Body Fat of British and Dutch Infants

ELSIE M. WIDDOWSON, M. JOY DAUNCEY, D. M. T. GAIRDNER, J. H. P. JONXIS, MARTA PELIKAN-FILÍPKOVÁ

British Medical Journal, 1975, 1, 653-655

Summary

The fatty acids in the body fat of 41 British and 37 Dutch infants between birth and 1 year were determined. At birth linoleic acid contributed 1-3% of the total fatty acids of the body fat in infants in both countries. By one month its proportion in the fat of the Dutch infants was about 25% and by four months 32-37%; in the fat of the British infants it was never more than 3%. In the Dutch infants this large increase in the linoleic acid percentage was accompanied by a fall in the percentage contribution of others, particularly the saturated acids myristic, palmitic, and stearic. Infants born preterm showed changes in their fat after birth similar to those in full-term infants.

The difference between the composition of the fat of the infants in the two countries is attributed to the nature of the fat in the milk they received. Until recently most British infants who are not breast-fed have been given milks based on cow's milk with only minor modifications. For the past 10 years many Dutch infants have been given a milk in which all the cow's milk fat has been replaced by maize oil.

Dutch infants also had a lower concentration of cholesterol in their serum than British infants, which was not unexpected. The results show that the triglycerides in the adipose tissue are profoundly influenced by the nature of the fat in the diet.

Introduction

A comparison was made recently of the composition of 32 dried milk powder preparations for infants on sale in seven European countries (Widdowson, 1973; Widdowson *et al.*, 1974). Some remarkable differences came to light, one of the most striking being in the fatty acid composition of the fat in the milks fed to infants in Britain and the Netherlands. Most British infants who are not breast-fed have, at least until recently, been given foods based on cow's milk with added carbohydrate. In the most widely used Dutch food for infants, Almiron, cow's milk fat has been entirely replaced by maize oil. The fatty-acid composition of these two types of milk is shown in table I, and values for the fat of human milk are given for comparison.

Diet can affect the fatty-acid composition of the body fat. In adults such changes in response to an alteration in dietary fat occur slowly (Hirsch *et al.*, 1960), but in periods of rapid weight gain, particularly in early infancy, changes in adipose-tissue composition can occur in a short time (Sweeney *et al.*, 1963; Hashim and Asfour, 1968; Ballabriga *et al.*, 1972). It therefore seemed likely that the composition of the body fat of Dutch infants might be different from that of British ones and we decided to see whether this was so.

Department of Investigative Medicine, University of Cambridge, Cambridge CB2 1QN
ELSIE M. WIDDOWSON, D.SC., M.R.C. Grant Holder

Dunn Nutritional Laboratory, Cambridge
M. JOY DAUNCEY, PH.D., Member of M.R.C. Staff

Addenbrooke's Hospital, Cambridge
D. M. T. GAIRDNER, D.M., F.R.C.P., Consultant Paediatrician

Paediatric Department, University of Groningen, The Netherlands
J. H. P. JONXIS, M.D., Professor of Paediatrics
MARTA PELIKAN-FILÍPKOVÁ, M.D.

TABLE I—*Fatty-acid Composition of Fat of Milks Fed to British and Dutch Infants (g/100 g Total Fatty Acids)*

Fatty-acid Designation	British Milk*	Dutch Milk†	Human Milk
	Saturated Acids		
C10:0 (Capric)	2·4	0	1·0
C12:0 (Lauric)	3·2	0	4·8
C14:0 (Myristic)	11·5	Trace	6·2
C16:0 (Palmitic)	30·0	10·7	23·7
C18:0 (Stearic)	14·3	2·0	6·7
	Unsaturated Acids		
C16:1 (Palmitoleic)	2·0	Trace	4·6
C18:1 (Oleic)	31·1	27·2	37·4
C18:2 (Linoleic)	1·8	58·2	9·0
C18:3 (Linolenic)	Trace	1·6	3·4

* Cow and Gate, Ostermilk, and National Dried Milk.
† Almiron.

