

## **Age-dependent fatty acid composition of erythrocyte membrane phospholipids in healthy children**

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*Summary:* The fatty-acid composition of red-cell-membrane phospholipids (total phospholipids, phosphatidylcholine, and phosphatidylethanolamine fractions) was determined in 88 apparently healthy children aged 1 to 15 years, 10 cord blood samples, and 6 infants below 1 year of age.

The major aim of the study was to determine the normal ranges of fatty-acid proportions, including trans- and odd-numbered fatty acids, for further studies of nutritional and metabolic disorders.

The concentrations of most fatty acids of the phospholipids analyzed increased or decreased after birth and assumed adult levels before the second year of life.  $\alpha$ -linolenic acid (C18:3n – 3) and trans fatty acids, however, continued to increase with age until late childhood.

*Zusammenfassung:* Bei insgesamt 88 gesunden Kindern im Alter zwischen 1 und 15 Jahren, 6 Kindern unter einem Jahr und in 10 Nabelschnurblutproben wurde die Fettsäurezusammensetzung der Phospholipide (Gesamt-Phospholipide, Phosphatidylethanolamin, Phosphatidylcholin) untersucht. Ziel der Arbeit war es, altersabhängige Normbereiche für die prozentuale Fettsäurenverteilung einschließlich der Trans-Fettsäuren und der ungeradzahligen Fettsäuren zu erstellen, als Grundlage für weitere Untersuchungen bei Ernährungsstörungen und Stoffwechselkrankheiten. Die untersuchten Phospholipide wiesen besonders im 1. Lebensjahr deutliche Veränderungen in der Fettsäurenverteilung auf. Bis zu Beginn des 2. Lebensjahres bildete sich ein „adultes“ Muster heraus. Lediglich die prozentualen Anteile der  $\alpha$ -Linolensäure (18:3n – 3) und die der Trans-Fettsäuren stiegen weiter bis zur zweiten Lebensdekade an.

*Key words:* children; fatty acids; erythrocyte phospholipids; phosphatidylethanolamine; phosphatidylcholine

*Schlüsselwörter:* Fettsäurezusammensetzung; Gesamt-Phospholipide; Phosphatidylethanolamin; Phosphatidylcholin

### **Introduction**

There are a few studies on the fatty acid composition in red-cell membrane lipids of normal newborns, infants, children, and adults (1–10). There is, however, no data to our knowledge, which describes the fatty acid patterns of red cell lipids throughout childhood, from birth to adolescence. Because of the known influence of dietary fat upon fatty-acid

composition of various lipids, fatty-acid patterns may vary with age and from country to country.

The aim of the present study was to set up the normal age-dependent ranges of the proportions of the fatty acids in red-cell-membrane lipids of children with average German dietary habits for further studies on nutritional and metabolic disorders.

## Materials and methods

### *Subjects*

The study included three males and three females aged 1–11 months and 51 boys and 37 girls aged 1–15 years. The age distribution is given in Table 1. In addition, cord blood from six males and four females was studied. All the children had been referred to the hospital for elective surgical treatment. None of them was ill. All had average German dietary habits. None of the infants was breastfed during the study.

Venous blood samples 3–5 ml were collected into EDTA tubes from the children after an overnight fast. Blood was drawn for checking some laboratory parameters before anesthesia after parental consent was obtained.

### *Analysis of fatty acid in red cell phospholipids*

The EDTA-blood was centrifuged at  $1500 \times g$  at room temperature for 10 min. Plasma was removed by suction and the red cells were washed twice with 10 ml of NaCl (154 mmol/l) containing BHT.

Extraction of lipids from 1 ml of the packed erythrocytes, separation of phosphatidylcholine, phosphatidylethanolamine by TLC, and base-catalyzed transesterification of the fatty acids in the phospholipid extracts using sodium methoxide were exactly as described previously (11).

The GLC of the fatty-acid methylesters was carried out with a Dani 6500 GR instrument (Dani Analysentechnik, Mainz, FRG) equipped with a flame-ionization detector and a programmed temperature vaporizing injector. Methods for GLC, identification, and quantification of the peaks as well as the reproducibility and precision of the complete technique have been described previously (11). In each sample, the proportions of the individual fatty acids were calculated and expressed as a percentage of the total C15–C22 fatty acids in the sample. Data are provided for total membrane lipids as well as for their phosphatidylcholine and phosphatidylethanolamine fractions. Data are reported as means  $\pm$  SD.

