteryl esters ($P < 0.05$). It is striking that Hoving et al (42) found similar positive relations between triacylglycerol and cholesteryl ester AA concentrations and length of gestation for infants born in the Netherlands. Relations between blood lipid AA concentrations and growth in preterm infants (2) were also reported, and AA is known to reverse the growth failure associated with deficiency of essential fatty acids (4). However, there is no known biological explanation for relations between triacylglycerol AA and cholesteryl ester AA, but not phospholipid AA, and length of gestation, infant birth weight, and infant birth length with diets providing LA in amounts greater than estimated dietary requirements.

It was suggested that TFAs might inhibit the desaturation of LA to AA and of ALA to DHA (9–14). A recent study showed reduced DHA concentrations in the total lipids of maternal and fetal liver and plasma, and reduced maternal liver Δ^6-desaturase activity in rats fed 14% or 30% TFAs with 19% LA and ≈2.5% ALA (13). However, other investigators suggested that inhibition of LA desaturation requires high concentrations of TFAs relative to LA, which are not relevant in usual human diets containing >2% of dietary energy as LA (43). On the basis of our dietary analysis, we estimated that daily intakes of all *cis* polyunsaturated fatty acids

and TFAs were ≈12–14 and 3.4–3.8 g/person, respectively, thereby providing much higher amounts of LA than of TFAs.

Our study found inverse associations between dietary TFAs and both DHA in triacylglycerols and AA in cholesteryl esters of newborn infant plasma and between dietary TFAs and both AA and DHA in maternal plasma cholesteryl esters. Δ^6-Desaturase acts preferentially on *cis* n−3 and n−6 fatty acids, as opposed to TFAs. In our study subjects, because the dietary intakes of all *cis* polyunsaturated fatty acids exceeded the intakes of TFAs, it seems reasonable to suggest that women with higher intakes of foods containing partially hydrogenated fats may have lower intakes of unhydrogenated polyunsaturated oils providing LA and ALA. Our data provide some evidence suggesting that this may be true, in that we found a significant inverse relation between TFAs and both LA and ALA in maternal plasma triacylglycerols and cholesteryl esters. More definitive studies of dietary intakes of different TFA isomers, including CLAs, and of n−6 and n−3 fatty acids and their relations to subsequent infant growth and development are needed to define appropriate dietary fat intakes during pregnancy.

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