British Journal of Nutrition (2009), **101**, 1761–1768
doi:10.1017/S0007114508123455

Ethnic differences in early pregnancy maternal *n*-3 and *n*-6 fatty acid concentrations: an explorative analysis

Manon van Eijsden[1,2]*, Gerard Hornstra[3], Marcel F. van der Wal[1] and Gouke J. Bonsel[4]

[1]*Department of Epidemiology, Documentation and Health Promotion, Public Health Service of Amsterdam, Amsterdam, The Netherlands*
[2]*Department of Social Medicine, Public Health Epidemiology, Academic Medical Centre, University of Amsterdam, Amsterdam, The Netherlands*
[3]*Nutrition and Toxicology Research Institute Maastricht, Maastricht University, Maastricht, The Netherlands*
[4]*The Institute Health Policy and Management, Erasmus Medical Centre, Rotterdam, The Netherlands*

(Received 3 March 2008 – Revised 22 September 2008 – Accepted 25 September 2008 – First published online 5 November 2008)

Ethnicity-related differences in maternal *n*-3 and *n*-6 fatty acid status may be relevant to ethnic disparities in birth outcomes observed worldwide. The present study explored differences in early pregnancy *n*-3 and *n*-6 fatty acid composition of maternal plasma phospholipids between Dutch and ethnic minority pregnant women in Amsterdam, the Netherlands, with a focus on the major functional fatty acids EPA (20 : 5*n*-3), DHA (22 : 6*n*-3), dihomo-γ-linolenic acid (DGLA; 20 : 3*n*-6) and arachidonic acid (AA; 20 : 4*n*-6). Data were derived from the Amsterdam Born Children and their Development (ABCD) cohort (inclusion January 2003 to March 2004). Compared with Dutch women (*n* 2443), Surinamese (*n* 286), Antillean (*n* 63), Turkish (*n* 167) and Moroccan (*n* 241) women had generally lower proportions of *n*-3 fatty acids (expressed as percentage of total fatty acids) but higher proportions of *n*-6 fatty acids (general linear model; $P<0{\cdot}001$). Ghanaian women (*n* 54) had higher proportions of EPA and DHA, but generally lower proportions of *n*-6 fatty acids ($P<0{\cdot}001$). Differences were most pronounced in Turkish and Ghanaian women, who, by means of a simple questionnaire, reported the lowest and highest fish consumption respectively. Adjustment for fish intake, however, hardly attenuated the differences in relative EPA, DHA, DGLA and AA concentrations between the various ethnic groups. Given the limitations of this observational study, further research into the ethnicity-related differences in maternal *n*-3 and *n*-6 fatty acid patterns is warranted, particularly to elucidate the explanatory role of fatty acid intake *v.* metabolic differences.

Long-chain polyunsaturated fatty acids: Ethnic groups: Pregnancy: Amsterdam Born Children and their Development study

Throughout the world, large ethnic disparities in the birthweight distribution can be observed, with the lowest birth weights and highest proportion of intra-uterine growth restriction usually being found in minority populations[1–3]. Existing evidence of nutritional differences between ethnic groups[4–7] suggests that maternal nutrition may be one of the factors contributing to these disparities.

Among the nutritional factors considered relevant to fetal growth, the maternal *n*-3 and *n*-6 long-chain PUFA EPA (20 : 5*n*-3), DHA (22 : 6*n*-3), dihomo-γ-linoleic acid (DGLA; 20 : 3*n*-6) and arachidonic acid (AA; 20 : 4*n*-6) have increasingly gained interest in the past few decades. DGLA, AA and EPA are precursors of the PG 1, 2 and 3 series respectively, a series of hormone-like substances involved in a range of pregnancy-related processes that include placental blood flow, cervix-ripening and initiation of parturition[8,9]. DHA, as well as AA, are major components of neural tissue in particular[10,11].

Recently, we have shown that the maternal *n*-3 long-chain PUFA status (reflected by maternal plasma phospholipid *n*-3 long-chain PUFA concentrations) in early pregnancy was positively associated with fetal growth[12], which was confirmed, for DHA, in a different cohort study[13]. For the *n*-6 long-chain PUFA AA and DGLA contrasting results were observed, with AA being negatively[12,13] and DGLA being positively associated with birth weight[12]. While this evidence suggests a role for the *n*-3 and *n*-6 fatty acids in the ethnicity-related disparities in perinatal health, few studies have investigated ethnicity-related differences in maternal fatty acid status. The present study is the first large-scale observational study to explore the within-country ethnic differences in maternal early pregnancy *n*-3 and *n*-6 fatty acid status (with a focus on the major functional long-chain PUFA DGLA, AA, EPA and DHA), taking into account maternal factors relevant to fatty acid metabolism[14–20] and dietary intake (i.e. fish and fish oil consumption)[21–24]. Data were derived from a large, unselected multi-ethnic cohort in Amsterdam, the Netherlands. In this population, considerable ethnic disparities in birth weight have been observed that could not be explained by conventional physiological and environmental

Abbreviations: AA, arachidonic acid; ABCD, Amsterdam Born Children and their Development; DGLA, dihomo-γ-linolenic acid.