## Results

For both sexes, identical results were obtained for the fatty-acid patterns of the phospholipid fractions studied.

Table 1. Number of patients in the different age groups.

Age group	Males	Females
Cord blood	6	4
1 to 11 months	5	1
1 to 3 years	12	5
3 to 6 years	14	13
6 to 9 years	11	11
9 to 12 years	10	4
12 to 15 years	4	4

Table 2. Fatty acid composition of erythrocyte membrane lipids (in %).

a) Total phospholipids		Cord blood (n = 10)		Infants (n = 6)		Age 1-3 (n = 17)		Age 3-6 (n = 27)		Age 6-9 (n = 22)		Age 9-12 (n = 14)		Age 12-15 (n = 8)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
15:0	0.22	0.09	0.07	0.18	0.07	0.21	0.08	0.21	0.06	0.20	0.07	0.20	0.03	0.19	0.06
16:0	24.42	0.97	1.63	23.16	1.63	19.90	1.08	19.77	0.80	19.43	0.66	19.52	0.85	19.66	0.67
16:1t	0.27	0.05	0.11	0.19	0.11	0.29	0.06	0.32	0.05	0.34	0.08	0.35	0.08	0.32	0.05
16:1c	0.66	0.20	0.22	0.46	0.22	0.46	0.05	0.43	0.10	0.41	0.11	0.40	0.09	0.44	0.05
17:0	0.40	0.03	0.14	0.38	0.14	0.42	0.05	0.42	0.06	0.43	0.07	0.45	0.05	0.40	0.05
17:1c	0.09	0.01	0.06	0.10	0.06	0.08	0.03	0.07	0.04	0.07	0.04	0.07	0.03	0.05	0.03
18:0	15.92	0.47	1.41	16.01	1.41	16.74	0.51	16.71	0.52	16.72	0.47	16.52	0.48	16.63	0.47
18:1t	0.27	0.07	0.14	0.43	0.14	1.03	0.39	1.17	0.36	1.54	0.53	1.43	0.58	1.60	0.35
18:1 n-9	13.89	0.85	1.66	16.46	1.66	15.44	0.76	15.68	0.84	15.10	0.79	15.40	1.26	15.13	1.07
18:2t	0.10	0.04	0.07	0.19	0.07	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04
18:2 n-6	4.29	0.34	1.50	12.03	1.50	11.35	1.05	12.33	1.63	12.35	1.34	12.21	1.51	11.27	0.65
18:3 n-6	0.10	0.05	0.02	0.08	0.02	0.07	0.03	0.07	0.05	0.07	0.03	0.06	0.01	0.05	0.02
18:3 n-3	0.01	0.01	0.01	0.06	0.01	0.13	0.07	0.14	0.04	0.14	0.03	0.15	0.03	0.13	0.06
20:0	0.16	0.02	0.07	0.20	0.07	0.18	0.03	0.18	0.04	0.17	0.04	0.18	0.07	0.15	0.03
20:1 n-9	0.24	0.06	0.09	0.46	0.09	0.34	0.05	0.34	0.05	0.34	0.04	0.33	0.05	0.36	0.05
20:2 n-6	0.23	0.03	0.08	0.38	0.08	0.26	0.04	0.27	0.06	0.27	0.03	0.26	0.04	0.28	0.04
20:3 n-9	0.83	0.16	0.12	0.26	0.12	0.12	0.02	0.12	0.04	0.09	0.04	0.11	0.03	0.11	0.03
20:3 n-6	3.19	0.50	0.42	3.04	0.42	1.66	0.30	1.76	0.41	1.73	0.33	1.92	0.28	1.63	0.15
20:4 n-6	19.56	1.26	1.70	15.81	1.70	17.52	1.07	16.53	1.07	16.84	1.08	16.39	1.63	17.07	0.49
20:5 n-3	0.17	0.03	0.05	0.20	0.05	0.54	0.09	0.59	0.19	0.61	0.13	0.71	0.18	0.60	0.11
22:4 n-6	4.79	0.52	0.65	4.24	0.65	3.78	0.46	3.54	0.58	3.75	0.51	3.43	0.53	4.06	0.67
22:5 n-6	1.85	0.31	0.61	1.42	0.61	0.87	0.12	0.75	0.14	0.66	0.14	0.63	0.10	0.63	0.10
22:5 n-3	0.71	0.06	0.41	1.36	0.41	2.71	0.42	2.67	0.42	2.61	0.36	2.88	0.36	2.78	0.18
22:6 n-3	7.01	0.93	1.11	2.28	1.11	5.03	0.83	4.98	0.97	5.24	0.77	5.45	0.92	5.61	0.64

