Adequacy of expressed breast milk for early growth of preterm infants

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SUMMARY Poor weight gain observed in preterm infants who were fed expressed breast milk compared with those fed a cows' milk formula prompted a detailed study of early postnatal growth in preterm infants fed these two milks. 68 infants were divided into two categories by gestational age at birth (i) 28–32 weeks (n=28), (ii) 33–36 weeks (n=40). They were randomly allocated to a feed of expressed breast milk or a milk formula (Ostermilk 1). Rates of weight gain, linear growth, and head circumference growth were evaluated over two periods: birth–1 month, 1–2 months.

The younger group who were fed breast milk showed slower overall growth rates over the first month than those fed formula. In the second month, and for the older infants over both of the 2-monthly periods, growth rates were similar in the two feeding regimens. It is concluded that expressed breast milk is inadequate for the growth of very immature preterm infants during early postnatal life.

Since the early years of caring for preterm infants it has been widely taught that breast milk is their food of choice (Budin, 1907; Hess, 1953; Corner, 1960; Crosse, 1966; Davies *et al.*, 1972). In Cardiff the milk bank at St. David's Hospital has made this teaching a reality for many years since sufficient amounts of expressed breast milk have usually been available for the city's preterm infants during the early weeks of life. Lately, however, this practice has been criticized because poor weight gain has been noted in many of these infants compared with those who have been fed on unmodified cows' milk formulae. Similar observations were made by earlier workers (Finkelstein, 1912; Gordon *et al.*, 1947; Powers, 1948; Omans *et al.*, 1961), but these seem to have been viewed with little concern since the widespread belief of the superiority of breast milk for preterm infants continues.

In recent years there has been considerable publicity given to the importance of early postnatal growth due to a growing body of evidence, mainly from animal studies, that early growth impairment might adversely affect later growth and mental development (Winick and Noble, 1966; Dobbing, 1974). The suspicion that breast milk was less able than cows' milk to maintain satisfactory growth in preterm infants prompted the present study which compares the early growth of preterm infants fed these two milks.

Material and methods

68 preterm infants were studied. They were born at Cardiff Maternity Hospital and St. David's Hospital, Cardiff, between 1 April 1972 and 30 March 1973, and cared for on the neonatal units. Multiple births and infants with major congenital abnormalities, chromosome disorders, and congenital infections were not included. For the purposes of later statistical analysis the infants were grouped into one of two categories; (a) 28 infants with gestational ages of 28 to 32 weeks, (b) 40 infants with gestational ages of 33 to 36 weeks.

Birthweights were all above the 5th centile allowing for maternal height, sex, and birth order (Tanner and Thomson, 1970). Gestational age to the nearest completed week was determined from menstrual data. Where this was unreliable or obvious discrepancy existed between calculated gestational age and the clinical appearance of the infant, gestational age was assessed by the Dubowitz score (Dubowitz *et al.*, 1970).

Milks. On admission to the neonatal unit the infants were randomly allocated to mature breast milk or Ostermilk 1 (Glaxo Laboratories), the cows' milk formula which was used at the time as an alternative to breast milk. The compositions of the milks are given in Table 1. Breast milk was collected at home from breast-feeding mothers, then pooled, heated to 65°C for 35 minutes and stored at −4°C until

Table 1 *Compositions of the milks per 100 ml*

Constituent	Expressed breast milk	Ostermilk 1
Calories	71	70
Protein (g)	1·1	2·7*
Fat (g)	4·4	2·8†
Carbohydrate (g)	7·3	8·4*‡
Sodium (mEq)	0·5	1·8
Potassium (mEq)	1·5	3·4
Chloride (mEq)	1·0	2·4
Calcium (mg)	32	94
Phosphorus (mg)	15	74
Magnesium (mg)	2·6	17

*Ratio of casein : whey proteins similar to that of cows' milk, i.e. about 4·5:1.
†Butter fat.
‡With added lactose.

required. During the study regular analysis of the breast milk was not available. The composition shown in Table 1 is that of samples of milk collected in 1975. However, since this milk was collected, heated, and stored in a similar manner to that of the present study its composition is unlikely to differ to any significant extent. The composition of the milk formula was provided by the manufacturer, with the milk powder being preweighed and kept in a plastic pack until reconstituted. Infants of mothers who wished to breast feed were initially given expressed breast milk if unable to feed naturally. There were only 2, of 33 and 36 weeks' gestation, and only the latter was successfully breast fed.