* **Corresponding author:** Dr Manon van Eijsden, fax +31 20 5555160, email mveijsden@ggd.amsterdam.nl

risk factors, such as maternal age, height, parity, BMI and smoking habits[25].

Methods

Study population and design

The Amsterdam Born Children and their Development (ABCD) study is a prospective community-based cohort study that examines the relationship between maternal lifestyle and psychosocial conditions during pregnancy and the child's health at birth as well as in later life. The essentials of the study design have been described previously[12,26]. In short, between January 2003 and March 2004, all pregnant women living in Amsterdam were invited to enrol in the ABCD study during their first prenatal visit to their obstetric care provider (about the 12th week of gestation). They were requested to complete a questionnaire, covering sociodemographic data, obstetric history, lifestyle, dietary habits and psychosocial factors. The questionnaire was available in Dutch as well as in English, Turkish and Arabic for immigrant women. In addition, women were invited to participate in the ABCD biomarker study. For this study, an additional blood sample was taken during routine blood collection for screening purposes following the first prenatal check-up.

Of the 12 373 pregnant women invited to participate, 8266 returned the pregnancy questionnaire (response rate 67 %). Of these respondents, 53 % (*n* 4389) participated in the biomarker study. Approval of the study was obtained from the Medical Ethical Committees of participating hospitals and the Registration Committee of Amsterdam, and participants gave written informed consent.

Blood collection and analytical methods

For each participant of the biomarker study, a blood sample was taken in a 10 ml EDTA (K2) Vacutainer (Becton and Dickinson BV, Alphen aan de Rijn, the Netherlands) and sent to the Regional Laboratory of Amsterdam for processing. The samples were sent by courier or overnight mail in special envelopes, enabling processing within 28 h of sampling. A previous study of our group demonstrated that this delay did not compromise the validity of the biomarkers measured[27]. At the laboratory, plasma was prepared by centrifugation (1600 ***g*** for 10 min at room temperature) and stored as 1 ml samples at −80°C until analysis.

Fatty acid analysis was performed at the Analytical Biochemical Laboratory (Assen, the Netherlands) using a previously described methodology[28,29]. In short, after the addition of an internal standard (1,2-dinonadecanoyl-*sn*-glycero-3-phosphocholine) and 10-heptadecenoic acid (17 : 1) to check for carry-over of NEFA during the isolation procedure, plasma lipid extracts were prepared by a modified Folch extraction method[30] and phospholipids were isolated by solid-phase extraction on aminopropyl-silica columns (500 mg/3 ml; Varian, Palo Alto, CA, USA)[31]. Subsequently, the phospholipids were hydrolysed and the resulting fatty acids methylated with boron trifluoride–methanol[32]. Finally, the fatty acid methyl esters were quantified by capillary GC with flame ionisation detection (HP5890 series II; Hewlett Packard, Palo Alto, CA, USA), using both a polar and a non-polar column (BPx70 and BP1 respectively; SGE Analytical Science Pty Ltd, Ringwood, Victoria, Australia). The oven temperature was programmed to begin at 160°C for 4 min, and then to increase to 200°C by 6·0°C/min. After 3 min, the temperature was further increased to 260°C at a rate of 7°C/min, and kept constant for 2·34 min. The injector temperature was kept at 250°C and the detector temperature at 300°C.

Absolute amounts of fatty acids (mg/l plasma) were quantified on the basis of recovery from the internal standard and calculated in relative values (percentage of total plasma phospholipid-associated fatty acids). The present study focused only on the *n*-3 and *n*-6 fatty acids and included the *n*-3 fatty acids α-linolenic acid (18 : 3*n*-3), eicosatetraenoic acid (20 : 4*n*-3), EPA (20 : 5*n*-3), docosapentaenoic acid (22 : 5*n*-3) and DHA (22 : 6*n*-3), and the *n*-6 fatty acids linoleic acid (18 : 2*n*-6), DGLA (20 : 3*n*-6), AA (20 : 4*n*-6), adrenic acid (22 : 4*n*-6) and Osbond acid (22 : 5*n*-6). Most fatty acids were determined by analysis using the apolar column; for 18 : 3*n*-3, 20 : 5*n*-3 and 22 : 5*n*-6, data obtained with the polar column were used. Inter-assay CV for the fatty acids varied from ≤ 22 % for 20 : 4*n*-3 (the fatty acid with the lowest relative concentration) to ≤ 2 % for 18 : 2*n*-6 (the fatty acid with the highest relative concentration). Stearidonic acid (18 : 4*n*-3) and γ-linolenic acid (18 : 3*n*-6) were not included, as their concentrations were <0·1 % of total fatty acids.

Questionnaire measurements

The pregnancy questionnaire provided information on ethnic group as well as covariables considered relevant to maternal fatty acid status. We defined ethnic group by the woman's country of birth or that of her mother, so that second-generation women could also be included[25]. In total, seven ethnic groups were defined: Dutch (reference group), Surinamese, Antillean, Turkish, Moroccan, Ghanaian, and other ethnic origin.

