ORIGINAL ARTICLE

Dietary trans fatty acid intake and maternal and infant adiposity

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Background/Objectives: The fatty acid composition in maternal diet and in breastmilk during lactation may be a factor in the development of childhood overweight later in life. To investigate the association between trans fatty acid and adiposity, 96 mother–infant pairs (exclusive breastfed; mixed fed; and formula fed) at 3 months postpartum were interviewed; body composition was measured onsite using the BOD POD and PEA POD for mothers and infants, respectively.

Subjects/Methods: This was a cross-sectional study. Participants were recruited via convenience sampling from Athens-Clarke and surrounding counties of the state of Georgia. Data were analyzed using χ^2 , analysis of variance and regression.

Results: There were no significant differences in maternal percent body fat by feeding group (32.70, 33.70, and 35.73%, for exclusive, mixed and formula feeding, respectively). Exclusively breastfed infants had higher percent body fat (24.87%) compared with their mixed-fed counterparts (22.15%) but not formula-fed infants (23.93). Mothers who consumed at least 4.5 g of trans fatty acids/day were 5.8 times more likely to have body fat $\geq 30\%$ than those consuming less (odds ratio = 5.81; 95% confidence interval (CI), 1.05, 32.32), and their infants were over two times more likely (odds ratio = 2.13; 95% CI, 0.75, 6.01) to have body fat $\geq 24\%$.

Conclusions: Trans fatty acid content of the maternal diet may be associated with both maternal and infant body composition in the early postpartum period. More research is warranted regarding maternal dietary and breastmilk fatty acid composition and their effects on maternal and infant body composition and the development of childhood overweight later in life.

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Introduction

Many prominent national and international organizations promote exclusive breastfeeding as the best method of infant feeding for the first 6 months after delivery for the general population because of the health benefits associated with this practice (World Health Organization, 1985; American Academy of Pediatrics, 2005; United States Department of Health Human Services, 2005). Maternal pregnancy weight gain above recommended amounts may lead to greater post-pregnancy weight retention and obesity (Kac *et al.*, 2004a, b). There is also evidence that overweight status of infants 6–11 months old has generally increased (Ogden *et al.*, 1997).

Although some studies have shown that the type of infant feeding affects the body composition of mothers and their infants, others have reported conflicting results (Dewey *et al.*, 1993; Butte *et al.*, 2000; Owen *et al.*, 2005; Stettler *et al.*, 2005). This suggests that other factors, such as fatty acid composition of maternal diet or breastmilk, together with infant feeding method, may act in synergy to affect the body composition of mothers and their infants.

Although breastmilk composition is relatively stable as a whole, the fatty acid composition of the maternal diet reflects the fatty acid composition of her breast milk (Francois *et al.*, 1998; Bahrani and Rahimi, 2005). These changes can occur hourly depending on the maternal eating pattern and diet composition (Francois *et al.*, 1998). One hypothesis by Aihaud and Guesnet (2004) states that changes in the fatty acid composition of ingested lipids, such as increasing intakes of omega-6 as opposed to ω -3 series, may contribute to the increasing prevalence of childhood overweight. Although human breastmilk provides optimal

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nutrition for infants, the majority of the energy content of breastmilk is provided by fatty acids (Neville and Picciano, 1997), and hence the importance of understanding the role of the individual fatty acids in the inconsistencies of results from studies examining the effect of infant feeding on overweight/obesity.

This study examines: (1) the association of infant feeding on the percent body fat (adiposity) of mothers and their infants and (2) the daily trans fatty acid intake of the mother and its association with the body composition of mother and infant at 3 months postpartum.

Materials and methods

This is a cross-sectional study conducted between January 2006 and June 2007. Participants were recruited through flyers posted at vantage points and by word of mouth from Athens-Clarke county and surrounding areas of the State of Georgia, United States. Potential subjects reported to the Maternal and Child Nutrition Research Laboratory, Department of Foods and Nutrition, University of Georgia, where they were informed of the study protocol. All study procedures were approved by the institutional review board of the University of Georgia, and participants provided a signed informed consent before participation.

