The Lancet · Saturday 25 July 1981

INFANT GROWTH AND HUMAN MILK REQUIREMENTS

A Fresh Approach

R. G. WHITEHEAD A. A. PAUL

M.R.C. Dunn Nutrition Unit, Cambridge, England, and Keneba, The Gambia, West Africa

Summary The relationship between growth and the breast-milk plus complementary food intake of a group of British babies has been studied prospectively up to 8 months. From the data the human milk needs of solely breast-fed children to grow along the 5th, 50th, and 95th centile of the NCHS standard have been predicted using multiple regression analysis. The values obtained are substantially lower than previous estimates and they may form a more practical guideline for the evaluation of lactational adequacy within a community. Individual variation is important. It is futile to identify a single age when breast-feeding becomes inadequate as the sole source of food.

Introduction

A NUMBER of investigators[1-3] have previously attempted to calculate the requirements for human milk of healthy infants, but there is good reason to believe that the values obtained were unrealistically large. Using, for example, the W.H.O./F.A.O.[4] recommendations for dietary energy, the theoretical milk need for a 50th centile male child at 3 months is 900 ml/day and at 6 months 1250 ml/day. Mean volumes of this magnitude from representative populations are not, with one possible exception,[5] encountered even in well-nourished mothers,[6-10] yet it is known that the great majority of women are quite capable of successfully breast-feeding their children to 3 months, and for 6 months, and much longer if complementary feeding is gradually introduced in a rational manner. such experiences indicate that breast-milk requirements for a satisfactory rate of growth may be substantially less than is now believed to be the case.

The purpose of this study was to investigate the total dietary energy intake of children breast and mixed fed up to 8 months of age, in relation to sex, age, body-weight, and monthly growth velocity, in an attempt to define a more practical basis for the assessment of lactational adequacy.

Methods

The 48 infants described (28 males and 20 females) formed part of a larger prospective longitudinal maternal and child study carried out in Cambridge during both pregnancy and lactation.[11,12] The subselection was made on the basis of their mothers' success at breast-feeding: all the children received breast-milk at least up to the 6th month. Each baby's weight and length were measured at monthly intervals, around the midpoint of each month. Exact postnatal 30-day growth velocities were regularly estimated from a growth chart separately drawn for each child. From 6 weeks of age onwards breast-milk intakes were also measured by test-weighing in the home on 4 consecutive days near the middle of each month, by the mothers themselves after they had received careful instruction. All other food and drink intake plus energy containing medicaments were also quantitatively recorded. Average milk and total energy intake at each monthly interval were estimated whenever possible from the mean of the two pairs of adjacent four-day measurements. Energy intakes were calculated using food composition tables[13] and from information provided by manufacturers. The mean energy content of breast-milk was taken to be 69kcal/100 g (289 kJ), the average value found in a recent national survey of British mothers' milk.[14]

Results

Food Intake

Table I summarises the milk intakes at different ages. The quantity of breast-milk consumed by boys was consistently more than by girls; in the second month the mean difference was 124 ml ($t=2\cdot79$, $p<0\cdot01$). Comparing longitudinally 5 boys and 6 girls solely breast-fed up to the end of the 4th month, the differences were even more marked, being 198 ml ($t=3\cdot25$, $p<0\cdot01$) and 203 ($t=2\cdot01$, $p=0\cdot08$) during the second and third months, respectively. The proportion of fully and partly breastfed male and female babies at progressive stages during infancy is also given in table I

TABLE I—MILK INTAKES (ml/day) OF FULLY AND PARTLY BREAST-FED BABIES

Month	Fully breast fed			Partly breast fed		
	No.	Mean	SD	No.	Mean	SD
Boys						
1–2	27	791	116	1	648	—
2–3	23	820	187	5	833	123
3–4	18	829	168	10	787	172
4–5	5	790	113	20	699	204
5–6	1	922	—	25	587	188
6–7	0	—	—	21	484	181
7–8	0	—	—	18	342	203
Girls						
1–2	20	677	87	0	—	—
2–3	17	742	119	2	601	—
3–4	14	775	138	6	664	258
4–5	6	814	113	11	662	267
5–6	4	838	88	15	500	194
6–7	1	854	—	15	481	246
7–8	1	786	—	11	329	242