The covariables included maternal age (years)[14], parity (0, 1, ≥2)[15,16], educational attainment (number of years after primary school)[17], pregravid BMI (kg/m^2) as based on self-reported height and weight[18], smoking and alcohol consumption during pregnancy (self-reported previous week's behaviour, recoded into yes, no)[19,20] and fish and fish oil consumption[22,24]. For height and weight, missing values (3·3 and 9·8 % respectively) were imputed by means of a random imputation procedure using linear regression[33], which accounted for the differences among the ethnic groups. Fish and fish oil consumption was assessed by four frequency questions adapted from the Danish fish frequency questionnaire of Olsen & Secher[34]. Women were asked to indicate how often during their pregnancy they had eaten (a) fish as part of a hot meal, (b) bread or toast with fish, (c) salad (such as a green salad or pasta salad) with fish, and (d) fish oil. Predefined response categories were: never, less than once per month, 1–3 times per month, 1–2 times per week, 3–6 times per week, and every day, assuming to correspond to 0, 0·5, 2, 4, 20 and 28 servings per 28 d respectively. To avoid uncertainties associated with differences in the average *n*-3 long-chain PUFA contents of various fish species and consequently with the calculated average *n*-3 long-chain PUFA intake[35], we computed a cumulative frequency measure to define overall fish consumption. This cumulative (or total)

number of fish and fish oil servings per week was arrived at by simple combination of the responses on the four questions. Subsequently, we defined three frequency groups in such a way that each group was of a reasonable size and that intake frequency increased progressively: (1) <1 serving per week, (2) 1–1·9 servings per week, and (3) 2 or more servings per week.

Statistical analysis

Fatty acid results were available for 4336 of the 4389 participants. We excluded all respondents with known diabetes (*n* 26), hypertension (*n* 152) or unknown gestational age at blood sampling (*n* 15), as well as all respondents with missing information on fish or fish oil consumption (*n* 25) or on any of the above-mentioned covariables (*n* 15). Restriction to the six main ethnic groups (Dutch, Surinamese, Antillean, Turkish, Moroccan and Ghanaian) provided the final sample for the analysis of 3254 subjects.

First, differences in the distribution of relevant maternal characteristics and the habitual fish and fish oil intake between the Dutch and ethnic minority groups were described and tested with the χ^2 test for categorical variables and ANOVA for continuous variables. Second, ethnic differences in relative fatty acid concentrations were explored using the general linear model function in SPSS (SPSS, Inc. Chicago, IL, USA), which tests both the overall association between ethnic origin and fatty acid concentrations as well as the fatty acid-specific ethnic differences[36]. Finally, the ethnic differences in the proportion of the major functional long-chain PUFA (EPA, DHA, DGLA and AA) in maternal plasma phospholipids were further explored, by stepwise extension of the basic general linear model (model 1, including only ethnicity). In the first step, we included gestational age at blood sampling (based on ultrasound or, if unavailable, on the time of the last menstrual period) to assess the influence of changes in the fatty acid contents of plasma phospholipids that normally occur during pregnancy[28] (model 2). In the next step, we added the potential confounders (model 3) and, in the final step, we included the fish frequency measure (model 4).

We used the model-estimated means to calculate the relative (i.e. percentage) differences between the ethnic minority groups and the Dutch reference group and assumed the changes in relative differences across the models to indicate the contribution of the covariables to these differences. When necessary, transformations were applied to obtain more symmetrical distributions and improve the normality of the residuals in the various models (18 : 3*n*-3, 20 : 4*n*-3, 22 : 5*n*-6, square root transformation; EPA (20 : 5*n*-3), log transformation). For 22 : 4*n*-6, 22 : 5*n*-6, 18 : 3*n*-3, 20 : 4*n*-3 and EPA, the measurements included zero values (<0·5 % of cases), which were replaced by half of the value of the lowest measured value.

Because of the multiple comparisons made, associations were considered significant at $P<0{\cdot}01$. All analyses were conducted in SPSS (version 15.0; SPSS, Inc.).

Results

In the present analysis, 25 % of the study population belonged to a non-Dutch ethnic group. The baseline characteristics of the ethnic groups are presented in Table 1. Overall, non-Dutch women had their prenatal check-up including the blood sampling at a later gestational age than the Dutch women (≥14·4 *v.* 12·9 weeks). Between the ethnic groups, significant differences existed in the distribution of maternal age, parity, educational attainment, BMI, smoking habits, alcohol consumption and fish consumption ($P<0{\cdot}001$). Dutch women were generally older and more highly educated than women of non-Dutch background; on average, Turkish women were the youngest mothers and Ghanaian women the

Table 1. Characteristics of the study population according to ethnic group
(Mean values and standard deviations or percentages)