Patients and Methods

Samples of adipose tissue were obtained from 41 British and 37 Dutch infants. Five Dutch infants were studied twice, and the total number of Dutch samples was 42. Twenty-nine of the British samples were obtained at surgical operation, usually herniotomy, or after perinatal death. The remaining 12 were obtained by needle biopsy, with parental permission, from infants born preterm at gestational ages from 28 to 35 weeks. These samples formed part of a study of the effects of different milk feeds on the growth of adipose tissue in premature infants (M. J. Dauncey and D. M. T. Gairdner, to be published). From 15 British infants who had died adipose tissue was obtained from three sites—anterior abdominal wall and the gluteal and perirenal regions. Since the fatty-acid composition of the fat did not vary from site to site all the results were grouped together irrespective of the site from which the samples came.

The Dutch samples were obtained, with parental consent, by needle biopsy from healthy infants, some of average and some of low birth weight. Those studied soon after birth were born in the State University Hospital, Groningen. Some of those studied later had remained in hospital because of domestic problems at home, and others attended an outpatient clinic where they were being measured in connexion with a study on growth and development.

The ages of the infants and the food they received are shown in table II. In both countries some samples were taken from preterm and full-term infants at birth, others during the first four months after birth, when the infants received no fat other than that in the milk, and others from infants up to 1 year of age, most of whom were having other foods.

TABLE II—*Numbers of Infants Studied and Source of Fat in their Food*

Age	British Infants: No. of Infants	British Infants: Food	Dutch Infants: No. of Infants	Dutch Infants: Food
Newborn	14		12	
0-4 months	18	Cow's milk	19*	Almiron
	2	Breast milk		
6-12 months	7	Mixed diet	4	Mixed diet
			2	Almiron

* 24 samples.

The samples of adipose tissue (10-20 mg from biopsy, 50-100 mg from operation or necropsy) were transferred to a glass phial containing isotonic saline. The contents of the phial were filtered through a nylon screen and the fragments of adipose tissue were washed with isotonic saline and stored at −20°C if they were not analysed immediately. In Cambridge lipid was extracted from the adipose tissue using a modification of the method of Southgate (1971). Methyl esters were prepared by the method of Bowyer *et al.* (1963), and the fatty-acid composition of the fat was determined by gas-liquid chromatography. In Groningen the method of Metcalfe *et al.* (1966) and that described by Lipsky *et al.* (1959) were used. Blood was taken from most of the Dutch infants at the same time as the fat samples. Serum was separated and the cholesterol determined by the method of Huang *et al.* (1961).

All the British and a few Dutch samples were analysed in Cambridge, though most Dutch samples were analysed in Groningen. Checks proved that the methods used in the two laboratories gave similar results.

Results

The percentage of the total fatty acids in the triglycerides of the adipose tissue accounted for by linoleic acid (C18:2) in British and Dutch infants of different ages is shown in fig. 1a. The mean values at birth for British and Dutch infants are shown in table III. The changes after birth were in the expected direction but their magnitude and speed in the Dutch infants were remarkable. After two weeks the percentage of linoleic acid in the fat of Dutch infants was between 10% and 20%, after four weeks it had risen to about 25%, and after 16 weeks to 32-37%. Two older infants, aged 6 and 10 months, still getting all or almost all of their fat from Almiron had 43% and 46% of linoleic acid in their body fat respectively. Preterm infants showed similar changes in the composition of their body fat in the weeks after birth to those born at term, and the two groups were not differentiated in the results.

TABLE III—*Mean Fatty-acid Composition (± S.D.) of Body Fat of 14 British and 12 Dutch Infants at Birth (g/100g Total Fatty Acids)*

Fatty Acid	British Infants	Dutch Infants
	Saturated Acids	
C14:0	3·8 ± 0·56	3·3 ± 0·44
C16:0	48·9 ± 3·6	45·8 ± 1·6
C18:0	4·1 ± 0·64	3·8 ± 0·37
	Unsaturated Acids	
C16:1	12·6 ± 1·6*	15·2 ± 1·2*
C18:1	29·6 ± 3·0	29·0 ± 1·8
C18:2	1·0 ± 0·75*	2·9 ± 0·71*

* Significance of difference between means $P<0·001$.