To be eligible for this study, potential participants were required to: (1) be at least 18 years old; (2) have delivered a full-term baby (>36 weeks gestation) of normal birth weight (>2500 g); and (3) have an infant no more than 3 months old before recruiting. The inclusion of only full-term and normal-weight babies in the study was decided to avoid potential problems (type of care, feeding practice, admission to the neonatal intensive care unit and supplement use) associated with preterm and low-birth weight deliveries that are likely to confound our findings.

Based on the initial interview during the time of recruitment, participants were divided into one of three groups: exclusive breastfeeding (EBF), mixed feeding (MF) or exclusive formula feeding (FF). The interview collected extensive data on: (1) demographic information, (2) pregnancy/delivery and medical histories, (3) dietary intake (using Food Frequency Questionnaire and 24-h dietary recall), (4) physical activity, (5) alcohol intake and (6) infant feeding history. Participants also self-reported their newborn's date of birth and gestational age, birth weight and length, maternal pre-pregnancy weight and pregnancy weight gain. Information regarding supplement use was also obtained. The 24-h dietary recall was analyzed using the Nutrition Data System for Research software (Nutrition Coordinating Center, University of Minnesota, School of Public Health).

Upon completion of the interview, the mother-infant pairs had their anthropometric measurements taken (weight and height/length) and body composition measured. The BOD POD body composition system (version 2.30; Life

Measurement I, 1995) was used for mothers, whereas the PEA POD body composition system (version 1.8; Life Measurement, I, 2000) was used for infants. Both the BOD POD and PEA POD (Life Measurement Inc., Concord, CA, USA) use a two-compartment model to calculate fat and lean mass percentages from body density. Both the BOD POD and PEA POD body composition systems were calibrated according to the manufacturer's guidelines before each body composition measurement (Life Measurement, 1995, 2000).

Data analysis

The main outcome variables for this study were maternal and infant percent body fat (adiposity). Independent variables included maternal dietary fatty acid composition and infant feeding method. SPSS version 15.0 (SPSS Inc., Chicago, IL, USA) was used for data analysis. The subject characteristics are reported as means $\pm$ s.d. and percentages. The χ^2 analyses were used to examine bivariate associations between outcome and independent variables. Analysis of variance was used to compare differences in continuous variables between groups. Finally, we developed multivariate logistic regression analysis to determine the independent association of each independent variable on the outcome variable. The *P*-value of ≤ 0.05 (two sided) was used as a measure of statistical significance.

Results

A total of 96 mother-infant pairs participated in this study (EBF, *n* = 65; MF, *n* = 20; FF, *n* = 11). On the average, about 56% of the daily nutrient intake of MF infants came from breastmilk. The characteristics of study participants are presented in Table 1. Of the participants, 83.0% were non-Hispanic white, and 13.0 and 4.0% were black/African American and Hispanics, respectively. The mean birthweight and birth length was 3.47 kg and 51.80 cm, respectively (Table 1). There were no statistically significant differences between any of the infant feeding groups with regard to the means for gestational age, infant birth weight, infant birth length and maternal weight gain during pregnancy. There were no significant associations between maternal demographic characteristics and dietary intake.

Differences in pre-pregnancy weight were not significant with regard to the type of infant feeding; however, there was a trend for EBF mothers to be lighter than FF mothers (*P* = 0.051; Table 1). EBF mothers had a significantly lower mean pre-pregnancy body mass index (22.99 ± 3.54 kg/m²) compared with the FF (25.46 ± 2.89 kg/m²; *P* = 0.032) but not significantly different compared with the MF group (24.43 ± 5.25 kg/m²). At 3 months postpartum, EBF mothers (60%) tended to have a body mass index <25 kg/m² compared with MF (45%) and FF (27.3%) mothers ($\chi^2 = 4.716$; *P* = 0.095). The mean body mass index at 3 months postpartum for EBF mothers was 24.25 ± 3.54 kg/m²

