CALORIE REQUIREMENTS OF FULL-TERM AND PREMATURE INFANTS IN THE NEONATAL PERIOD

A FORMULA, ITS USES AND LIMITATIONS

BY

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Medical students and nurses in children's hospitals are now taught how to calculate the calorie needs of babies past the neonatal period, and every textbook on paediatrics deals with the subject: but of the day to day needs of the first weeks of life of babies, varying in birth-weight from 2 lb. to 10 lb. and more, textbooks give meagre and conflicting information.

Some current teaching on quantitative food requirements in the first two weeks of life

Some examples, chosen almost at random, of the teaching furnished in textbooks are given below.

Von Reuss (1921) in his book on 'Diseases of the Newborn,' which is still a standard work, gives numerous examples of the widely different quantities of breast milk taken by healthy babies in the neonatal period: he states that a volume providing 50 calories per kilo. (23 calories per lb.) body-weight per day is sufficient for the first eight to ten days. This figure for the average daily intake, derived as it is from a period of rapid change in the quantity of milk secreted, is not, however, very helpful in ordering each day's supply of food. Von Reuss also quotes a formula of Finkelstein's for 'the first days' needs:— $(\text{day of life} - 1) \times 70$ to 80 gm. This formula, it will be observed, takes no account of body-weight. It provides a total of about 50 calories on the second day of life (assuming the calorie value of the milk to be 20 per fluid oz.), and an increase of about 50 calories daily, presumably reaching 350 calories on the eighth day. Supposing average birth-weight to be approximately 7 lb., this would represent an allowance of 50 calories per lb. birth-weight on the eighth day of life, or an average intake of 25 calories per lb. per day during the first eight days. Most British textbooks give no information as to the quantity of food required by full-term babies in the neonatal period, but Paterson and Forest Smith (1938) say that 25 calories per lb. birth-weight should be given on the second day, and furnish a table of instructions for artificial feeding according to which approximately 50 calories per lb. birth-weight would be given by the fourth day of life instead of the eighth, as in Finkelstein's formula. On this basis the allowance for the whole of the first eight days would average 39 calories per lb. per day, a figure 70 per cent. higher than that (23 calories per lb.) given by von Reuss (1921), and the allowance for ten days would be 45 calories per lb. per day, or nearly double von Reuss's figure. Contrast with this the advice

of Tallerman and Hamilton (1928): they would not give 50 calories per lb. body-weight until the third week, and consider that it is often impossible to give more than 25 to 30 calories per lb. body-weight on any day before the tenth, or Moncrieff's (1940) advice that a bottle-fed baby should have saline only and no food till the third day of life, when he should, according to the author's feeding table, receive about 2 calories per lb. birth-weight, increasing to 50 calories per lb. by the seventh to tenth day. Of three American encyclopaedic works on paediatrics, those edited by Abt (1923) and by Brennemann (1938) apparently give no information as to the quantitative needs of full-term babies at this period, but in 'Clinical Pediatrics,' Wilcox (1928) states that the calorie requirement of babies during the first two weeks is equivalent to an average of 35 calories per lb. per day.

As regards the needs of premature infants textbooks furnish much fuller information, often in the form of tables, but give little indication as to any principle or formula governing the choice of the quantities prescribed, which are remarkably varied. For instance, for a baby weighing 2 lb. at birth, Hess (1922) prescribes, on the second day of life, in all 14 to 28 calories; Owen and Dobbs (1940) 20 calories; Brown (1933) probably 20 calories; Holt and McIntosh (1936) 50 calories, and Paterson (1937) 60 calories—a four-fold variation. Moreover, Holt and McIntosh, as well as Paterson, would give as much or more to a 2 lb. baby of this age as Finkelstein (1921) would give to a full-term baby weighing presumably three or four times as much. For a 2 lb. baby an allowance of about 50 calories per lb. body-weight (i.e. 100 calories in the day) would be reached by Holt and McIntosh by five days old, by Paterson by seven days old, by Dobbs and Owen by about thirteen days old, and by Hess by twelve to eighteen days old.