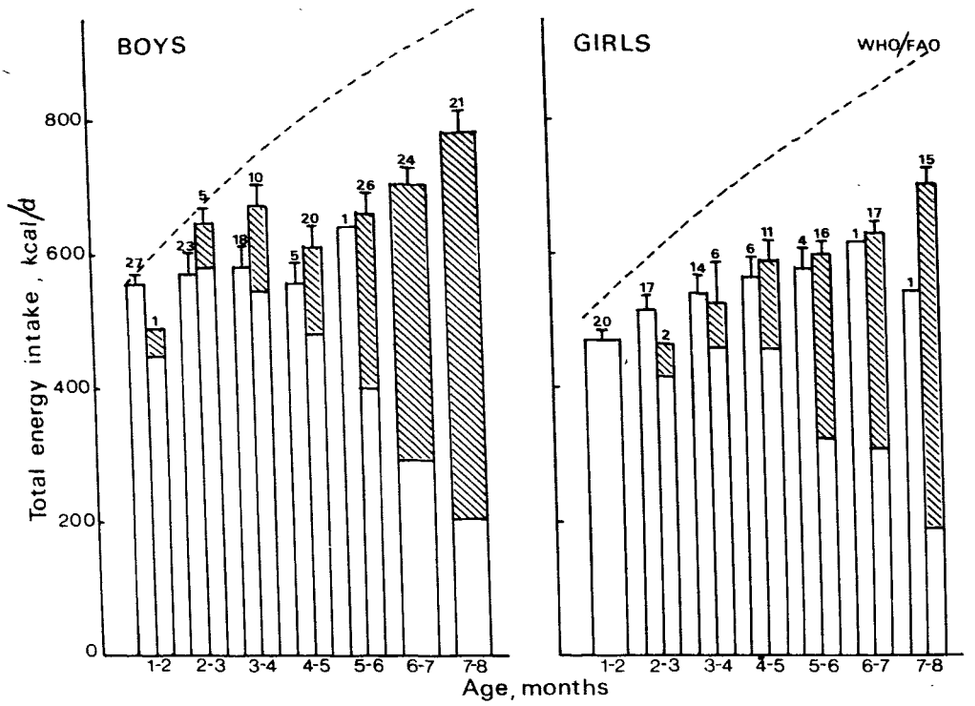

Fig. 1—Breast-milk and complementary food energy intake of boys and girls at different ages relative to the WHO/FAO[4] estimated requirement.

The shaded area represents non-breast-milk energy. Values: mean and SEM.

Despite their lower intakes, there was a tendency for the girls to be fed solely at the breast for longer: the mean age when boys were first offered other foods was 4·1 months, and 4·9 months in the case of girls. After 4 months only 20% of the boys were not receiving other food, while the corresponding value for girls was 35%. The commitment of all the mothers to breast-feeding, however, is illustrated by the fact that at 8 months 70% of the boys and 65% of the girls were still receiving some breast milk.

The total energy intakes of the boys and girls relative to their requirements as estimated from W.H.O./F.A.O.[4] are given in fig. 1. Except during very early infancy intake was substantially below theoretical needs. In the girls there was little difference in intake whether they were wholly or partly breast fed. In the boys, on the other hand, complementary feeding did result in some increase in total energy intake but not sufficient to match assumed needs. Even by the 8th month, when about 70% of the energy came from complementary food, the gap between theoretical requirement and actual intake remained.

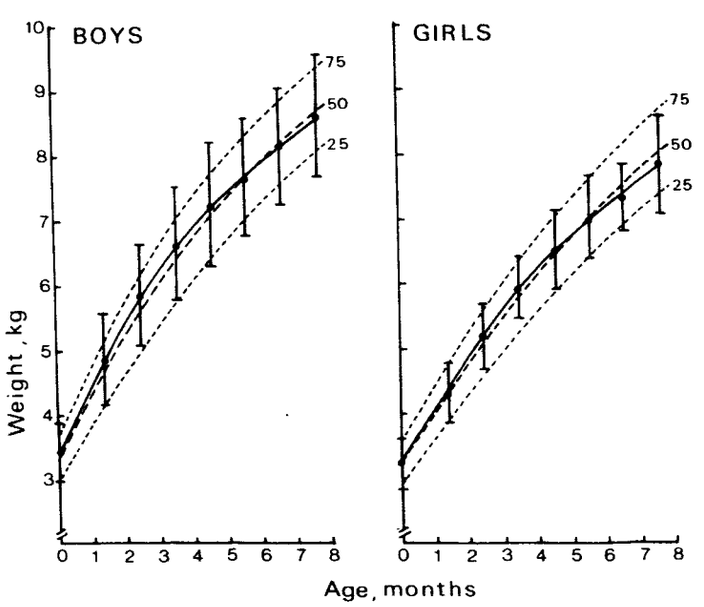

Fig. 2—Weight growth of boys and girls relative to the NCHS[15] standards.