Table 1 Characteristics of study participants ($N=96$)

Variables	All, $N=96$, mean $\pm$ s.d.	EBF, $n=65$, mean $\pm$ s.d. ^a	MF, $n=20$, mean $\pm$ s.d.	FF, $n=11$, mean $\pm$ s.d.
Maternal age (years)	29.89 $\pm$ 5.28	30.91 $\pm$ 5.04	27.6 $\pm$ 5.52 ($P=0.014$)	28.0 $\pm$ 4.86 (NS)
Years of formal schooling	16.88 $\pm$ 2.65	17.27 $\pm$ 2.25	16.30 $\pm$ 2.77 (NS)	15.64 $\pm$ 4.06 ($P=0.055$)
Pre-pregnancy weight (kg)	63.20 $\pm$ 9.81	62.29 $\pm$ 9.69	63.26 $\pm$ 10.65 (NS)	68.43 $\pm$ 7.97 ($P=0.051$)
Pre-pregnancy BMI	23.58 $\pm$ 3.96	22.99 $\pm$ 3.54	24.43 $\pm$ 5.25 (NS)	25.46 $\pm$ 2.89 ($P=0.032$)
Weight gain during pregnancy (kg)	15.40 $\pm$ 4.63	14.87 $\pm$ 4.21	16.57 $\pm$ 5.56 (NS)	16.41 $\pm$ 5.05 (NS)
Gestational age (weeks)	39.39 $\pm$ 1.12	39.54 $\pm$ 1.06	39.14 $\pm$ 1.33 (NS)	38.99 $\pm$ 0.96 (NS)
Infant birthweight (kg)	3.47 $\pm$ 0.42	3.50 $\pm$ 0.39	3.41 $\pm$ 0.54 (NS)	3.39 $\pm$ 0.41 (NS)
Infant birth length (cm)	51.80 $\pm$ 2.44	51.91 $\pm$ 2.41	51.08 $\pm$ 2.56 (NS)	52.42 $\pm$ 2.35 (NS)

Abbreviations: BMI, body mass index; EBF, exclusive breastfeeding; FF, exclusive formula feeding; MF, mixed feeding; NS, nonsignificant.

EBF was defined as giving the infant no water, formula or other food items except breastmilk since birth. MF was defined as giving some proportion of breastmilk and infant formula. FF was defined as having given nothing but infant formula (no breast milk) to the infant since birth.

^aEBF participants were used as the reference to compare the MF and FF participant groups.

Figure 1 Infant total body weight by type of feeding. EBF, exclusive breastfeeding; FF, formula feeding; MF, mixed feeding.

compared with $26.37 \pm 4.80 \text{ kg/m}^2$ ($P=0.035$) for MF mothers and $26.99 \pm 3.48 \text{ kg/m}^2$ ($P=0.020$) for FF mothers. EBF mothers had less mean percent body fat ($32.70 \pm 7.31\%$) compared with MF ($33.70 \pm 6.80\%$) and FF ($35.73 \pm 7.43\%$) mothers, although the differences were not statistically significant (Table 1).

Regarding the infants, there were no significant differences between type of feeding and birth weight or infant total weight at 3 months (Figure 1). Infant length at birth and at 3 months also did not significantly differ between feeding groups (data not shown). MF and FF infants tended to have slightly less percent body fat at 3 months compared with EBF infants (EBF: 24.87%; MF: 22.15%; FF: 23.93%), although the difference was not statistically significant.

Table 2 presents data on maternal total energy and nutrient intake from 24-h dietary recall. Total maternal caloric intake was highest whereas total fat intake was lowest among EBF mothers when compared with their MF and FF counterparts, although differences between the groups were not statistically significant. Intake of the individual fatty acids was very similar between the groups. The overall mean maternal trans fatty acid intake was $4.51 \pm 3.36 \text{ g}$ with

average intake lower among EBF mothers compared with MF and FF mothers (Table 2). Both intake of carbohydrate and total sugars were highest among EBF mothers when compared with their MF and FF counterparts, with the difference being statistically significant between EBF and FF (carbohydrate: $P=0.037$; sugars: $P=0.019$) but not MF mothers. The difference in the intake of calcium ($P=0.009$) and iron ($P=0.003$) was significantly different between EBF and MF mothers but not their FF counterparts (Table 2).