Appetite as a guide to food requirements

Most writers stress the importance of such factors as appetite and rate of gain in weight in determining quantitative needs. Faber (1922) has analysed the food intake and rate of gain of over eighty babies given the breast and as much supplementary feeding as appetite prompted them to take (see table 3). Taking averages, these babies regained their birth weight (3.35 kilo.) by seven days old, and they showed no sign of digestive disturbance. So that in these respects appetite proved a good guide to quantitative needs, though, as Faber points out, slightly less milk was taken from the breast by the babies offered unlimited bottle feeding compared with those fed at the breast only, and Faber specifically states that he does not advocate this system for general use. Though it is true that the normal baby, having a normal mother with normal lactation, will satisfactorily regulate his own consumption of breast milk: yet if all is not going well in the neonatal period, the baby's appetite often gives scant guidance as to his needs. Mistakes in the feeding of full-term new-born babies are certainly common, but quantitative errors in the feeding of premature babies are still more common, and with a small premature baby appetite gives little or no guidance as to the needs of the first weeks.

Purpose of present paper

The purpose of this paper is to suggest a scheme whereby the quantitative food intake of the first couple of weeks of life can be regulated or checked, to show how the scheme has worked out in practice for babies of different birth-weights, and to indicate its limitations. The differential diagnosis in the neonatal period between underfeeding and overfeeding on the breast is often uncertain, unless it is possible by test-feeding or expression of feeds to estimate

the food intake and to compare this with the calculated need. At the same time there are in practice so many unknown factors that any quantitative scheme can only be used as a guide and not as a hard-and-fast system of feeding, and the final criterion of a baby's quantitative needs must always be his progress, including his rate of gain in weight.

The calorie value of colostrum and human milk in the first weeks of lactation

One of the biggest unknown factors in the feeding of new-born babies is the actual calorie value of the colostrum and early milk of the individual mother on any one day. Statements of the 'average' calorie value of colostrum are sometimes misleading when dealing with an individual baby, unless it is remembered that these values vary considerably. The variations in composition are greatest in the first few days. According to Langstein, Rott and Edelstein (1913) the calorie value of colostrum obtained immediately after birth may be double that of mature milk. It is highest when the secretion of the breasts is thick and yellow. Nevertheless, in spite of such extremes, average calorie values do furnish a good working basis for feeding most babies.

Table 1 gives some typical analyses of colostrum and early breast milk published by different authors. In the secretion obtained from the breasts in the first few days of life, protein is high, and sugar (and probably also fat) are low, as compared with the percentages in milk after lactation is fully established. The composition changes rapidly during the first week of life. Individual variations are illustrated by the figures of Widdows and her co-workers (1935).

TABLE 1
COMPOSITION AND CALORIE VALUE OF COLOSTRUM AND EARLY BREAST MILK

PERIOD AFTER PARTURITION	COMPOSITION PER CENT.			CALORIES PER FLUID OZ. (CALCULATED FROM PREVIOUS COLUMNS)	AUTHORS AND DATE
	PROTEIN	SUGAR	FAT		
1st day: Average ..	7.86 (11)	3.17 (14)	—	—	Widdows, Lowenfeld, Bond, Shiskin and Taylor, 1935.
Range ..	2.64-14.1	1.08-6.26	—	—	
3rd day: Average ..	2.80 (27)	6.32 (37)	—	—	Same
Range ..	1.36-8.67	3.55-7.77	—	—	
5th day: Average ..	1.70 (20)	6.94 (28)	—	—	Same
Range ..	1.27-2.34	4.77-7.87	—	—	
1st to 3rd days ..	4.35 (30)	5.34 (30)	2.07 (3)	16.8 (3-30)	Widdows, Lowenfeld, Bond and Taylor, 1930. Widdows and Lowenfeld, 1933.
8th to 13th days ..	1.45 (26)	6.35 (46)	4.34 (11)	20.7 (11-46)	Same
1st to 13th days ..	2.39 (108)	5.84 (115)	3.53 (24)	18.9 (24-115)	Same
3rd day ..	3.52 (8)	5.43 (8)	4.34 (8)	21.9 (8)	Hammett, 1917.
5th day ..	1.74 (8)	6.08 (8)	2.88 (8)	17.3 (8)	Same
3rd to 11th days ..	2.00 (40)	6.09 (40)	3.62 (40)	18.9 (40)	Same
3rd to 12th days ..	2.25 (5)	7.59 (5)	3.15 (5)	18.7 (5)	Holt, Courtney and Fales, 1915.
1-9 months ..	1.15 (17)	7.50 (17)	3.26 (17)	18.4 (17)	Same

The number of estimations on which each average is based is shown by the figure or figures in brackets. Holt, Courtney and Fales' figures are based on individual 24-hour samples and pooled composite samples.