Feeding regimen. Milk feedings started at 50 ml/kg on the first day, increasing by 15 ml/kg daily until an oral intake of 200 ml/kg was reached. Thereafter this intake was maintained by twice weekly adjustments according to increases in weight. Infants demanding more milk were fed until satisfied. A careful record of milk intake was kept and the inevitable losses resulting from small amounts of milk being spilt, left in the bottle after feeds or in vomiting allowed for (Gordon *et al.*, 1940). If milk feeds could not be tolerated, 10% dextrose was given via the umbilical vein in similar volumes to those which would have been given orally as milk feeds. Vitamin and iron supplements were given to all infants.

Duration of study. The study covered the first 2 months of postnatal life. When the infants were sent home their mothers were given enough formula to last the study period. For the infants fed breast milk arrangements were made for its daily delivery from the milk bank.

Evaluation of growth. Growth was evaluated by serial measurements of weight, length, and head circumference made by the author. Weight was recorded on Avery Scales accurate to 10 g. Crown-heel length was measured with a neonatometer (Davies and Holding, 1972) and head circumference with a disposable paper tape. Birthweight was recorded on admission to the neonatal unit. Initial measurements of length and head circumference were taken between 36 and 48 hours. Thereafter measurements were made on, or as near as possible to, the 28th and 56th days. For each growth parameter the definitive recorded measurement was the mean of duplicate observations. Coefficients of variation for weight, length, and head circumference were respectively 0·26, 0·17, and 0·38% showing the anthropometric methods to be very accurate.

Weekly rates of weight gain (g), linear growth (mm), and head circumference growth (mm) were studied in two periods: (a) birth–1 month, (b) 1–2 months. The mean growth rates of the infants born between 28 and 32 weeks' gestation over the first month were also compared with expected rates, that is the fetal growth rate over the equivalent intrauterine period (Usher and McLean, 1974). This standard of comparison was not used in the second month since the deceleration of fetal growth, which begins around the 36th week (Shaw, 1973), makes intrauterine standards unreliable as a source of comparison. The growth standards for weight, length, and head circumference are taken from composite data summarized by Gairdner and Pearson (1971).

Results

General. Data for gestational age and weight, crown-heel length, and head circumference at birth are given in Table 3. Analysis of variance showed no

Table 2 *Gestational age, weight, length, and head circumference at birth. Comparison between feeding groups (mean ±SEM)*

Birth variable	Preterm infants			
	28–32 weeks' gestation		33–36 weeks' gestation	
	Breast milk (n=14, 7M, 7F)	Formula (n=14, 6M, 8F)	Breast milk (n=20, 10M, 10F)	Formula (n=20, 11M, 9F)
Gestational age (w)	30·8±0·35	30·4±0·45	34·5±0·24	34·6±0·25
Weight (g)	1680±0·11	1689±0·11	2091±0·06	2193±0·03
Length (cm)	41·6±0·86	41·9±0·91	45·4±0·33	45·2±0·32
Head circumference (cm)	28·7±0·58	28·8±0·62	31·7±0·19	31·9±0·19

significant differences between the two feeding groups within either category. Perinatal complications were also equally distributed between the groups.*

Milk intake. Details of milk intake are shown in Table 3. Daily water and calorie intakes were similar