	Ethnic group												
	Dutch (*n* 2443)		Surinamese (*n* 286)		Antillean (*n* 63)		Turkish (*n* 167)		Moroccan (*n* 241)		Ghanaian (*n* 54)		
Characteristic	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P*†
Gestational age at blood sampling (weeks)	12·9	2·7	14·7**	4·4	14·7**	4·9	14·6**	3·5	15·3**	4·4	14·4*	4·4	<0·001
Maternal age (years)	31·9	4·0	28·8**	6·3	28·5**	6·4	25·7**	4·9	27·2**	5·1	31·5	5·8	<0·001
Parity (%)													
0	60·8		49·0**		74·6		46·1**		48·1**		29·6**		<0·001
1	32·1		28·3		19·0		34·1		26·1		25·9		
≥ 2	7·1		22·7		6·3		19·8		25·7		44·4		
Educational attainment (years)	10·4	3·0	7·3**	3·7	8·9**	4·3	5·0**	3·6	5·3**	3·5	4·9**	4·1	<0·001
Pregravid BMI (kg/m^2)	22·5	3·2	23·6**	4·3	23·1	4·6	23·6**	4·1	24·7**	4·4	26·3**	4·6	<0·001
Smoking (%)	9·8		15·7*		3·2		24·0**		2·5**		1·9		<0·001
Alcohol consumption (%)	31·0		10·8**		15·9		0·6**		0·4**		11·1*		<0·001
Fish and fish oil consumption (%)													
< 1 serving per week	45·6		49·0		58·7		69·5**		33·6**		16·7**		<0·001
1–1·9 servings per week	36·6		33·2		23·8		17·4		30·7		27·8		
≥ 2 servings per week	17·8		17·8		17·5		13·2		35·7		55·6		

Mean value or percentage was significantly different from that of the Dutch ethnic group: *$P<0{\cdot}01$, **$P<0{\cdot}001$.
†Test for differences between groups: χ^2 statistic for categorical variables; ANOVA for continuous variables.

least educated mothers. Antillean and Dutch women were more often nulliparous and had a lower BMI on average. Women from Ghana were more often multiparous (i.e. parity ≥ 2) and had the highest BMI. Turkish women reported smoking during pregnancy more often than Dutch or other non-Dutch women, while alcohol consumption was most common among Dutch women. Fish consumption, lastly, was similarly low among Dutch, Surinamese and Antillean women; in these groups 17 % of women reported consuming a serving of fish or fish oil at least twice per week. Consumption was lower among Turkish women (13 %) and higher among Moroccan women (33 %). The highest consumption was found among Ghanaian women, of whom 56 % reported consuming a serving of fish or fish oil at least twice per week.

Table 2 shows the fatty acid composition in maternal plasma phospholipids for each ethnic group separately; for those fatty acids with a skewed distribution, the median and interquartile range are given instead of the mean and standard deviation. For both *n*-3 and *n*-6 fatty acids, considerable ethnicity-related differences were observed (Pillai's trace criterion for multiple outcomes; $P<0{\cdot}001$).

Compared with the Dutch women, all ethnic minority groups had lower proportions of α-linolenic acid (18 : 3*n*-3) and its derivative eicosatetraenoic acid (20 : 4*n*-3). For Surinamese, Antillean and Moroccan women, proportions of EPA (20 : 5*n*-3) and docosapentaenoic acid (22 : 5*n*-3) were also (significantly) lower. The lowest proportions of EPA and docosapentaenoic acid, as well as DHA (22 : 6*n*-3) (the three fatty acids found primarily in fish and fish oil) were observed for the Turkish women; in contrast, Ghanaian women were found to have the highest proportions.

Ethnic patterns were more complex for the *n*-6 fatty acids. Surinamese, Antillean, Turkish and Moroccan women all showed higher proportions of linoleic acid (18 : 2*n*-6) and its longer-chain derivatives AA (20 : 4*n*-6), adrenic acid (22 : 4*n*-6) and Osbond acid (22 : 5*n*-6), but lower or comparable proportions of DGLA (20 : 3*n*-6). Interestingly, the Turkish women showed the largest deviation from the Dutch group for linoleic acid, Osbond acid and adrenic acid, but the smallest deviation for AA and DGLA. The pattern for Ghanaian women was again different; they showed lower proportions of DGLA as well as linoleic acid, adrenic acid and Osbond acid, but higher proportions of AA.

Adjustment for gestational age at blood sampling did not alter the size of the model coefficients (results not shown), but did affect the significance levels for five of the forty-four associations (Table 2).

Table 3 compares the observed differences in EPA, DHA, DGLA and AA across the ethnic minority groups. Results are presented as relative differences (i.e. percentage differences) from the Dutch proportions, with models 1 to 4 representing the increasing levels of adjustment. For the fish fatty acids EPA and DHA the Table reveals the extreme position of Ghanaian and Turkish women *v.* Dutch women, showing differences of +93 and −55 % for EPA, and differences of +41 and −21 % for DHA respectively (model 1). For Surinamese, Antillean and Moroccan women, adjustment for gestational age at blood sampling and maternal characteristics attenuated the EPA differences but augmented the DHA differences (models 2 and 3 *v.* model 1). In contrast, adjustment attenuated both EPA and DHA differences for Turkish women, but augmented these for Ghanaian women. For the *n*-6 fatty acids, differences across the ethnic minority groups and across models were less pronounced. The changes across models 3 and 4 show a modest attenuation of the Dutch–Ghanaian differences in EPA and DHA proportions after adjustment for fish consumption, but only minor changes in other group comparisons.

Discussion

In the present observational study, we found distinct patterns of fatty acid proportions in maternal plasma phospholipids across ethnic groups, with the Ghanaian and Turkish ethnic groups deviating most from the Dutch reference group. Ghanaian women, who reported the highest fish intake, had generally higher proportions of *n*-3 and lower proportions of *n*-6 fatty acids, while for Turkish women, who reported the lowest fish consumption, the opposite was observed. Attenuation of the differences in relative EPA, DHA, DGLA and AA concentrations after adjustment for maternal physiological and lifestyle-related variables and fish and fish oil consumption was, however, modest.