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They found that on the first day the protein varied between 2.64 per cent. and 14.1 per cent., and the sugar between 1.08 per cent. and 6.26 per cent. Moreover, the drop in protein content occurred more rapidly in multiparae than in primiparae, and a sudden increase in the volume secreted by the breasts may be accompanied by a large drop in fat percentage, and consequently in calorie value. The calorie values shown in table 1 are calculated from data in the articles quoted. The low calorie value inserted for the first to third days, 16.8 calories per fluid oz., must be taken with caution; the authors quoted (Widdows and Lowenfeld, 1933) themselves give no average values for fat for these days, and the low fat percentage, and consequent low calorie value, here tentatively given, is based on only three analyses for fat. The greatest variability in composition occurs in the first three to four days of life when the volume secreted is small, consequently the calorie value of this early and rather scanty secretion would play only a small part in determining the calorie value of the composite secretion of the first ten days. For example, in the series, analysed below, of breast-fed babies who regained their birth weight by ten days old (see table 2), the volume sucked in the first three days of life was only 9.5 per cent. of that of the next seven days, and if the calorie value per oz. of fluid for the first three days were as much as 30 (certainly too high a figure), and for the next seven days was 20, the average for the whole intake of the ten days would be only 21. For the first two weeks of life, the average calorie values per fluid oz., based on the average composition of series of samples taken by different authors are surprisingly similar [see table 1: Widdows et al. (1930 and 1933) first to thirteenth day; Hammett (1917) third to eleventh day; and Holt et al. (1915) third to twelfth day respectively]. Neglecting decimals, the value is 19, i.e. about the average of human milk after lactation is fully established.

For convenience, the round number 20 is generally taken as the calorie value of human milk. From the figures here given, it therefore seems legitimate for practical purposes (and the aim of this paper is essentially practical), to use the same round number as representing the average calorie value of the secretion of the breasts in the first two weeks after parturition. By reckoning the calorie value as 20 instead of 19 per oz. about 5 per cent. is added to the calorie value, but an error of this grade in average values is relatively unimportant when the measure of intake is also subject to error, and calorie values are known to vary.

The calorie concentration of artificial feeds employed

All artificial feeds used by the author in the feeding of new-born babies have been made up to provide approximately 20 calories per fluid oz. Dilute feeds have not been used. Artificial feeds given to babies in the present investigation, can therefore be assumed to have a calorie value approximately the same as that of breast milk.

Formula for the calculation of food requirements

The scheme here suggested may not be original, though the present author has not come across it elsewhere. The scheme is empirical. It is an attempt to

reduce to an easily remembered formula the food intake on which most babies will make satisfactory progress during the first two weeks of life. The scheme assumes that the average value of human colostrum and milk during the first two weeks is 20 calories to each fluid oz., and that by the seventh day of life (i.e. at six days old), and for the following week the baby requires 50 calories per lb. of his birth-weight. The calorie requirement of the seventh day is divided by seven, and to give a steady rate of increase in food in the first week the scheme assumes that, starting from one-seventh on the first day, the baby requires an increase of one-seventh each day, or, calling the birth weight x lb., say $\frac{1}{7} \times 50x$ calories. Thus if the baby weighs 7 lb. at birth, the calorie intake on the seventh day (six days old) would be 50×7 or 350 calories; on the first day he would receive $\frac{350}{7}$ or 50 calories, with an increase of 50 calories each day till six days old. Since most mothers have little secretion in the breasts till the third day after parturition, it is obvious that this scheme overestimates the normal baby's food intake from the breast for the first two days. Moreover, since in the following tables (see tables 2 and 6) the intake is reckoned from midnight to midnight, the 'first day' might be any period under twenty-four hours, and would average say twelve hours. If a baby has to be hand-fed from the outset, then feeding on the basis of this table can be started on the first day, provided breast milk is available; if the baby is artificially fed the rate of increase must often be rather slower, especially in the first four days: certainly if there is any tendency to vomit or the baby's abdomen is distended a more gradual increase is indicated, perhaps reaching 50 calories per lb. birth-weight about the tenth day of life.