## b) Phosphatidylethanolamine

	Cord blood (n = 10)		Infants (n = 6)		Age 1-3 (n = 17)		Age 3-6 (n = 27)		Age 6-9 (n = 22)		Age 9-12 (n = 14)		Age 12-15 (n = 8)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
15:0	0.18	0.07	0.17	0.06	0.19	0.09	0.19	0.07	0.21	0.10	0.18	0.06	0.16	0.07
16:0	22.79	1.18	17.52	1.05	15.23	1.41	14.73	1.05	14.60	1.01	14.96	1.68	14.62	0.98
16:1t	0.21	0.04	0.14	0.04	0.27	0.18	0.25	0.08	0.31	0.13	0.26	0.07	0.26	0.05
16:1c	0.44	0.23	0.26	0.05	0.27	0.15	0.26	0.09	0.30	0.15	0.32	0.12	0.29	0.10
17:0	0.36	0.03	0.32	0.06	0.42	0.11	0.36	0.05	0.42	0.10	0.38	0.07	0.35	0.04
17:1c	0.24	0.04	0.40	0.36	0.06	0.04	0.09	0.06	0.13	0.09	0.16	0.16	0.08	0.05
18:0	6.16	0.73	7.21	1.37	7.49	0.73	7.46	0.55	7.42	0.68	7.22	0.79	6.92	0.61
18:1t	0.24	0.08	0.36	0.11	0.72	0.20	0.86	0.23	1.09	0.54	0.90	0.30	0.97	0.25
18:1 n-9	16.31	1.09	20.31	1.25	19.38	1.43	19.53	1.24	19.24	1.35	19.65	2.16	19.22	1.57
18:2tt	0.09	0.03	0.15	0.07	0.02	0.03	0.03	0.04	0.02	0.03	0.05	0.04	0.02	0.03
18:2 n-6	2.33	0.24	7.59	1.24	6.13	0.80	6.83	1.38	6.82	0.91	7.25	1.48	6.15	0.48
18:3 n-6	0.08	0.04	0.07	0.01	0.04	0.04	0.07	0.07	0.06	0.05	0.04	0.04	0.04	0.03
18:3 n-3	0.06	0.03	0.07	0.03	0.13	0.06	0.14	0.06	0.18	0.08	0.15	0.06	0.16	0.08
20:0	0.18	0.06	0.31	0.16	0.13	0.06	0.19	0.12	0.14	0.07	0.14	0.09	0.12	0.04
20:1 n-9	0.54	0.08	0.79	0.14	0.63	0.07	0.66	0.12	0.66	0.13	0.62	0.12	0.66	0.08
20:2 n-6	0.18	0.03	0.43	0.11	0.30	0.20	0.26	0.08	0.28	0.07	0.27	0.06	0.30	0.06
20:3 n-9	1.25	0.19	0.45	0.27	0.17	0.07	0.23	0.14	0.15	0.06	0.18	0.13	0.11	0.03
20:3 n-6	1.96	0.38	2.69	0.76	1.26	0.30	1.43	0.37	1.37	0.33	1.53	0.33	1.26	0.16
20:4 n-6	24.45	1.68	23.56	1.93	25.95	1.73	24.97	1.72	25.15	1.43	24.23	2.47	25.26	0.94
20:5 n-3	0.24	0.06	0.40	0.13	1.00	0.16	1.12	0.37	1.11	0.22	1.26	0.24	1.10	0.23
22:4 n-6	9.09	0.87	8.79	1.25	7.76	0.81	7.38	1.12	7.70	1.00	7.03	1.11	8.43	1.32
22:5 n-6	2.22	0.44	1.86	0.70	0.98	0.27	0.94	0.21	0.78	0.18	0.76	0.14	0.78	0.16
22:5 n-3	1.05	0.08	2.44	0.69	4.55	0.61	4.62	0.75	4.36	0.64	4.85	0.71	4.70	0.33
22:6 n-3	9.01	0.74	3.17	1.27	6.29	1.10	6.57	1.24	6.63	0.95	6.80	1.16	7.33	0.76