Table 3   *Daily water and calorie intakes per kg. Mean values (SD)*

Feeding group	Birth–28 days		29–42 days	
	Water (ml)	Calories	Water (ml)	Calories
Preterm infants, 28–32 weeks' gestation				
Breast milk	186 (32)	130 (22)	227 (30)	159 (21)
Formula	176 (54)	123 (38)	224 (41)	157 (29)
Preterm infants, 33–36 weeks' gestation				
Breast milk	206 (23)	144 (16)		
Formula	190 (27)	133 (19)		

in the feeding groups of both categories. For infants born between 28 and 32 weeks' gestation intakes were recorded from birth to 28 days and also from 29 to 42 days. Thereafter too few infants remained in hospital to give meaningful estimates. For similar reasons intake was recorded only for the first month in infants born between 33 and 36 weeks' gestation.

Growth.

(1) Preterm infants, 28–32 weeks' gestation (Fig. 1, Table 4).

(a) Weight gain. In the first and second months the rates of weight gain in the infants fed breast milk were slower than those fed formula thôugh the differences were not statistically significant. Both groups showed much slower than expected rates in the first month, particularly the breast milk group. After one month the centile distributions of the mean weights for both groups were much lower than at birth, particularly the breast milk group whose mean weight was below the 10th centile after starting at the 50th. In the second month there were attempts at 'catch-up' weight gain but birth centiles were not regained. The poorest recovery was shown in those fed breast milk.

(b) Linear growth. In the first month the infants fed breast milk showed a significantly slower growth rate than those fed formula. In the second month there were no significant differences between the
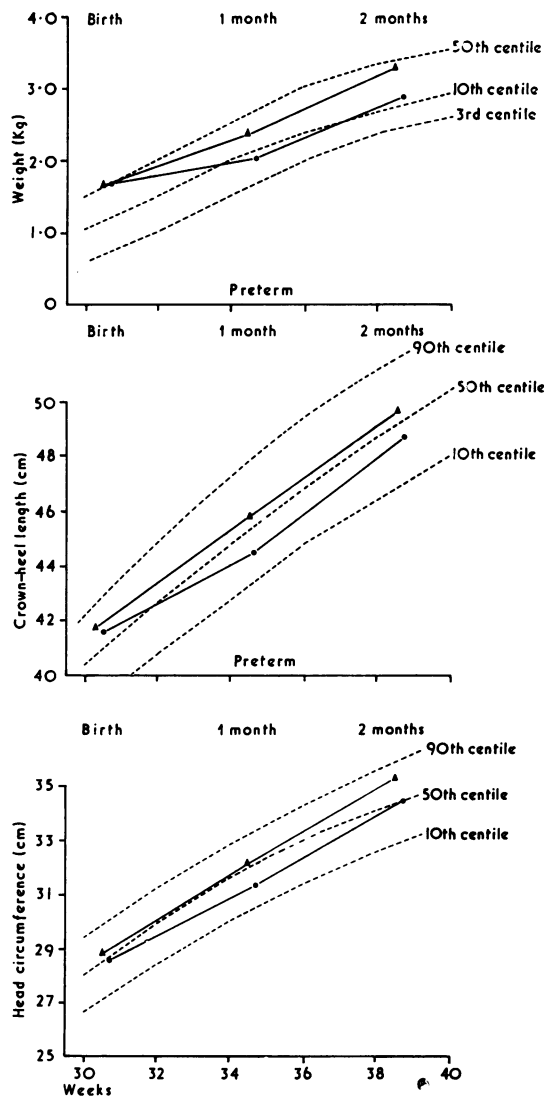
*An appendix providing these data is available from the author.

Fig. 1   *Distance growth curves for weight, length, and head circumference in preterm infants of 28–32 weeks' gestation.* ●——● *breast milk,* ▲——▲ *formula. The growth charts are constructed from the composite data of Gairdner and Pearson (1971), both sexes combined.*

groups. The rate of growth of the formula-fed infants over the first month was closer to the expected intrauterine rate than that of the infants fed breast milk. As a result the growth curve of the formula-fed group showed much less deviation from the expected trajectory than that of the breast milk group.