According to the formula a baby would receive within the whole of the first week of life 4×50 calories per lb. birth-weight, and within the first ten days 7×50 calories per lb. birth-weight. This amounts to an average of 29 calories per lb. per day for the first seven days, 31 calories per lb. per day for the first eight days, or 35 calories per lb. per day for the first ten days. These figures are 30 per cent. to 52 per cent. higher than those of von Reuss, depending on whether the intake for eight days or ten days is considered.

The actual food intake of twenty consecutive breast-fed babies at the Mothers' Hospital compared with their requirements according to the formula

Table 2 shows the daily food intake (calculated in calories) for the first ten days of life of twenty consecutive babies who were entirely breast-fed. All but two twins were over $5\frac{1}{2}$ lb. at birth. All the mothers were in one ward at the Mothers' Hospital, Clapton, London; three were married and the rest were unmarried mothers; fourteen were primiparae. The babies were fed either six or five times daily and were weighed before and after each feed for the first ten days of life. The volume of feeds was recorded to the nearest quarter-ounce, reckoning one-ounce increase in weight as representing one fluid ounce of milk. With small volumes of milk, weighing only to the nearest quarter-ounce may introduce a large percentage error. If a baby did not suck well the breast was sometimes emptied and the milk given by hand. In the table the babies are divided into three groups, according to their weight at ten days old:

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i.e. those over birth-weight, at birth-weight, and under birth-weight. For the whole of the first ten days (on the assumption that the calorie value of the milk was 20 per ounce), it was found that the intake of those babies who more than regained their birth-weight averaged 93 per cent. of the formula requirements: those at birth weight 88 per cent.: and those under birth-weight (average three ounces under birth-weight) 73 per cent. Presumably the intake in the first two days would have been rather larger if the series had included a larger proportion of babies of multiparae. If the period two to six days old (i.e. the first week with the exclusion of the first two days when there is little secretion of milk) is taken, the figures for the three groups are 101 per cent., 93 per cent. and 72 per cent. respectively. Combining the first two groups, the average for all babies at or above their birth weight by ten days old is 99 per cent. So the average actually taken over this period by breast-fed babies progressing satisfactorily closely approximated to the formula.

So far the average total intake as compared with the formula has been considered. The average daily intake for each day after the first two is also not very different from the schedule. Taking all the babies who regained their birth-weight by ten days old, the average calorie intake on any one day from the third to the tenth day of life was within 12 per cent. of that required by the formula.

Turning from group averages to individuals it is found, of course, that the intake of individual babies varies widely. In the first ten days the babies over birth-weight by ten days old took anything between 69 per cent. and 122 per cent. of the quantity required by the formula, and those at birth-weight between 72 per cent. and 103 per cent., i.e. the intake of babies making satisfactory progress might be as much as 31 per cent. under the formula figure (assuming always that the calorie value of the milk was 20 per fluid ounce). Nevertheless, from two to six days old, and also from seven to nine days old, more than two-thirds of the babies took over 85 per cent. of their formula requirements. Probably, those babies who gained well on a smaller volumetric intake, were actually getting milk of a higher calorie value than the average, and their calorie intake has been underestimated as a result. After ten days old the number of babies weighed before and after all feeds was too small to be worth quoting.

The fluid intake of these babies was augmented during the first week: they were usually given some water between feeds during the first three to five days of life, sometimes for longer, but the total amount of water given was not large, say, half to four ounces in the day. None of these babies suffered from inanition fever. Their average loss in weight in the first few days was 5.1 oz. or about 4.5 per cent. of birth weight.

The food intake of other groups of full-term babies compared with the formula requirement

In order further to check the utility of the formula for feeding full-term babies, the intake of other groups of infants is given in table 3 in terms of the formula requirement.