To our knowledge, only one previous study has examined ethnicity-related differences in maternal fatty acid status in early pregnancy[37], applying a cross-country rather than a within-country comparison and not adjusting for potential explanatory factors such as fish consumption[21–24]. Yet, in the present study, fish consumption did not appear to explain the ethnic variation in long-chain PUFA status to a relevant degree. This was perhaps to be expected for the ethnic groups that reported intake levels comparable with the Dutch, but not for those who deviated. However, the fish FFQ was relatively short, and may have been too crude to adequately assess EPA and DHA intake. Alternatively, being developed in Denmark, it may have had a lower validity in this multi-ethnic context. When we examined the Spearman rank correlation between the relative EPA concentrations and the number of fish servings per week, the overall correlation (0·33) was well in the range of previous questionnaire–concentration correlations (0·19–0·50)[22], but the correlations for the Ghanaian (0·13) and Moroccan (0·15) groups in particular were indeed lower. As these were the groups reporting the highest fish consumption, this could also reflect a lower power of the questionnaire to explain EPA variability at higher intakes. Given these uncertainties, we cannot make any final conclusions about the contribution of differential fish consumption to ethnic disparities in maternal early pregnancy fatty acid status at this stage. Further study is required, not only to gain more insight in ethnicity-related differences in maternal fatty acid intake, but also to explore potential alternative explanations that are beyond the scope of the present paper, such as the possible inter-ethnic differences in the consumption of the parent essential fatty acids and their conversion to long-chain PUFA[38–41], and potential differences in post-conceptional long-chain PUFA mobilisation[28,42] or synthesis[43].

In the present study a comparison was made between the Dutch ethnic group and the five main ethnic minority groups in the Netherlands. It should be noted though that this sample may reflect a relatively healthy subpopulation. Indeed, compared with the group of non-respondents

Table 2. Maternal *n*-3 and *n*-6 fatty acids in plasma phospholipids (percentage of total fatty acids) according to ethnic group
(Mean values and standard deviations or medians and interquartile ranges for skewed distributions)

	Ethnic group												
	Dutch (*n* 2443)		Surinamese (*n* 286)		Antillean (*n* 63)		Turkish (*n* 167)		Moroccan (*n* 241)		Ghanaian (*n* 54)		
Fatty acid fractions	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P*†
n-3 Fatty acids													
18 : 3*n*-3	0·18	0·14, 0·23	0·14**	0·10, 0·19	0·17‡	0·12, 0·20	0·12**	0·09, 0·17	0·14**	0·10, 0·18	0·14**	0·11, 0·19	<0·001
20 : 4*n*-3	0·14	0·11, 0·18	0·09**	0·06, 0·12	0·11**	0·07, 0·16	0·08**	0·05, 0·11	0·08**	0·06, 0·10	0·09**	0·07, 0·13	<0·001
20 : 5*n*-3 (EPA)	0·57	0·44, 0·77	0·36**	0·26, 0·51	0·42**	0·30, 0·59	0·26**	0·18, 0·37	0·35**	0·27, 0·46	1·03**	0·73, 1·88	<0·001
22 : 5*n*-3	0·77	0·17	0·63**	0·16	0·70*§	0·18	0·56**	0·16	0·57**	0·15	0·89**	0·25	<0·001
22 : 6*n*-3 (DHA)	4·81	1·05	4·76	0·92	4·80	1·01	3·78**	0·94	4·69	0·93	6·77**	1·14	<0·001
n-6 Fatty acids													
18 : 2*n*-6	18·77	2·39	19·27*§	2·45	19·12	2·12	20·63**	2·70	19·97**	2·45	17·76*	2·59	<0·001
20 : 3*n*-6 (DGLA)	3·50	0·72	3·12**	0·69	3·20*	0·59	3·64	0·79	3·28**	0·69	2·48**	0·60	<0·001
20 : 4*n*-6 (AA)	9·08	1·48	10·32**	1·77	9·73*	1·64	9·71**	1·70	9·81**	1·84	9·93**	1·55	<0·001
22 : 4*n*-6	0·37	0·10	0·45**	0·12	0·42**	0·11	0·45**	0·15	0·40**	0·10	0·29**	0·10	<0·001
22 : 5*n*-6	0·33	0·26, 0·43	0·42**	0·31, 0·53	0·38*§	0·29, 0·50	0·52**	0·40, 0·65	0·36*§	0·28, 0·46	0·22**	0·16, 0·28	<0·001

DGLA, dihomo-γ-linolenic acid; AA, arachidonic acid.
Mean or median value was significantly different from that of the Dutch ethnic group: *$P<0·01$, **$P<0·001$.
† General linear model; ANOVA statistics for fatty acid-specific difference between groups following the significant overall association between ethnicity and fatty acid concentrations (Pillai's trace criterion; $P<0·001$). For skewed distributions, statistics are based on transformed data as described in the Methods section.
‡ After standardisation for gestational age at blood sampling, mean value became significantly different from that of the Dutch ethnic group ($P<0·01$).
§ After standardisation for gestational age at blood sampling, mean or median value became non-significantly different from that of the Dutch ethnic group ($P\geq0·01$).