## c) Phosphatidylcholine

	Cord blood (n = 10)		Infants (n = 6)		Age 1-3 (n = 17)		Age 3-6 (n = 27)		Age 6-9 (n = 22)		Age 9-12 (n = 14)		Age 12-15 (n = 8)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
15:0	0.28	0.06	0.25	0.12	0.33	0.08	0.35	0.13	0.36	0.14	0.39	0.12	0.31	0.08
16:0	39.07	0.80	37.85	1.32	34.11	1.07	33.17	1.16	32.87	1.07	33.31	0.85	33.70	0.88
16:1t	0.36	0.08	0.23	0.08	0.45	0.10	0.48	0.10	0.51	0.10	0.55	0.08	0.49	0.10
16:1c	1.49	0.43	0.68	0.32	0.73	0.13	0.69	0.17	0.68	0.21	0.68	0.23	0.72	0.18
17:0	0.55	0.08	0.44	0.15	0.61	0.07	0.60	0.08	0.63	0.08	0.65	0.09	0.59	0.09
17:1c	0.14	0.07	0.09	0.02	0.11	0.05	0.11	0.05	0.13	0.07	0.14	0.05	0.10	0.03
18:0	9.34	0.53	9.96	1.18	11.61	0.70	11.72	0.85	11.97	0.74	11.62	0.56	11.48	0.77
18:1t	0.27	0.13	0.41	0.20	0.82	0.29	0.92	0.26	1.30	0.56	1.16	0.46	1.17	0.34
18:1 n-9	19.00	1.32	19.53	2.17	19.12	1.06	19.15	1.25	18.30	1.06	19.00	1.43	18.56	0.73
18:2tt	0.11	0.05	0.26	0.05	0.04	0.04	0.06	0.03	0.05	0.05	0.07	0.06	0.04	0.03
18:2 n-6	8.02	0.52	20.74	2.67	21.20	1.68	22.03	2.25	22.22	1.98	22.37	2.09	21.06	1.17
18:3 n-6	0.12	0.06	0.09	0.02	0.10	0.06	0.11	0.05	0.11	0.08	0.09	0.02	0.08	0.02
18:3 n-3	0.02	0.01	0.09	0.02	0.18	0.08	0.21	0.09	0.23	0.11	0.25	0.07	0.18	0.07
20:0	0.13	0.08	0.19	0.10	0.12	0.05	0.13	0.15	0.13	0.06	0.11	0.05	0.12	0.03
20:1 n-9	0.13	0.03	0.34	0.14	0.24	0.04	0.25	0.06	0.26	0.06	0.25	0.05	0.25	0.04
20:2 n-6	0.33	0.07	0.38	0.09	0.29	0.03	0.34	0.23	0.31	0.04	0.32	0.06	0.32	0.02
20:3 n-9	0.52	0.21	0.22	0.17	0.13	0.07	0.14	0.19	0.10	0.06	0.14	0.10	0.10	0.03
20:3 n-6	4.04	0.51	2.55	0.12	1.81	0.33	1.78	0.40	1.77	0.31	1.85	0.31	1.77	0.20
20:4 n-6	11.81	1.52	4.19	1.23	5.17	0.85	4.71	0.82	4.94	1.15	4.27	1.15	5.39	0.50
20:5 n-3	0.18	0.04	0.09	0.05	0.29	0.07	0.30	0.14	0.34	0.14	0.34	0.19	0.35	0.09
22:4 n-6	0.60	0.08	0.34	0.12	0.25	0.04	0.24	0.06	0.34	0.48	0.19	0.06	0.31	0.09
22:5 n-6	0.41	0.11	0.21	0.09	0.12	0.03	0.10	0.06	0.08	0.05	0.08	0.05	0.10	0.05
22:5 n-3	0.25	0.07	0.21	0.11	0.43	0.09	0.43	0.12	0.43	0.12	0.39	0.15	0.50	0.06
22:6 n-3	2.50	0.74	0.44	0.16	1.05	0.29	1.07	0.45	1.14	0.43	0.93	0.43	1.57	0.28

Table 3. Age-related parameters of erythrocyte membrane phospholipids (%).