TABLE 2
CALORIE INTAKE IN THE FIRST TEN DAYS OF LIFE OF TWENTY CONSECUTIVE BREAST-FED BABIES
AT THE MOTHERS' HOSPITAL
Formula value of 1 fluid ounce of breast milk or colostrum reckoned as 20
Formula figures calculated to nearest quarter pound

WEIGHT AT 10 DAYS	PARITY OF MOTHER	BIRTH WEIGHT LB. OZ.	LOSS OR GAIN IN OZ.		CALORIE INTAKE ON EACH OF FIRST 10 DAYS OF LIFE: AGE IN DAYS										INTAKE AS PER CENT OF FORMULA FIGURES: AGE IN DAYS			
			MAX.	AT 7 DAYS	AT 10 DAYS	0	1	2	3	4	5	6	7	8	9	0-9	2-6	7-9
						*												
Over birth weight ..	M	6 5	3½	+ 3½	+ 7½	0	50	130	300	350	360	330	400	360	380	122	132	122
	M	5 12	½	+ 8½	+ 7	30	60	190	290	310	290	270	310	290	300	111	132	105
	P	8 4	3	+ 4½	+ 5	0	90	150	300	360	380	380	370	370	360	96	107	89
	M	6 11	8	- 1	+ 4	0	80	120	170	170	280	300	250	250	320	82	87	81
	P	6 15	1½	+ 1	+ 4	0	50	130	190	230	270	320	290	330	310	87	91	89
	P	7 5	6	+ ½	+ 4	0	0	110	210	290	280	280	330	320	320	84	91	89
	P	5 7	6	+ 2½	+ 1½	0	20	60	100	130	160	210	180	230	240	69	67	79
	P	6 3	3½	+ 1½	+ 1½	0	40	130	180	260	310	300	350	340	280	100	106	104
	P	7 5	8½	+ 0	+ 1	0	30	130	260	320	370	400	410	400	430	109	115	114
	M	9 10	8	+ ½	+ 1	0	30	140	240	320	330	330	360	370	380	75	80	78
At birth weight ..	Average:	6 15½	4-85	+ 1-35	+ 3-65	3	45	129	224	274	303	312	325	326	332	93	101	95
	P	6 0	5½	1	+ 0	0	30	90	180	160	240	230	260	240	230	79	84	81
	P	6 10	6½	4½	+ 0	0	0	30	90	100	180	280	260	310	360	72	95	99
	M	7 2	5½	1	+ 0	0	150	270	270	320	280	330	280	330	305	103	118	78
Over or at birth weight (combined)		8 1	5	½	+ 0	0	110	270	280	350	340	340	350	410	350	100	111	93
	Average:	6 15½	5-50	1-75	+ 0	0	72	165	205	232	260	295	295	322	311	88	93	90
	Average:	6 15½	5-1	+ 0-5	+ 2-6	2	53	139	219	262	291	307	316	325	326	92	99	93
			As per cent. of formula figures ..				4	53	93	105	97	88	90	93	93			
Under birth weight ..	M	7 0	7	2½	1	0	0	70	120	240	310	270	260	350	300	78	81	78
	P	5 5	8	5	1½	0	20	60	120	100	130	190	220	220	230	66	66	52
	P	6 0	7½	4	2½	0	60	70	90	130	320	280	292	270	300	80	75	26
	P	6 5	8½	5	2½	0	30	90	140	200	260	280	300	250	310	85	87	92
	P	9 3	11	8	3	0	0	70	100	150	200	260	290	270	330	52	47	69
	P	6 8	12	7	7½	0	60	100	150	180	280	230	260	270	270	79	81	82
	Average:	6 11½	9-0	5-25	3-0	0	28	77	120	167	235	252	252	272	290	73	72	82
			As per cent. of formula figures ..				0	29	53	70	81	75	75	81	86			
			As per cent. of formula figures ..				0		63	81	75	75	75	81	86			
			As per cent. of formula figures ..				0		63	70	81	75	75	81	86			

* This column shows intake from birth to midnight, at an average of 21½ days.

TABLE 3
CALORIE INTAKE OF GROUPS OF FULL-TERM BABIES IN THE FIRST TEN DAYS OF LIFE
100 c.c. breast milk reckoned as 70 calories, i.e. approximately 20 calories per fluid oz.