Table 3. Differences (%) in EPA, DHA, dihomo-γ-linolenic acid (DGLA) and arachidonic acid (AA) in maternal plasma phospholipids for the five main ethnic minority groups compared with the Dutch reference group†

	Ethnic group				
Fatty acid fractions	Surinamese (*n* 286)	Antillean (*n* 63)	Turkish (*n* 167)	Moroccan (*n* 241)	Ghanaian (*n* 54)
20 : 5*n*-3 (EPA)‡					
Model 1	−38·1**	−28·7**	−54·9**	−39·6**	93·2**
Model 2	−34·5**	−24·8**	−52·7**	−35·1**	101·8**
Model 3	−26·7**	−17·6*	−41·4**	−23·1**	117·3**
Model 4	−27·7**	−17·0*	−40·7**	−28·9**	91·9**
22 : 6*n*-3 (DHA)‡					
Model 1	−1·0	0·1	−21·3**	−2·5	40·8**
Model 2	−0·5	0·4	−20·9**	−1·8	41·3**
Model 3	5·6**	2·8	−11·4**	5·6*	49·2**
Model 4	4·7**	3·4	−10·1**	1·6	41·8**
20 : 3*n*-6 (DGLA)‡					
Model 1	−10·8**	−8·5*	3·9	−6·1**	−29·2**
Model 2	−11·4**	−9·0*	3·3	−6·9**	−29·6**
Model 3	−14·2**	−10·3**	−1·1	−11·3**	−34·4**
Model 4	−14·1**	−10·6**	−1·3	−9·9**	−32·2**
20 : 4*n*-6 (AA)‡					
Model 1	13·7**	7·3*	7·0**	8·2**	9·4**
Model 2	15·7**	9·2**	8·8**	10·7**	11·0**
Model 3	12·9**	8·0**	4·8*	5·9**	4·7
Model 4	13·2**	7·9**	4·6*	7·2**	6·7*

*$P<0·01$, **$P<0·001$.

† Differences are expressed as percentage differences from values in the reference group (i.e. Dutch ethnic group).

‡ Model 1, crude (not adjusted); model 2, as model 1 + adjustment for gestational age at blood sampling; model 3, as model 2 + adjustment for maternal age, parity, educational attainment, pregravid BMI, smoking and alcohol consumption; model 4, as model 3 + adjustment for fish and fish oil consumption.

(neither questionnaire nor biomarker study), women in the present analysis were more often of Dutch ethnic background, more highly educated and started prenatal care earlier in pregnancy (data not shown). However, differences in lifestyle factors, such as BMI, smoking habits and fish consumption between the ABCD study respondents who did and who did not donate blood were small (data not shown), which suggest only a minimal selection bias. It should also be kept in mind that our measure of ethnicity (country of birth), though commonly used in Dutch research and prescribed by the Netherland Organisation for Health Research (www.zonmw.nl/en), does not capture heterogeneity in genetic make-up, history, culture or dietary preferences within ethnic groups, such as exists between the Creole and Hindustani populations of Surinam. However, to the extent that information for these subpopulations was available, no significant differences in fatty acid status were observed, allowing for inclusion of both in one Surinamese group.

Interestingly, the observed high proportions of EPA and DHA among the Ghanaian women coincided with high AA, but low DGLA, content of plasma phospholipids in this group. A similar contrast between the relative AA and DGLA concentrations was observed for the Surinamese and Antillean women, who, together with the Ghanaians, form the ethnic minority women at highest risk of adverse perinatal outcomes (fetal growth restriction and preterm birth)[25,44]. Over the past years, the main focus in perinatal fatty acid research has been on the positive effects of the *n*-3 fatty acids. Our present observations, in conjunction with previous results showing significant but contrasting associations of DGLA (positive) and AA (negative) with birth weight[12], however, suggest distinct roles of the *n*-6 fatty acids in perinatal health as well. More detailed intervention studies would be worthwhile to investigate if and how adaptation of the maternal fatty acid profile can affect perinatal health, and ethnic disparities therein. Specific groups could potentially benefit from GLA and EPA supplements, a combination shown to improve DGLA and EPA concentration without raising AA[45].

In conclusion, the present results suggest the presence of considerable ethnic disparities in the maternal *n*-3 and *n*-6 fatty acid status during pregnancy, which, in view of the existing and newly emerging evidence of the role of these nutrients in human growth and development, may be relevant to ethnic disparities in perinatal health. Given the limitations of this observational study, further research into these distinct ethnicity-related fatty acid patterns is warranted, particularly to elucidate the role of fatty acid intake *v.* metabolic differences, and to explore the potential benefits of fatty acid supplementation.

Acknowledgements

The research described in this paper was performed at the Public Health Service of Amsterdam and the Academic Medical Centre (University of Amsterdam) as part of the ABCD study.

Financial support for the ABCD cohort study was granted by the Netherlands Organisation for Health Research and Development (ZonMw) in The Hague, the Public Health Service and Municipal Council of Amsterdam, the Academic Medical Centre, and Nutricia Research BV in Zoetermeer.