Tables 3 presents associations between selected independent variables and maternal and infant percent body fat. Results from the univariate linear regression analyses show significant inverse relationship between maternal total energy, carbohydrate, fiber, total sugars and eicosapentaenoic acid with maternal percent body fat at 3 months postpartum. There were significant positive associations between maternal total energy intake, total fat intake and several of the fatty acids with percent body fat at 3 months of infants who were either EBF or MF. Maternal carbohydrate intake was inversely associated with body fat percentage (Table 3) of infants who were either EBF or MF. Ethnicity was inversely associated with infant body fat percent with Black (22.43%) and Hispanic (18.23%) infants having a lower percent body fat compared with their Caucasian (24.75%) counterparts at 3 months postpartum.

For the multivariate linear regression analyses with maternal percent body fat as the outcome of interest, the only significant predictor ($R^2=0.917$; $P=0.005$) was the total weight of the mother at delivery after adjusting for covariates from Table 3. However, when maternal total body weight at 3 months postpartum was used as the dependent variable, pre-pregnancy weight, total weight at delivery, total energy intake and percent energy from carbohydrate, fat, polyunsaturated fatty acids and monounsaturated fatty acids were significant predictors ($R^2=0.920$; $P<0.001$) after adjusting for other covariates (Table 4).

In a multivariate logistic regression analysis where maternal percent body fat was dichotomized ($<30\%$ and $\geq 30\%$) as the dependent variable, mothers consuming $>4.5 \text{ g}$ of trans fatty acid per day were over five times

Table 2 Distribution of maternal nutrient intake by infant feeding group

	All, N = 96, mean $\pm$ s.d.	EBF, n = 65, mean $\pm$ s.d.	MF, n = 20, mean $\pm$ s.d.	FF, n = 11, mean $\pm$ s.d.
Total energy (kcal)	1838.89 $\pm$ 644.67	1889.73 $\pm$ 702.49	1792.80 $\pm$ 429.59	1622.26 $\pm$ 605.45
Fat (g)	67.72 $\pm$ 29.29	67.20 $\pm$ 29.03	68.75 $\pm$ 24.88	68.97 $\pm$ 39.71
Carbohydrate (g)	241.36 $\pm$ 89.98	252.63 $\pm$ 100.47	230.28 $\pm$ 55.43	194.90 $\pm$ 55.08
Protein (g)	72.53 $\pm$ 31.99	75.65 $\pm$ 35.14	69.79 $\pm$ 24.68	59.03 $\pm$ 19.54
Cholesterol (mg)	236.28 $\pm$ 158.28	236.18 $\pm$ 164.84	251.48 $\pm$ 144.71	209.24 $\pm$ 151.84
Saturated fat (g)	24.83 $\pm$ 12.62	25.27 $\pm$ 13.40	25.14 $\pm$ 10.20	21.67 $\pm$ 12.38
Trans fatty acid (g)	4.51 $\pm$ 2.98	4.25 $\pm$ 2.86	5.21 $\pm$ 3.50	4.77 $\pm$ 2.71
MUFA (g)	25.36 $\pm$ 10.18	24.98 $\pm$ 9.73	25.99 $\pm$ 8.95	26.41 $\pm$ 14.94
PUFA (g)	13.25 $\pm$ 7.89	13.03 $\pm$ 7.71	12.57 $\pm$ 6.42	15.80 $\pm$ 11.10
Fiber (g)	18.82 $\pm$ 8.15	20.12 $\pm$ 9.00 ^a	16.01 $\pm$ 5.69 ^a	16.22 $\pm$ 4.24
Sugars (g)	105.77 $\pm$ 58.04	111.40 $\pm$ 64.55 ^b	107.41 $\pm$ 37.49 ^{b†}	69.50 $\pm$ 31.73 [‡]
Calcium (mg)	872.86 $\pm$ 444.59	941.43 $\pm$ 490.32 ^c	796.35 $\pm$ 278.86 ^{c*}	606.74 $\pm$ 266.79 [*]
Iron (mg)	15.77 $\pm$ 6.68	16.84 $\pm$ 7.39 ^d	14.61 $\pm$ 4.04 ^{d‡}	11.52 $\pm$ 3.71 [‡]
Vitamin D (IU)	245.66 $\pm$ 236.28	269.77 $\pm$ 213.64	235.31 $\pm$ 218.19	122.00 $\pm$ 92.14
Linoleic acid (g)	11.57 $\pm$ 6.96	11.41 $\pm$ 6.71	10.57 $\pm$ 5.48	14.31 $\pm$ 10.20
α -linolenic acid (g)	1.21 $\pm$ 0.93	1.19 $\pm$ 0.94	1.23 $\pm$ 0.72	1.29 $\pm$ 1.23