Table 4 *Weekly rates of weight gain (g), linear growth (mm), and head circumference growth (mm) in preterm infants of 28–32 weeks' gestation (mean±SEM)*

	Breast milk	Formula	Expected intrauterine rate (see text)
Weight gain			
Birth–1 m	100±20	160±21	188
1–2 m	190±22	230±23	—
Linear growth			
Birth–1 m	7·3±0·7	9·8±0·5*	11·6
1–2 m	10·1±0·9	9·5±0·5	
Head circumference growth			
Birth–1 m	6·9±0·4	8·4±0·4†	8·3
1–2 m	7·3±0·8	7·6±0·4	—

*When compared with breast milk group, t=2·91; P <0·01.
†When compared with breast milk group, t=2·68; P <0·02.

(c) *Head growth.* The pattern was similar to that of linear growth. The infants fed breast milk showed a significantly slower rate of head growth over the first month than the formula-fed group whose rate was similar to expected. On the other hand the infants fed breast milk showed a much slower than expected rate with the result that their growth curve deviated considerably from its expected path.

In the second month there were no significant differences between the two groups.

(2) *Preterm infants, 33–36 weeks' gestation (Fig. 2, Table 5).* There were no significant differences in the rates of weight gain, linear growth, and head circumference between the two groups in either the first or second month. It is interesting that the mean values for weight, length, and head circumference were at much higher centiles at 2 months than at birth, particularly weight. This probably represents the normal growth pattern of infants who have escaped from the constraining influence of the uterus during the last weeks of pregnancy.

Discussion

The most significant finding of this study was that infants born early in the last trimester of pregnancy grew less well on mature breast milk than on the cows' milk formula during the first month of postnatal life. Failure of breast milk to maintain satisfactory growth in preterm infants has been described by earlier paediatricians (Finkelstein, 1912; Gordon *et al.*, 1947; Powers, 1948; Omans *et al.*, 1961), but their conclusions were based mainly on demonstrating poor weight gain. The unsatisfactory growth in length and head circumference shown in the present study is much stronger evidence for
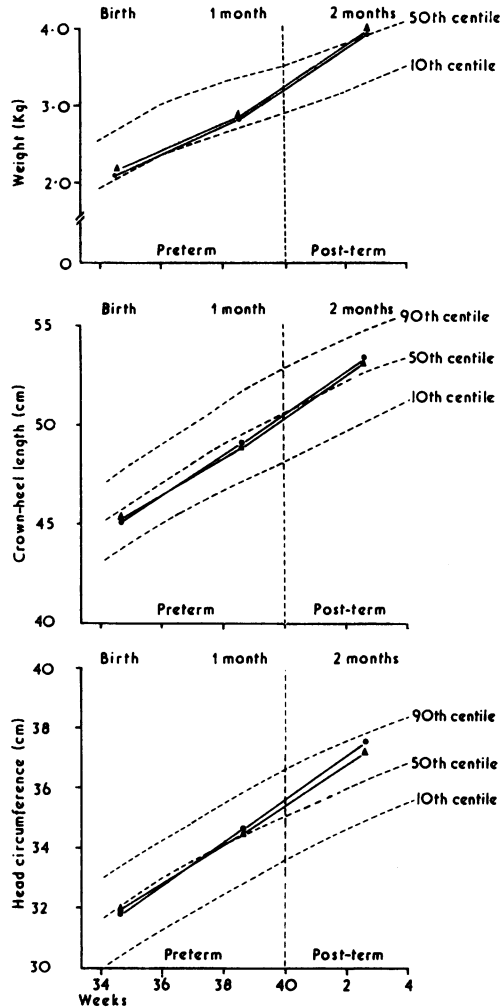

Fig. 2 *Distance growth curves for weight, length, and head circumference in preterm infants of 33–36 weeks' gestation.* ●——● *breast milk,* ▲——▲ *formula. The growth charts are constructed from the composite data of Gairdner and Pearson (1971), both sexes combined.*

inadequacy since it indicates impaired skeletal growth (Cheek, 1968; Babson and Bramhall,1969) and brain growth (Bray *et al.*, 1969; Winick and Rosso, 1969).