The British infants receiving only cow's milk fat never had more than 3% of linoleic acid in their body fat and many had less than 1%. Two breast-fed infants aged 12 weeks had between 3% and 4%.

The large increase in linoleic acid in the fat of the Dutch infants was accompanied by a fall in the percentage contributed by other acids. The proportion of myristic acid (C14:0) in the Dutch infants fell from the newborn level of 3-4% to between 1 and 2% at four months (fig. 1b). In the British infants the percentage rose to about 10%.

The body fat of the infants at birth contained over 45% of palmitic acid (C16:0), and in both groups the percentage of palmitic acid fell though the fall was greater in the Dutch infants (fig. 1c).

At birth the amount of stearic acid (C18:0) in the body fat of infants in both countries was smaller than that in cow's milk fat and greater than that in Almiron. The percentage of stearic acid in the body fat of the Dutch infants fell (fig. 1d). The figures for the fat of British infants were very variable but tended to be higher than those for the Dutch infants.

The unsaturated acid palmitoleic (C16:1) was present in very small amounts in both the British and Dutch "milks", and the body fat at birth contained considerably more. In both countries the percentage of palmitoleic acid in the body fat tended to fall after birth, but the changes were small. Oleic acid (C18:1) was present in about the same proportions in the fat of the two milks and in the body fat of the infants at birth. The percentage tended to rise in the British infants and remain unchanged in the Dutch ones.

Seven British and four Dutch infants were between six months and one year and had been having a mixed diet before the fat samples were taken. The mean fatty-acid composition of their body fat is shown in table IV. There were still differences in the percentage contribution of all the main fatty acids except oleic acid, which had also been similar in the two groups at the younger ages. The fatty-acid pattern of the body fat established by the type of fat fed up to 4 months of age was still evident, at least for some months after mixed feeding began.

Our results suggest that there was a difference in the composition of the body fat of British and Dutch infants when they were born (see table III). Preterm and full-term infants were averaged together as changes in the composition of the body fat during the latter part of gestation were negligible. By the time the Dutch infants were born they already seemed to have acquired a more unsaturated body fat than British infants. This was due to the higher proportions of palmitoleic and linoleic acids, and the differences in both between the two groups were