Values: mean±SD. Number of subjects as in fig. 1.

Growth

The growth in weight of the boys and girls relative to NCHS[15] standards is given in fig. 2. In spite of a theoretically low total energy intake, growth performance was good. During the first 4 months mean weights were above the NCHS 50th centile and there was even a tendency for this position to improve. After 4 months, growth velocities decelerated relative to those of the standard, resulting in both boys and girls falling below the 50th centile. Deviations in

TABLE II—MULTIPLE REGRESSION CORRELATION COEFFICIENTS FOR THE RELATIONSHIP BETWEEN ENERGY INTAKE, BODY-WEIGHT, AND GROWTH VELOCITY, TOGETHER WITH PREDICTED BREASTMILK (ml/day) AND ENERGY REQUIREMENTS (kcal/kg/day) FOR CHILDREN TO GROW ALONG THE 5th, 50th, AND 95th CENTILE OF THE NCHS WEIGHT STANDARD

Age (months)	No..	R	p	Breast-milk needs			Energy
				5*	50*	95*	50*
Boys							
2	28	0·64	<0·001	590	780	950	104
3	28	0·69	<0·001	630	840	1020	97
4	28	0·64	<0·001	720	880	1040	91
5	27	0·60	<0·01	860	950	1060	89
6	23	0·47	<0·05	860	980	1100	87
8	20	0·51	<0·05	980	1130	1290	89
Girls							
2	20	0·60	<0·01	580	690	820	101
3	20	0·56	<0·02	560	740	930	94
4	20	0·62	<0·01	640	800	980	93
5	20	0·56	<0·02	790	860	930	90
6	19	0·42	0·07	830	910	1000	88
8	15	0·55	<0·05	990	1090	1190	92

NCHS centile.

length growth from the NCHS standard were practically identical.

Energy Intake and Growth

At each month, total energy intake was significantly correlated with both body weight and, until 6 months, also with growth velocity, but higher correlation coefficients were obtained using multiple regression analysis with the two anthropometric measurements as independent variables, and it is these values which are given in table II. The partial multiple regression coefficients differed according to sex and changed with age. At 3 months the equation for boys was: Energy intake = 77 (body−wt, kg) + 186(monthly weight gain, kg) − 20.

From each monthly multiple regression equation theoretical energy needs were predicted for both boys and girls to grow exactly along the 5th, 50th, and 95th centiles of the NCHS[15] standards, the accepted international yardstick for a good growth performance. The amount of human milk such children would have needed had they been solely dependent on breast-milk for the whole of this period was then calculated and the results are given in table II. It should be recognised, however, that the range of values for each month does not represent the total potential variability. Some small children may need to exhibit catch-up growth, likewise large children at birth may subsequently grow comparatively slowly. The multiple regression equation for the 3-month-old boys predicts that a 4·5 kg baby growing 400 g/month would need only 580 ml of milk/day, but the corresponding amount for the same child to grow at the readily attainable rate of 1000 g/month would be as much as 740 ml.

The predicted energy requirements per kg body-weight are lower than those recommended by W.H.O/F.A.O., which for male children during the first 2 months are 120 kcal/kg, then 115 kcal/kg for the subsequent three months, and 110 kcal/kg until 8 months. Our values for the 50th centile child are consistently 15–20% lower.

Discussion

We suggest that the human milk requirements for young infants predicted here form a better guideline for evaluating lactational adequacy at a community level than calculations based on current recommended dietary allowances for energy or protein. In European women the average peak milk yield is around 800 ml.[6-10] Using W.H.O./F.A.O.[4] energy values this would theoretically be sufficient for the *average* boy only until 6 weeks, and for the *average* girl, 8 weeks, while we would predict it to be satisfactory until 16 weeks in the case of girls and 10 weeks with boys. Yields of 1000 ml/day are not uncommon when mothers have large babies.[9] We calculate that this volume would meet the needs of a boy growing along the 95th centile up to 12 weeks and a comparable girl for as long as 24 weeks. In The Gambia, a typical developing country, 720 ml[9] is the mean peak value but the children are smaller, being on average only 89–94% of the NCHS standard between birth and 3 months. Even this lower volume we would predict as adequate for the average-sized rural Gambian boy and girl for 10 and 12 weeks, respectively, the time when in practice children's growth velocities start to fall away from international standards.[16]

This approach emphasises the futility of attempting to define any single age when breast-feeding ceases, by itself, to be sufficient. This is clearly specific to the individual and depends not only on the mother's milk yield but also on the sex, size, and growth velocity of her baby at any given moment in time. The difference in milk requirements between boys and girls is particularly intriguing and could be the reason why the mothers were able to feed girls solely at the breast for longer. Our data still indicate that the majority of children will need complementary feeding at some stage between 4–6 months, otherwise there will be a measureable negative response in growth-rate, but the predicted number needing supplementation prior to 3 months is far less than would appear to be the case from W.H.O./F.A.O.[4] energy values.