	Cord blood (n = 10)		Infants (n = 6)		Age 1-3 (n = 17)		Age 3-6 (n = 27)		Age 6-9 (n = 22)		Age 9-12 (n = 14)		Age 12-15 (n = 8)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
a) Total phospholipids														
C15 + C17	0.71	0.12	0.60	0.26	0.72	0.11	0.69	0.13	0.71	0.14	0.72	0.07	0.65	0.12
pufa	42.91	1.35	41.49	2.76	44.36	1.31	44.06	1.25	44.69	1.06	44.60	1.75	44.54	1.19
sat	40.73	0.93	39.58	2.04	36.93	0.90	36.88	0.88	36.50	0.82	36.41	0.95	36.62	0.43
trans	0.62	0.13	0.81	0.23	1.52	0.42	1.68	0.37	2.07	0.61	2.01	0.65	2.11	0.38
sum n-9	15.02	0.98	17.27	1.75	15.96	0.73	16.22	0.86	15.65	0.82	15.86	1.27	15.66	1.04
met n-9	1.13	0.22	0.81	0.15	0.52	0.08	0.54	0.07	0.52	0.09	0.53	0.08	0.54	0.10
sum n-6	34.02	1.08	37.07	2.50	35.67	1.06	35.23	1.47	35.73	1.34	35.07	1.61	35.06	1.02
met n-6	29.73	1.05	25.05	2.35	24.28	1.33	22.90	1.58	23.38	1.31	22.85	1.79	23.79	1.04
sum n-3	7.99	0.96	3.97	1.20	8.39	0.93	8.52	1.11	8.65	1.00	9.23	1.05	9.19	0.83
met n-3	7.99	0.96	3.92	1.19	8.26	0.92	8.37	1.12	8.52	1.00	9.08	1.05	9.06	0.82
monoenic	15.47	1.16	18.17	1.58	17.72	0.68	18.09	0.90	17.90	0.65	18.04	1.40	17.98	0.91
p/s ratio	1.05	0.05	1.05	0.11	1.20	0.06	1.20	0.06	1.23	0.05	1.23	0.07	1.22	0.04

## b) Phosphatidylethanolamine

	Cord blood (n = 10)		Infants (n = 6)		Age 1-3 (n = 17)		Age 3-6 (n = 27)		Age 6-9 (n = 22)		Age 9-12 (n = 14)		Age 12-15 (n = 8)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
C15 + C17	0.63	0.14	0.54	0.08	0.66	0.17	0.64	0.14	0.76	0.26	0.69	0.18	0.59	0.13
pufa	52.15	2.35	51.99	2.00	54.84	2.56	54.93	2.03	55.06	1.66	54.81	3.78	55.95	1.57
sat	29.21	1.85	25.11	1.95	22.89	1.42	22.42	1.08	22.22	0.98	22.34	1.86	21.68	0.55
trans	0.54	0.14	0.66	0.18	1.10	0.35	1.25	0.28	1.57	0.68	1.35	0.37	1.38	0.27
sum n-9	18.14	1.08	21.64	1.28	20.21	1.42	20.49	1.24	20.13	1.43	20.52	2.26	20.07	1.57
met n-9	1.83	0.26	1.33	0.89	0.84	0.15	0.97	0.19	0.88	0.15	0.87	0.17	0.85	0.07
sum n-6	40.32	1.93	45.13	2.10	42.49	2.07	41.96	1.75	42.26	1.73	41.23	2.95	42.32	1.18
met n-6	37.99	1.84	37.54	2.65	36.35	2.14	35.13	2.11	35.45	2.00	33.98	3.15	36.17	1.37
sum n-3	10.50	0.77	6.26	1.36	12.09	1.11	12.59	1.67	12.48	1.32	13.20	1.68	13.38	1.20
met n-3	10.50	0.78	6.21	1.36	11.96	1.10	12.45	1.67	12.30	1.34	13.05	1.67	13.22	1.16
monoenic	17.86	1.10	22.01	1.28	21.36	1.46	21.72	1.35	21.80	1.35	21.97	2.38	21.57	1.43
p/s ratio	1.80	0.19	2.09	0.22	2.41	0.24	2.46	0.20	2.49	0.17	2.48	0.33	2.58	0.12