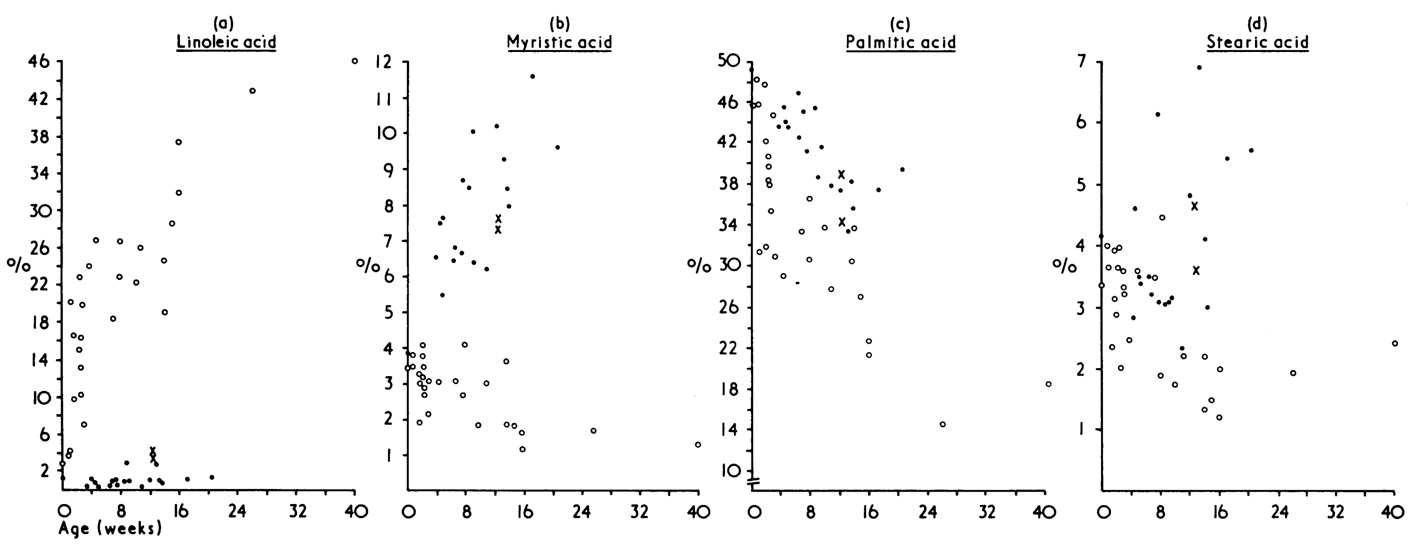

FIG. 1—Individual fatty acids as percentage of total fatty acids in body fat of British and Dutch infants: (a) linoleic acid (C18:2); (b) myristic acid (C14:0); (c) Palmitic acid (C16:0); (d) Stearic acid (C18:0). ● = British infants fed on cow's milk fat. X = British breast-fed infants. O = Dutch infants fed on Almiron containing maize oil.

highly significant (P <0·001). More work is needed, however, and all the fat samples should certainly be analysed "blind" in the same laboratory before a definite statement can be made.

TABLE IV—*Mean Fatty-acid Composition (± S.D.) of Body Fat of Seven British and Four Dutch Infants 6-12 Months Old on Mixed Diet (g/100 g Total Fatty Acids)*

Fatty Acid	British Infants	Dutch Infants
	Saturated Acids	
C14:0	8·5 ± 1·1	4·8 ± 1·2
C16:0	32·0 ± 2·7	29·7 ± 4·6
C18:0	5·6 ± 0·97	2·9 ± 0·72
	Unsaturated Acids	
C16:1	7·0 ± 1·9	13·8 ± 2·7
C18:1	43·4 ± 2·9	40·8 ± 3·3
C18:2	3·5 ± 0·78	8·0 ± 4·1

Discussion

Feeding habits among adults in the Netherlands have changed over the past five to 10 years. "Soft" margarine containing a high percentage of linoleic acid is used instead of butter by most people. A change from a saturated to a highly unsaturated "spreading fat" may have altered the fatty-acid composition of the body fat of older children and adults, including pregnant women. Possibly fatty acids, particularly inoleic acid, cross the human placenta in small amounts (Szabo *et al.*, 1969), and the change in diet of the women in the Netherlands may have influenced the composition of the fat of their babies at birth.

Whether this proves to be so or not there is no doubt about the difference between British and Dutch infants in the fatty-acid composition of their body fat during the first four months after birth. Pape *et al.* (1974) found that German infants of 2-6 months have a mean of 11% linoleic acid in their body fat. This fits in with the fatty-acid composition of infant formulae on sale in the Federal Republic of Germany (Widdowson *et al.*, 1974). Does the composition of the body fat matter? Are the Dutch children any the better or worse than British children, either at the time or later, for having a highly unsaturated body fat in infancy? They have a lower serum cholesterol than British infants fed on breast milk or full cream cow's milk (fig. 2; Darmady *et al.*, 1972), which would be regarded by many as an advantage. Beyond this we come to a series of unknowns. Does the degree of saturation of the body fat affect cell multiplication and the likelihood of obesity (Launay *et al.*, 1972)? Are lipids other than those in the depot fats—for example, those in the arteries or the cell membranes, including those of the nervous system—influenced by the nature of the fat in the diet? If so, does this alter the fragility, permeability, or function of the membranes or their behaviour in the presence of disease? Is the nature of the lipid deposited in the brain during the first months after birth affected by a large or small intake of linoleic acid? The results of studies on animals with diets deficient in linoleic acid suggest that the lipids of the central nervous system are not easily altered (Svennerholm *et al.*, 1972), but until the effect of an excess has been investigated we cannot be sure.