Some discretion needs to be exercised before the present and other similar data can unreservedly be adopted as the basis for more general recommended dietary allowances in young babies. More data are required, particularly under different prevailing environmental circumstances, before we can be sure of our predictions and their universality. The interrelationships clearly need to be investigated in bottle-fed babies as well. There have been few studies where growth and milk intake have been measured simultaneously, especially with the modern formulas. In a preliminary study carried out in Cambridge on 6 bottle-fed baby girls, we found that between 2 and 4 months the mean energy intake was also low, but not to the extent found in the breast-fed children, averaging 105 kcal/kg, in comparison with the international allowance of 115–120 kcal/kg. Very similar findings have been recorded by Yeung and colleagues[17] from Canada. As our equations would predict, the Cambridge bottle-fed babies were larger at 2 months and subsequently grew more quickly than their breast-fed counterparts.

We thank the staff of the Cambridge Maternity Hospital and Dr N. C. R. Roberton for making the study possible, and Miss Alison Black, Miss Susan Wiles, and Mrs Janet Evans for the dietary and anthropometric measurements. The study was part-funded by a grant from D.H.S.S.

Correspondence and requests for reprints may be addressed to R. G. W., M. R. C. Dunn Nutrition Unit, Milton Road, Cambridge CB4 1XJ.

REFERENCES

1. Rutishauser IHE, Burgess AP, Jones PRM, Krueger RH, Stanfield JP. Growth and development. In: Shaper AG, Kibuka Musoke JW, Hutt MSR. Medicine in a tropical environment. London: British Medical Association, 1972: 229.
2. Whitehead RG. Infant feeding practices and the development of malnutrition in rural Gambia. *UN Univ Fd Nutr Bull* 1979; **1**: 36–41.
3. Waterlow JC, Thomson AM. Observations on the adequacy of breast feeding. *Lancet* 1979; ii: 238–42.
4. WHO/FAO. Energy and protein requirements *Wld Hlth Org Tech Rep Ser* 1973; **522.** *FAO Nutr Meetings Rep Ser* 1973; **52.**
5. Rattigan S, Ghisalberti AV, Hartmann PE. Breast-milk production in Australian women. *Br J Nutr* 1981; **45**: 243–49.
6. Lönnerdal B, Forsum F, Hambraeus I. A longitudinal study of the protein, nitrogen and lactose contents of human milk from Swedish well-nourished mothers. *Am J Clin Nutr* 1976; **29**: 1127–33.
7. Hofvander Y, Hagman S, Sjölin S. Breast milk consumption in healthy Swedish infants. *Vår Föda* 1979; **31**: suppl. 3: 57.
8. Wallgren A. Breast milk consumption of healthy full-term infants. *Acta Paed Scand* 1944–5; **32**: 778–90.
9. Whitehead RG, Paul AA, Rowland MGM. Lactation in Cambridge and in The Gambia. In: Wharton BA, ed. Topics in Paediatrics 2, Nutrition. Tunbridge Wells: Pitman Medical 1980: 22–33.
10. Chandra RK. Breast feeding, growth and morbidity. *Nutr Res* 1981. **1**: 25–31.
11. Whitehead RG, Paul AA, Black AE, Wiles SJ. Recommended dietary amounts of energy for pregnancy and lactation in the United Kingdom. *UN Univ Fd Nutr Bull* suppl. (in the press).
12. Whitehead RG, Paul AA, Black AE, Wiles SJ. Recommended dietary intakes for the first 6 months of life. *UN Univ Fd Nutr Bull* suppl. (in the press)
13. Paul AA, Southgate DAT. McCance and Widdowson's The Composion of Foods. 4th edn. London: HMSO, 1978.
14. Department of Health and Social Security. The composition of mature human milk. *Rep Hlth Soc Subj* 1977; **12.**
15. NCHS Growth curves for children, birth to 18 years. U.S Department of Health, Education, and Welfare, 1977, publ no (PHS) 78–1650
16. Lunn PG, Whitehead RG, Cole TJ, Austin S. The relationship between hormonal balance and growth in malnourished children and rats. *Br J Nutr* 1979; **41**: 73–84.
17. Yeung DL, Hall J, Leung M Adequacy of energy intakes of infants. *J Canad Diet Ass* 1980; **41**: 48–52