## c) Phosphatidylcholine

	Cord blood (n = 10)		Infants (n = 6)		Age 1-3 (n = 17)		Age 3-6 (n = 27)		Age 6-9 (n = 22)		Age 9-12 (n = 14)		Age 12-15 (n = 8)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
C15 + C17	0.92	0.13	0.71	0.30	1.03	0.18	1.03	0.24	1.12	0.23	1.17	0.20	0.99	0.17
pufa	29.01	1.77	21.22	1.88	31.45	1.27	31.99	1.36	32.54	1.32	31.84	1.66	32.21	0.91
sat	48.58	0.91	48.00	1.43	45.87	1.01	45.12	0.89	45.02	0.95	45.07	0.61	45.35	0.71
trans	0.72	0.15	0.90	0.30	1.52	0.43	1.69	0.30	2.12	0.63	2.06	0.61	1.92	0.38
sum n-9	19.66	1.46	20.10	2.22	19.53	1.11	19.59	1.33	18.71	1.07	19.44	1.40	18.95	0.72
met n-9	0.65	0.22	0.56	0.19	0.41	0.13	0.44	0.20	0.40	0.11	0.44	0.11	0.40	0.05
sum n-6	25.33	1.47	28.55	1.99	29.02	1.30	29.39	1.58	29.86	1.37	29.31	1.48	29.13	1.03
met n-6	17.31	1.35	7.81	1.40	7.82	0.93	7.36	1.21	7.64	1.34	6.94	1.41	8.07	0.50
sum n-3	3.07	0.77	0.87	0.36	2.05	0.38	2.18	0.69	2.27	0.65	2.03	0.63	2.72	0.41
met n-3	3.06	0.76	0.78	0.36	1.86	0.36	1.97	0.67	2.03	0.62	1.78	0.63	2.54	0.39
monoenic	21.40	1.55	21.22	1.88	21.51	1.23	21.65	1.31	21.22	1.06	21.82	1.29	21.33	0.80
p/s ratio	0.60	0.04	0.62	0.05	0.69	0.04	0.71	0.04	0.72	0.04	0.71	0.04	0.71	0.03

met n-9 = sum n-9 minus 18:1 n-9; met n-6 = sum n-6 minus 18:2 n-6; met n-3 = sum n-3 minus 18:3 n-3



Table 2a-c shows the age-related fatty-acid pattern of total lipids and of the phosphatidylcholine (PC) and phosphatidylethanolamine (PE) fractions of erythrocyte membranes of healthy children.

Table 3a-c shows a variety of age-related parameters of red-cell-membrane lipids. With either phospholipid fraction, about 25 % of total red-cell-membrane phospholipids were analyzed (6). In PE, which is predominantly located within the inner-membrane bilayer (12), the polyunsaturated fatty acids contributed approximately 55 % and the saturated fatty acids 22 % of all fatty acids. In PC, which is located predominantly within the outer membrane bilayer, (12) the saturated fatty acids amounted to approximately 44 % and the polyunsaturated fatty acids to approximately 32 %.

Age-dependent alterations in the most important polyunsaturated fatty acids and in trans-fatty acids in the different red-cell-membrane phospholipid fractions were as follows:

After infancy there were only a few changes in the proportions of the fatty acids with increasing age. Extensive alterations were observed within the first few months after birth. These were predominantly related to the linoleic (C 18:2 n-6) and  $\alpha$ -linolenic (C 18:3 n-3) acids and their by enzymatic desaturation and chain-elongation derived long-chain polyunsaturated fatty acids of the n-6 and n-3 families.