Because the composition of the two milks differed in so many respects it is difficult to account for the differences in growth rates over the first month in these very small infants. The mean calorie intake of the infants fed breast milk was 130 kcal/kg (543 kJ), which was higher not only than that of the

Table 5 *Weekly rates of weight gain (g), linear growth (mm), and head circumference growth (mm) in preterm infants, 33–36 weeks' gestation (mean value ±SEM)*

	Breast milk	Formula
Weight gain		
Birth–1 m	160±10	180±10
1–2 m	250±20	251±12
Linear growth		
Birth–1 m	8·3±0·4	8·8±0·4
1–2 m	1·0±0·5	9·0±0·6
Head circumference growth		
Birth–1 m	6·6±0·4	6·0±0·3
1–2 m	6·6±0·3	7·8±0·5

formula-fed infants (123 kcal/kg; 514 kJ), but also than the 120 kcal/kg (501 kJ) usually recommended for preterm infants (Gordon *et al.*, 1940). There were obvious differences in their intakes of minerals and electrolytes but it is difficult to envisage how these could be responsible for growth rate differences. It is therefore tempting to suggest, as have earlier workers, that the inadequacy of breast milk is due to its low protein content (Finkelstein, 1912; Gordon *et al.*, 1947). Thus if preterm infants are to grow at their expected intrauterine rate they must continue to retain as large amounts of protein as would have been laid down had gestation continued normally (Young *et al.*, 1950). The intrauterine equivalent of the first postnatal month in the category of smaller preterm infants is the gestation period between 30 and 34 weeks when protein retention by the fetus amounts to about 2·1 g/kg per day (Kelly *et al.*, 1950; Widdowson and Dickerson, 1964). The infants fed breast milk averaged 2·0 g of protein/kg per day in their first month so that with a 70% protein utilization at this intake (Snyderman *et al.*, 1969) theoretical protein retention would be only 1·4 g/kg per day. The poor growth of these infants supports this theoretical estimate. On the other hand, the infants fed the milk formula averaged 4·7 g protein/kg per day so that with a utilization of about 60% at this intake (Snyderman *et al.*, 1969) protein retained would be in the order of 2·8 g/kg per day, which is slightly greater than that accumulated by the fetus. For these reasons it is therefore possible that the differences in growth rates between the two feeding groups reflect differences in protein intake.

It is unknown whether a short period of poor growth at this stage of development will adversely affect later growth and intellectual achievement. However, since this stage contains the accelerating phase of the brain growth spurt (Dobbing, 1974) it seems important to encourage the best

possible growth at this time. Expressed breast milk does not achieve this so that its suitability for very immature preterm infants must be seriously questioned. What their optimum diet should be is clearly an area for further study.

References

Babson, S. G., and Bramhall, J. L. (1969). Diet and growth in the premature infant. The effect of different dietary intakes of ash-electrolyte and protein on weight gain and linear growth. *Journal of Pediatrics*, **74**, 890–900.

Bray, P. F., Shields, W. D., Wolcott, G. J., and Madsen, J. A. (1969). Occipito-frontal head circumference—an accurate measure of intracranial volume. *Journal of Pediatrics*, **75**, 303–305.

Budin, P. (1907). *The Nursling*, p. 34. Caxton, London.

Cheek, D. B. (1968). *Human Growth: Body Composition, Cell Growth, Energy and Intelligence*, p. 3. Lea and Febiger, Philadelphia.

Corner, B. (1960). *Prematurity*, p. 242. Cassell, London.

Crosse, V. M. (1966). *The Preterm Baby and Other Babies with Low Birth Weight*, 6th ed., p. 81. Churchill Livingstone, Edinburgh and London.