Abbreviations: EBF, exclusive breastfeeding; FF, exclusive formula feeding; MF, mixed feeding; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid.

^aP = 0.058; ^bP = 0.039; ^cP = 0.031; ^dP = 0.023; [†]P = 0.008; ^{*}P = 0.076; [‡]P = 0.045.

Table 3 Univariate linear regression: factors associated with percent body fat at 3 months postpartum (N = 96)

Variable	Standardized coefficient	95% CI	P-value
Mother			
Total energy	-0.327	-0.006, -0.001	0.001
% Energy from CHO	-0.316	-0.412, -0.098	0.002
Total CHO (g)	-0.440	-0.050, -0.021	<0.0001
Fiber (g)	-0.316	-0.451, -0.108	0.002
Sugars (g)	-0.386	-0.071, -0.024	<0.0001
% Energy from fat	0.273	0.072, 0.442	0.007
% Energy from MUFA	0.331	0.246, 1.196	0.002
EPA (g)	-0.246	-13.265, -595	0.027
Calcium (mg)	-0.287	-0.008, -0.001	0.005
Maternal total body weight	0.746	0.443, 0.642	<0.0001
Pre-pregnancy BMI	0.671	0.946, 1.500	<0.0001
Pre-pregnancy weight	0.656	0.369, 0.596	<0.0001
Infant			
Total energy (kcal)	0.241	0.000, 0.003	0.018
Total fat intake (g)	0.274	0.013, 0.077	0.007
Saturated fat intake (g)	0.273	0.029, 0.179	0.007
MUFA intake (g)	0.258	0.028, 0.215	0.011
PUFA intake (g)	0.172	-0.018, 0.228	0.095
LA:ALA ratio (≥ 11)	0.186	-0.520, 12.961	0.070
% Energy from CHO	-0.204	-0.218, -0.002	0.047
Fiber intake (g)	0.207	0.004, 0.240	0.043
Calcium intake (mg)	0.101	-0.001, 0.003	NS
Number of servings of fish or shellfish per week (> 2)	0.290	0.123, 5.830	0.004
Maternal age	0.187	-0.013, 353	0.068
Black and Hispanic	-0.299	-5.908, -0.834	0.005

Abbreviations: ALA, α -linolenic acid; BMI, body mass index; CHO, carbohydrate; CI, confidence interval; EPA, eicosapentaenoic acid; LA, linoleic acid; MUFA, monounsaturated fatty acid; NS, nonsignificant; PUFA, polyunsaturated fatty acid.

(odds ratio = 5.81; 95% confidence interval (CI), 1.05, 32.32) more likely to have excess body fat than those consuming less amounts (Table 5). Pre-pregnancy weight and pregnancy

Table 4 Multivariate linear regression: predictors of maternal total body weight at 3 months postpartum (N = 96)

Variable	Standardized coefficient	P-value
Pre-pregnancy weight (kg)	0.401	0.001
Total weight at delivery (kg)	0.525	<0.001
Total energy (kcal)	-0.148	0.036
% Energy from CHO	-0.118	0.043
% Energy from fat	-0.338	<0.001
% Energy from PUFAs	0.111	0.011
% Energy from MUFAs	0.258	0.001
Total calcium intake (mg)	0.107	0.078

Abbreviations: CHO, carbohydrate; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid.