We thank the hospitals, obstetric clinics and general practitioners for their assistance in the implementation of the

ABCD study, and all pregnant women who participated for their cooperation.

M. F. W. and G. J. B. conceived of and designed the ABCD study; G. H. was advisor in study design. M. E. and M. F. W. collected and processed the data. M. E. conducted the statistical analysis, with G. J. B. providing supervision. All authors contributed to the interpretation of the results and writing of the manuscript, and have seen and approved the final version. None of the authors had a financial or personal conflict of interest related to the content of the study.

References

1. Troe EJ, Raat H, Jaddoe VW, *et al.* (2007) Explaining differences in birthweight between ethnic populations. The Generation R study. *BJOG* **114**, 1557–1565.
2. Harding S, Rosato MG & Cruickshank JK (2004) Lack of change in birthweights of infants by generational status among Indian, Pakistani, Bangladeshi, Black Caribbean, and Black African mothers in a British cohort study. *Int J Epidemiol* **33**, 1279–1285.
3. Shiono PH, Rauh VA, Park M, *et al.* (1997) Ethnic differences in birthweight: the role of lifestyle and other factors. *Am J Public Health* **87**, 787–793.
4. Suitor CW, Gardner JD & Feldstein ML (1990) Characteristics of diet among a culturally diverse group of low-income pregnant women. *J Am Diet Assoc* **90**, 543–549.
5. Siega-Riz AM, Bodnar LM & Savitz DA (2002) What are pregnant women eating? Nutrient and food group differences by race. *Am J Obstet Gynecol* **186**, 480–486.
6. Arab L, Carriquiry A, Steck-Scott S, *et al.* (2003) Ethnic differences in the nutrient intake adequacy of premenopausal US women: results from the third national health examination survey. *J Am Diet Assoc* **103**, 1008–1014.
7. Rees GA, Doyle W, Srivasta A, *et al.* (2005) The nutrient intakes of mothers of low birth weight babies – a comparison of ethnic groups in East London, UK. *Matern Child Nutr* **1**, 91–99.
8. Uauy R, Treen M & Hoffman DR (1989) Essential fatty acid metabolism and requirements during development. *Semin Perinatol* **13**, 118–130.
9. Allen KG & Harris MA (2001) The role of *n*-3 fatty acids in gestation and parturition. *Exp Biol Med* **226**, 498–506.
10. Uauy R, Calderon F & Mena P (2001) Essential fatty acids in somatic growth and brain development. *World Rev Nutr Diet* **89**, 134–160.
11. Innis SM (2003) Perinatal biochemistry and physiology of long-chain polyunsaturated fatty acids. *J Pediatr* **143**, Suppl. 4, S1–S8.
12. van Eijsden M, Hornstra G, van der Wal MF, *et al.* (2008) Maternal *n*-3, *n*-6, and *trans* fatty acid profile early in pregnancy and term birth weight: a prospective cohort study. *Am J Clin Nutr* **87**, 887–895.
13. Dirix CE, Kester AD & Hornstra G (2008) Associations between neonatal birth dimensions and maternal essential and *trans* fatty acid contents during pregnancy and at delivery. *Br J Nutr*, (Epublication ahead of print version 10 July 2008).
14. Maniongui C, Blond JP, Ulmann L, *et al.* (1993) Age-related changes in Δ6 and Δ5 desaturase activities in rat liver microsomes. *Lipids* **28**, 291–297.
15. Al MD, van Houwelingen AC & Hornstra G (1997) Relation between birth order and the maternal and neonatal docosahexaenoic acid status. *Eur J Clin Nutr* **51**, 548–553.
16. Levant B, Ozias MK & Carlson SE (2007) Diet (*n*-3) polyunsaturated fatty acid content and parity affect liver and erythrocyte phospholipid fatty acid composition in female rats. *J Nutr* **137**, 2425–2430.
17. Sontrop JM, Campbell MK, Evers SE, *et al.* (2007) Fish consumption among pregnant women in London, Ontario: associations with socio-demographic and health and lifestyle factors. *Can J Public Health* **98**, 389–394.
18. Warensjö E, Örhvall M & Vessby B (2006) Fatty acid composition and estimated desaturase activities are associated with obesity and lifestyle variables in men and women. *Nutr Metab Cardiovasc Dis* **16**, 128–136.
19. Simon JA, Fong J, Bernert JT, *et al.* (1996) Relation of smoking and alcohol consumption to serum fatty acids. *Am J Epidemiol* **144**, 325–334.
20. Pawlosky R, Hibbeln J, Wegher B, *et al.* (1999) The effects of cigarette smoking on the metabolism of essential fatty acids. *Lipids* **34**, Suppl., S287.
21. van Houwelingen AC, Sørensen JD, Hornstra G, *et al.* (1995) Essential fatty acid status in neonates after fish-oil supplementation during late pregnancy. *Br J Nutr* **74**, 723–731.
22. Hjartåker A, Lund E & Bjerve KS (1997) Serum phospholipid fatty acid composition and habitual intake of marine foods registered by a semi-quantitative food frequency questionnaire. *Eur J Clin Nutr* **51**, 736–742.
23. Dunstan JA, Mori TA, Barden A, *et al.* (2004) Effects of *n*-3 polyunsaturated fatty acid supplementation in pregnancy on maternal and fetal erythrocyte fatty acid composition. *Eur J Clin Nutr* **58**, 429–437.
24. Williams MA, Frederick IO, Qiu C, *et al.* (2006) Maternal erythrocyte omega-3 and omega-6 fatty acids, and plasma lipid concentrations, are associated with habitual dietary fish consumption in early pregnancy. *Clin Biochem* **39**, 1063–1070.
25. Goedhart G, van Eijsden M & van der Wal MF (2008) Ethnic differences in term birthweight: the role of constitutional and environmental factors. *Paediatr Perinat Epidemiol* **22**, 360–368.
26. van Eijsden M, van der Wal MF & Bonsel GJ (2006) Folic acid knowledge and use in a multi-ethnic pregnancy cohort: the role of language proficiency. *BJOG* **113**, 1446–1451.
27. van Eijsden M, van der Wal MF, Hornstra G, *et al.* (2005) Can whole-blood samples be stored over 24 hours without compromising stability of C-reactive protein, retinol, ferritin, folic acid and fatty acids in epidemiologic research? *Clin Chem* **51**, 230–232.
28. Al MD, van Houwelingen AC, Kester AD, *et al.* (1995) Maternal essential fatty acid patterns during normal pregnancy and their relationship to the neonatal essential fatty acid status. *Br J Nutr* **74**, 55–68.
29. Otto SJ, van Houwelingen AC & Hornstra G (2000) The effect of different supplements containing docosahexaenoic acid on plasma and erythrocyte fatty acids of healthy non-pregnant women. *Nutr Res* **20**, 917–927.
30. Hoving EB, Jansen G, Volmer M, *et al.* (1988) Profiling of plasma cholesterol ester and triglyceride fatty acids as their methyl esters by capillary gas chromatography, preceded by a rapid aminopropyl-silica column chromatographic separation of lipid classes. *J Chromatogr* **434**, 395–409.
31. Kaluzny MA, Duncan LA, Merritt MV, *et al.* (1985) Rapid separation of lipid classes in high yield and purity bonded phase columns. *J Lipid Res* **26**, 135–140.
32. Morrison WR & Smith LM (1964) Preparation of fatty acid methylesters and dimethylacetals from lipids with boron fluoride–methanol. *J Lipid Res* **5**, 600–608.
33. Allison PD (2001) *Missing Data*. Thousand Oaks, CA: Sage Publications.
34. Olsen SF & Secher NJ (2002) Low consumption of seafood in early pregnancy as a risk factor for preterm delivery: prospective cohort study. *BMJ* **324**, 447–450.