Davies, D. P., and Holding, R. E. (1972). Neonatometer: a new infant length measurer. *Archives of Disease in Childhood*, **47**, 938–940.

Davies, P. A., Robinson, R. J., Scopes, J. W., Tizard, J. P. M., and Wigglesworth, J. S. (1972). *Medical Care of Newborn Babies*, p. 96. Clinics in Developmental Medicine No. 44/45. Heinemann, London.

Dobbing, J. (1974). Later development of the brain and its vulnerability. *Scientific Foundations of Paediatrics*, p. 565. Ed. by J. A. Davis, and J. Dobbing. Heinemann, London.

Dubowitz, L. M. S., Dubowitz, V., and Goldberg, C. (1970). Clinical assessment of gestational age in the newborn infant. *Journal of Pediatrics*, **77**, 1–10.

Finkelstein, H. (1912). *Lehrbuch der Säuglingskrankheiten*. Springer, Berlin. Referred to by Powers (1948).

Gairdner, D., and Pearson, J. (1971). A growth chart for premature and other infants. *Archives of Disease in Childhood*, **46**, 783–787.

Gordon, H. H., Levine, S. Z., Deamer, W. C., and McNamara, H. (1940). Respiratory metabolism in infancy and in childhood. XXIII. Daily energy requirements of premature infants. *American Journal of Diseases of Children*, **59**, 1185–1202.

Gordon, H. H., Levine, S. Z., and McNamara, H. (1947). Feeding of premature infants, a comparison of human and cow's milk. *American Journal of Diseases of Children*, **73**, 442–452.

Hess, J. H. (1953). Experiences gained in a 30 year study of prematurely born infants. *Pediatrics*, 11, 425–434.

Kelly, H. J., Sloan, R. E., Hoffman, W., and Saunders, C. (1950). Accumulation of nitrogen and six minerals in the human foetus during gestation. *Human Biology*, 2, 61–74.

Omans, W. B., Barness, L. A., Rose, C. S., and György, P. (1961). Prolonged feeding studies in premature infants. *Journal of Pediatrics*, 59, 951–957.

Powers, G. F. (1948). Some observations on the feeding of premature infants based on 20 years' experience at the New Haven Hospital. *Pediatrics*, 1, 145–158.

Shaw, J. C. L. (1973). Parenteral nutrition in the management of sick low birth weight infants. *Pediatric Clinics of North America*, 20, 333–358.

Snyderman, S. E., Boyer, A., Kogut, M. D., and Holt, K. E., Jr. (1969). The protein requirement of the premature infant. 1. The effect of protein intake on the retention of nitrogen. *Journal of Pediatrics*, 74, 872–880.

Tanner, J. M., and Thomson, A. M. (1970). Standards for birthweight at gestation periods for 32 to 42 weeks, allowing for maternal height and weight. *Archives of Disease in Childhood*, 45, 566–569.

Usher, R. H., and McLean, F. H. (1974). Normal fetal growth and the significance of fetal growth retardation. *Scientific Foundations of Paediatrics*, p. 69. Ed. by J. A. Davis and J. Dobbing. Heinemann, London.

Widdowson, E. M., and Dickerson, J. W. T. (1964). Chemical composition of the body. *Mineral Metabolism*, Vol. II, Part A, p. 1. Ed. by C. L. Comar and F. Bronner. Academic Press, New York.

Winick, M., and Noble, A. (1966). Cellular response in rats during malnutrition at various ages. *Journal of Nutrition*, 89, 300–306.

Winick, M., and Rosso, P. (1969). Head circumference and cellular growth of the brain in normal and marasmic children. *Journal of Pediatrics*, 74, 774–778.

Young, W. F., Poyner-Wall, P., Humphreys, H. C., Finch, E., and Broadbent, M. A. (1950). Protein in requirements of infants. *Archives of Disease in Childhood*, 25, 31–51.

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