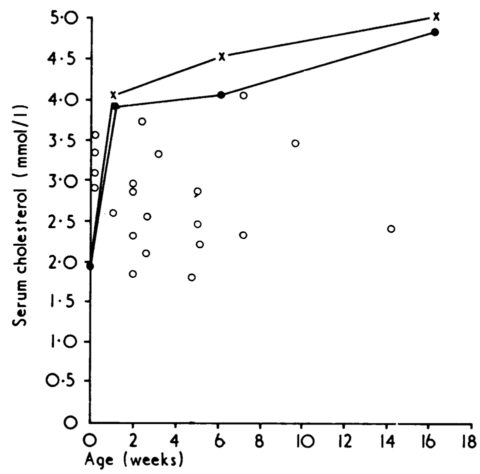

FIG. 2—Serum cholesterol values of individual Dutch infants (○) compared with values of Darmady *et al.* (1972 for British infants fed cow's milk (●) and breast-fed (X).
Conversion: SI to Traditional Units—Cholesterol: 1 mmol/l ≈ 39 mg/100 ml.

Relatively large amounts of α-tocopherol must be required to maintain the high degree of unsaturation of the body fat. What happens to the body fat when the intakes of vitamin E and linoleic acid are reduced on weaning? These and many other problems can be posed and probably solved experimentally in either man or animals. Some of them are already being investigated.

E. M. W. and M. J. D. are grateful to the M.R.C. for its support.

References

Ballabriga, A., Martinez, A., and Gallart-Catala, A. (1972). *Helvetia Paediatrica Acta*, **27**, 91.
Bowyer, D. E., *et al.* (1963). *Biochimica et Biophysica Acta*, **70**, 423.
Darmady, J. M., Fosbrooke, A. S., and Lloyd, J. K. (1972). *British Medical Journal*, **2**, 685.
Hashim, S. A., and Asfour, R. H. (1968). *American Journal of Clinical Nutrition*, **21**, 75.
Hirsch, J., *et al.* (1960). *American Journal of Clinical Nutrition*, **8**, 499.
Huang, T. C., *et al.* (1961). *Analytical Chemistry*, **33**, 1405.
Launay, M., *et al.* (1972). *Nutrition Reports International*, **5**, 339.
Lipsky, S. R., Landown, R. A., and Godet, M. R. (1959). *Biochimica et Biophysica Acta*, **31**, 336.
Metcalfe, L. D., Smitz, A. A., and Pelka, J. R. P. (1966). *Analytical Chemistry*, **38**, 514.
Pape, E., Stolley, H., and Droese, W. (1974). *Zeitschrift für Kinderheilkunde*, **116**, 269.
Southgate, D. A. T. (1971). *Journal of the Science of Food and Agriculture*, **22**, 590.
Svennerholm, L., *et al.* (1972). In *Lipids, Malnutrition and the Developing Brain*, ed. K. Elliott and J. Knight, p. 141. Amsterdam, Elsevier.
Sweeney, M. J., *et al.* (1963). *Journal of Clinical Investigation*, **42**, 1.
Szabo, A. J., Grimaldi, R. D., and Jung, W. F. (1969). *Metabolism*, **18**, 406.
Widdowson, E. M. (1973). In *Nutritional Problems in a Changing World*, ed. D. Hollingsworth and M. Russell, p. 101. London, Applied Science Publishers Ltd.
Widdowson, E. M., Southgate, D. A. T., and Schutz, Y. (1974). *Archives of Disease in Childhood*, **49**, 867.