$R^2 = 0.920$; $P < 0.001$.

Adjusted for pre-pregnancy BMI, infant feeding method, ethnicity, physical activity score and sugar intake.

weight gain also came out as significant risk factors, whereas total sugar intake had a slight protective effect for excess maternal body fat at 3 months postpartum after adjusting for a number of covariates (Table 5).

For infants, the multivariate logistic regression analysis was conducted only with infants who were either exclusively breastfed or mixed fed to 3 months postpartum to examine the association between maternal dietary trans fatty acid intake and infant percent body fat dichotomized ($< 24\%$ body fat and $\geq 24\%$ body fat). Infants of mothers aged ≥ 30 years were significantly more likely to have a body fat percentage $> 24\%$ (odds ratio = 4.20; 95% CI, 1.44, 12.29). Also, infants of mothers who consumed > 4.5 g trans fatty acid per day were two times more likely to have a higher percent body fat compared with their counterparts whose mothers consumed less, although this was not significant after adjusting for important covariates (Table 5). Infant birthweight was also a significant independent

Table 5 Multivariate logistic regression of independent predictors of percent body fat $\geq 30\%$ ($N = 96$)

Variable	Odds ratio	95% CI
Mother^a		
Trans fat intake		
> 4.5 g	5.81	1.05, 32.32
≤ 4.5 g	1.00	
Pre-pregnancy weight	1.38	1.17, 1.63
Weight gain during pregnancy	1.24	1.19, 1.52
Sugar intake	0.96	0.91, 0.99
Infant^b		
Maternal age		
≥ 30 years	4.20	1.44, 12.29
< 30 years	1.000	
Infant birth weight	6.54	1.70, 25.13
Trans fat intake		
> 4.5 g	2.13	0.75, 6.01
≤ 4.5 g	1.000	

^aHosmer and Lemeshow test of good fit: $\chi^2 = 4.194$; $P = 0.839$. Adjusted for marital status, physical activity, parity, total energy intake, fat intake, type of infant feeding, maternal age, pre-pregnancy BMI and ethnicity.

^bHosmer and Lemeshow test of good fit: $\chi^2 = 13.314$; $P = 0.065$. Adjusted for type of infant feeding, total maternal fat intake, total maternal energy intake, maternal pre-pregnancy BMI, pre-pregnancy weight and pregnancy weight gain.

predictor of higher infant percent body fat at 3 months postpartum, with infant born higher birthweight having higher body fat (Table 5).

Discussion

Our study sample consisted primarily of older, highly educated non-Hispanic white women. The mean pre-pregnancy body mass index was within the healthy range and the mean total weight gain during pregnancy (15.40 ± 4.63 kg) was near the upper limit of the recommended weight gain range for normal-weight women (25–35 lb; 11.36–15.90 kg) (Institute of Medicine, 2009). Regarding the effect of infant feeding practice on adiposity, no statistically significant associations were found between EBF, MF, FF mothers and maternal percent body fat in this study. This observation confirms findings from other cross-sectional studies that did not find significant associations between the choice of infant feeding and maternal overweight/obesity (Potter *et al.*, 1991).