35. Racine RA & Deckelbaum RJ (2007) Sources of the very-long-chain unsaturated omega-3 fatty acids: eicosapentaenoic acid and docosahexaenoic acid. *Curr Opin Clin Nutr Metab Care* **10**, 123–128.
36. Tabachnik B & Fidell L (2007) *Using Multivariate Statistics*, 5th ed. Boston, MA: Pearson/Allyn and Bacon.
37. Otto SJ, van Houwelingen AC, Antal M, *et al.* (1997) Maternal and neonatal essential fatty acid status in phospholipids: an international comparative study. *Eur J Clin Nutr* **51**, 232–242.
38. Emken EA, Adlof RO & Gulley RM (1994) Dietary linoleic acid influences desaturation and acylation of deuterium-labeled linoleic acid and linolenic acids in young adult males. *Biochim Biophys Acta* **1213**, 277–288.
39. Grønn M, Gørbitz C, Christensen E, *et al.* (1991) Dietary *n*-6 fatty acids inhibit the incorporation of dietary *n*-3 fatty acids in thrombocyte and serum phospholipids in humans: a controlled dietetic study. *Scand J Clin Lab Invest* **51**, 255–263.
40. Cho HP, Nakamura MT & Clarke SD (1999) Cloning, expression, and nutritional regulation of the mammalian Δ-6 desaturase. *J Biol Chem* **274**, 471–477.
41. Schaeffer L, Gohlke H, Muller M, *et al.* (2006) Common genetic variants of the FADS1 FADS2 gene cluster and their reconstructed haplotypes are associated with the fatty acid composition in phospholipids. *Hum Mol Genet* **15**, 1745–1756.
42. Otto SJ, van Houwelingen AC, Badart-Smook A, *et al.* (2001) Changes in the maternal essential fatty acid profile during early pregnancy and the relation of the profile to diet. *Am J Clin Nutr* **73**, 302–307.
43. Burdge GC, Sherman RC, Ali Z, *et al.* (2006) Docosahexaenoic acid is selectively enriched in plasma phospholipids during pregnancy in Trinidian women – results of a pilot study. *Reprod Nutr Dev* **46**, 63–67.
44. Goedhart G, van Eijsden M, van der Wal MF, *et al.* (2008) Ethnic differences in preterm birth and its subtypes: the effect of a cumulative risk profile. *BJOG* **115**, 710–719.
45. Barham JB, Edens MB, Fonteh AN, *et al.* (2000) Addition of eicosapentaenoic acid to γ-linolenic acid-supplemented diets prevents serum arachidonic accumulation in humans. *J Nutr* **130**, 1925–1931.

British Journal of Nutrition