Compared to the values at birth, linoleic acid, which was higher in the PC fraction than in the PE fraction, increased by approximately 2½- to 3-fold in total phospholipids and in both fractions. The percentage of arachidonic acid (C 20: 4-6), which was much higher in PE than in PC fraction, remained practically unchanged in PE and decreased by approximately 50 % in the PC fraction. There was a small decline in docosatetraenoic acid (C 22: 4 n-6) membrane concentration and a 50 % decline in docosapentaenoic acid (C 22: 5 n-6), which continued into early childhood.

After birth, we found a steep increase in membrane concentration of  $\alpha$ -linolenic acid, which continued into early childhood. The concentration of eicosapentaenoic acid (EPA; C 20: 5 n-3) remained quite constant during the first year of age in total phospholipids (slight increase in PE; slight decrease in PC) and showed a steep increase predominantly during the second and third years of life. There was a distinct decline in docosahexaenoic acid (DHA; C 22: 6 n-3) during the first year of life, followed by a re-increase during the second year of life.

There was also a small increase of total n-6 fatty acids during infancy, and in each PL fraction studied a considerable decrease in total n-3 fatty acids followed by a re-increase during the second and third years of age. There was hardly any change in the odd-numbered long-chain fatty acids (C15 and C17) during infancy and childhood.

Only the trans-fatty acid family showed significant alterations still during childhood. In both phospholipid classes studied, we found an abrupt linear increase during the first two years of life, which became less steep during the next five years. The highest mean percentage of trans-fatty acids was found in the 6- to 9-year-old children and there seems to be a decline later.

## Discussion

This study demonstrates again that extensive alterations of the fatty-acid composition of red-cell lipids occur during infancy. They are particularly related to the long-chain polyunsaturated fatty acids (PUFA), which are important components of membrane systems in all tissues, influencing by their concentrations different membrane functions. Within a few months after birth, the different red-cell phospholipid classes assume a fatty-acid pattern of adult type, which then remains rather constant throughout childhood.

It is well known that most of the alterations in membrane PUFA concentration following birth occur before or during the first four weeks of age (7, 13–15).

The low concentration of linoleic and  $\alpha$ -linolenic acids in cord red cells, resulting from a low supply of those fatty acids by the placenta (3), increase rapidly after introduction of oral feeding. Another characteristic alteration is related to membrane DHA, which is a major constituent of red-cell phosphatidylethanolamine at birth. There is a steady decline in membrane DHA after birth possibly due to a poor ability to convert  $\alpha$ -linolenic acid to DHA (low activity of delta 4-desaturase (13), and it takes more than one year of dietary intake to reach an adult membrane concentration, which remains persistently  $\frac{1}{3}$  to  $\frac{1}{2}$  of the DHA levels found in cord-erythrocyte membranes. The concentration of total n-3 fatty acids in membranes showed a trough during the first weeks of life and reach adult levels not before the second year of life. Very little change occurred in the total fatty acid of the n-6 series.

With respect to trans fatty acids an "adult pattern" in red-cell-membrane phospholipids was not attained before childhood. The continuing increase in the trans-fatty-acid concentration, which forms a plateau in erythrocyte membranes of 6- to 9-year-old children can be explained by the augmented intake of foods containing hydrogenated vegetable oil, such as infant formulas, sweets, and bread spreads (16, 17).

The fatty-acid pattern of total phospholipids and the PE and PC fractions of healthy children between the ages of 2 and 14 years, which we obtained, were in good agreement with the findings of Rogiers and colleagues (5, 6), who investigated the red-cell fatty-acid patterns of 8- to 10-year-old Belgian children and are comparable with those described for healthy adults (9, 10, 11).

In addition to data on previous studies using conventional packed GC-columns, we also are able to provide mean values of proportions of the trans-fatty-acids and the odd-numbered fatty-acids in erythrocytes membrane lipids in healthy children of different ages. The measurement of both types of fatty acids in easily obtainable samples, such as erythrocytes, might be of interest in assessing the effect of differences in long-term trans-fatty acid intake and in odd-numbered fatty-acid (C15 and C17 acids) production in metabolic diseases (18).

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