Although several researchers have reported that breastfeeding, especially for longer duration, protects against obesity later in life, a mechanism is yet to be determined. Speculation has been focused mainly on child feeding practices and self-regulation of energy intake by the breastfed child (Koletzko and Rodriguez-Palmero, 1999; Bogen *et al.*, 2004; Grummer-Strawn and Mei, 2004; Anderson *et al.*, 2005; Aihaud *et al.*, 2006). Aihaud *et al.*

(2006) have also attributed the risk of breastmilk to overweight and obesity in later life to its fatty acid content. The fatty acid composition of human milk is reported to be influenced by maternal dietary fatty acid composition (Anderson *et al.*, 2005; Bahrami and Rahimi, 2005; Koletzko *et al.*, 2005). Although the fatty acid composition of infant formula differs from breastmilk, it remains constant over time, whereas the fatty acid composition of human milk varies greatly from one mother to another and even within a breastfeeding episode (Koletzko and Rodriguez-Palmero, 1999; Koletzko *et al.*, 2005). Polyunsaturated fatty acids have been implicated as the possible culprit in relation to fatty acid composition and adiposity because of their effect on gene expression. Linoleic acid has been shown to be possibly adipogenic, especially during the gestation and lactation period, whereas α -linolenic acid may promote lipid oxidation (Sampath and Ntambi, 2005; Aihaud *et al.*, 2006; Simopoulos, 2006). We did not observe significant association between linoleic acid, α -linolenic acid, and their ratio and adiposity in this study as previously reported by others (Blankson *et al.*, 2000; Mougios *et al.*, 2001; Smedman and Vessby, 2001; Gaullier *et al.*, 2004, 2007; Aihaud *et al.*, 2006; Li *et al.*, 2008). Most of these studies reported a significant reduction in body fat mass in overweight and obese individuals who received linoleic acid and α -linolenic acid or their isomers (Blankson *et al.*, 2000; Mougios *et al.*, 2001; Gaullier *et al.*, 2004, 2005, 2007). However, our finding of no significant association between these fatty acids and maternal percent body fat confirms observations from other studies (Blankson *et al.*, 2000; Kamphuis *et al.*, 2003; Malpuech-Brugere *et al.*, 2004). Our inability to observe significant associations between these fatty acids and maternal percent body fat may be because of our use of early postpartum women and the cross-sectional nature of the study where dietary intake was assessed only once. In our multivariate analysis, daily trans fatty acid intake > 4.5 g, and higher pre-pregnancy weight and pregnancy weight gain independently predicted higher maternal percent body fat at 3 months postpartum after adjusting for a number of covariates (Table 4). This observation is of great public health importance as excess intake of trans fatty acid and body fat are linked with coronary heart diseases (Mozzafarian *et al.*, 2006; Sun *et al.*, 2007; Woodside *et al.*, 2008; Mente *et al.*, 2009) and other chronic diseases (Lichtenstein *et al.*, 1998; Mello, 2009). It is therefore important for women to guard against the consumption of foods high in trans fatty acids in order to reduce their risk of excess deposition of body fat and the associated health problems.

EBF infants had significantly higher body fat percentages when compared with the MF but not the FF group at 3 months of age. A study by Butte *et al.* (2000) also found that breastfed infants had higher fat mass and body fat percentages when compared with formula-fed infants at 3 months of age despite 15–20% higher energy intakes among the formula-fed infants. In that study, the difference in adiposity between breastfed and formula-fed infants was

only seen earlier in infancy and disappeared once complementary foods were introduced into the infants' diets.

Overall, the results of this study suggest that maternal dietary trans fatty acid intake may influence adiposity of both mothers and their infants. This observation calls for closer look at the trans fatty acid content in the maternal diet, especially during the period of breastfeeding, to prevent the risk of excess adiposity and the associated chronic diseases later in life. As reported by previous studies, higher pre-pregnancy weight and excessive total weight gain during pregnancy are risk factors for increased maternal adiposity (Brewer *et al.*, 1989; Ogden *et al.*, 1997; Butte and Hopkinson, 1998; Gunderson *et al.*, 2000a, b; Kac *et al.*, 2004a, b), but the present study also found that higher intakes of trans fatty acid (>4.5 g per day) increased the risk of excessive adipose tissue in mothers 3 months postpartum independently of pre-pregnancy weight and pregnancy weight gain. Interestingly, the influence of higher trans fatty acid intake was greater than that of pre-pregnancy weight and pregnancy weight gain in increasing the risk of maternal percent body fat $\geq 30\%$. The odds of higher trans fatty acid intake in increasing maternal percent body fat is over five times compared with 1.38 and 1.24 for pre-pregnancy weight and pregnancy weight gain, respectively. This finding was significant irrespective of infant feeding practice and independent of total caloric intake. What this suggests is that the content of a mother's diet in terms of trans fatty acid intake is a stronger predictor of maternal percent body fat than both pre-pregnancy weight and pregnancy weight gain. This calls for nutrition education by health-care providers to help postpartum women select healthy nutritious foods low in trans fatty acids. Women with body fat percentages $\geq 30\%$ may be at an increased risk for various health conditions such as heart disease and diabetes (Fontaine *et al.*, 2003), hence the need for mothers to restrict their trans fatty acid intake.

Higher maternal intakes of trans fatty acids also predicted higher body fat percentages in breastfed infants. Breastfed infants of mothers consuming >4.5 g per day of trans fatty acids were over two times more likely to have higher body fat percentages at 3 months postpartum compared with infants of mothers who consumed less than this amount. Although this observation was no longer significant after adjusting for important covariates, it needs further investigating. The current recommendation regarding trans fatty acid intake is to consume no more than 1% of the total daily calories from trans fatty acid according to the American Heart Association (American Heart Association Nutrition Committee, 2006). Interestingly, our study revealed no significant results when percentage of maternal energy from trans fatty acid was inserted into the model. It will therefore be important for future studies to measure the actual trans fatty acid content of breastmilk to ascertain if this actually affects the adiposity of the infant at that early age. Mothers consuming >4.5 g per day of trans fatty acid (but not percent trans fatty acid of total caloric intake) were at an increased risk of excess maternal and infant body fat irrespective of caloric or total

fat intake. Other factors increasing the risk of higher infant adiposity were infants of older mothers (>29 years old) and infants with higher birth weights. The ability to quantitatively link trans fatty acid content of breastmilk to the weight and adiposity of the infant will further aid our understanding of the inconsistencies in the literature regarding whether or not breastfeeding protects against childhood and later-life overweight/obesity.

A 2005 study in Iran found that increased maternal intakes of trans fatty acids leads to increased amounts of trans fatty acids in the breastmilk (Bahrami and Rahimi, 2005). Other studies have also reported strong correlations between maternal and infant plasma trans fatty acid concentrations (Koletzko and Muller, 1990; Craig-Schmidt, 2001). To the best of our knowledge, no study has directly examined the influence or association between maternal trans fatty acid intake and early postpartum infant adiposity. Our current observation of higher intake of maternal dietary trans fatty acid intake predicting higher infant percent body fat at 3 months postpartum contributes to the literature of the negative association between trans fatty acid and human health.

In spite of the present trend of increasing childhood overweight and chronic diseases, it is of public health interest to limit the trans fatty acid content of maternal diet, especially during the period of breastfeeding, to protect health. In general, infant formulas contain less trans fatty acids than typical human milk (Koletzko, 1989). This may explain the differences in infant adiposity as reported by Butte *et al.* (2000) during the early postpartum period.

The lack of statistical significance between a number of fatty acid components and maternal and infant adiposity compared with previous studies could be attributed to our smaller sample size, use of convenience sample and the cross-sectional design employed in this study. Another important limitation of this study is that EBF mothers were more educated, non-Hispanic white, healthier and ate healthy as reflected in their trans fatty acid and other nutrient intakes compared with the other groups.

Our findings suggest that the adiposity of breastfed infants and their mothers may be influenced by the trans fatty acid content of maternal diet. Therefore, maternal dietary fatty acid composition may influence the development of excess adipose tissue in breastfed infants as well as mothers in the early postpartum months. Findings from this study should be interpreted with great caution as this is a cross-sectional study, has unequal group size and lacks quantitative measure of breastmilk fatty acid concentrations. Further studies are required to prospectively assess the effect of maternal intake and breastmilk concentration of trans fatty acid on childhood adiposity and overweight.

Conflict of interest

The authors declare no conflict of interest.

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