AUTHOR AND YEAR	NO. OF BABIES AND FEEDING	BIRTH-WEIGHT	PROGRESS	AVERAGE CALORIE INTAKE ON EACH OF FIRST 10 DAYS OF LIFE: AGE IN DAYS										INTAKE AS PER CENT. OF FORMULA FIGURES: AGE IN DAYS			
				0	1	2	3	4	5	6	7	8	9	0-9	2-6	7-9	
Feer (1902) ..	10 Breast only	7 lb. 12½ oz.	At 13 days old nearly 2 oz. over average birth-weight	3	35	124	220	319	384	386	397	393	422	99	104	104	
			Per cent. of formula fig.	5	32	75	100	116	116	100	103	102	109				
			Average birth-weight re- gained at 7 days old	73	152	220	286	317	338	360	363	356	368	108	114		97
Faber (1922) ..	179-64 Breast and supplement	7 lb. 6 oz.	Per cent. of formula fig.	135	142	137	134	119	105	96	97	95	98				
			Birth-weight regained at 8 days old	40	138	208	260	302	324	319	340	327	334	102	109		92
Opitz (1911) ..	75 Breast and presumably supplement	3-0-3.5 kilo. Average taken as 7 lb. 2½ oz.	Per cent. of formula fig.	77	134	134	126	117	104	88	94	90	92				

The calorie values here given do not always correspond with the calorie values as reckoned in the papers quoted, because they have been re-calculated on the basis of one fluid oz. of breast milk supplying 20 calories, in order that the figures in this paper may be comparable with those in the rest of this paper.

* Opitz does not give the intake at nine days old: this figure is the average of the two previous days.

Feer (1902) gives the quantity of breast milk taken by ten babies who averaged 7 lb. 12 oz. at birth. By thirteen days old they averaged nearly two ounces over birth-weight, so they probably regained their birth-weight by about ten days old. For the first three days, i.e. before the milk came in, they took less than the formula requirement, and thereafter slightly more than this estimate, so that the intake for the first ten days was almost exactly that required by the formula. Faber's (1922) babies, who were supplemented from the first day with as much food as they would take from a bottle, took well over the formula requirement in the first five days, and from the sixth day rather less, so that they averaged 8 per cent. over the formula figures for the first ten days. Opitz's (1911) cases show the same sort of tendency as Faber's, and presumably received supplements in the first few days of life: within the first ten days they took almost exactly the formula requirement.

Hence, judged by these three series, as well as by the author's own series, the formula approximated fairly closely to the quantity of food taken by groups of babies who made normal progress. The calorie intake for each of these groups has been calculated (or re-calculated) on the basis of 20 calories per fluid ounce in order to compare them with the author's own cases, so that the calculated calorie intake here shown does not always tally with that of the authors themselves. It would seem that if a baby is given fairly liberal feeds in the first two or three days, he will probably take rather less than the average in the latter part of the first ten days.

The progress made by 107 consecutive premature babies at the Mother's Hospital whose feeding was guided by the formula

For a number of years this formula has been used as a guide in feeding premature and immature babies at the Mothers' Hospital, Clapton, a maternity hospital of one hundred beds. Table 4 sets forth the average gain in weight

TABLE 4
PREMATURE BABIES WHOSE FEEDS WERE ADJUSTED BY THE FORMULA:
AVERAGE WEIGHTS TO SHOW THE BABIES' PROGRESS

All babies, born in the Mothers' Hospital between July 1938 and June 1939, who weighed $5\frac{1}{2}$ lb. and less at birth

GROUP BY BIRTH WEIGHT	NUMBER		BABIES SURVIVING AT 10 DAYS OLD			
	BORN	SURVIVING AT 10 DAYS	AVERAGE BIRTH-WEIGHT. LB. OZ.	LOSS IN WEIGHT		AVERAGE GAIN AT 10 DAYS OLD IN OZ.
				AVERAGE IN OZ.	PER CENT. BIRTH-WEIGHT	
$2\frac{1}{2}$ lb. to 4 lb.	14	8	3 10.3	-1.81	3.1	-2.56
Over 4 lb. to $4\frac{1}{2}$ lb. . . .	12	10	4 4.4	-3.20	4.7	-1.00
Over $4\frac{1}{2}$ lb. to 5 lb. . . .	35	33	4 12.9	-3.54	4.6	-0.44
Over 5 lb. to $5\frac{1}{2}$ lb. . . .	57	56	5 5.2	-4.04	4.7	-1.21
$2\frac{1}{2}$ lb. to $5\frac{1}{2}$ lb. (combined)	118	107	4 15.0	-3.64	4.6	-1.07

of all the babies of $5\frac{1}{2}$ lb. and less born in the twelve months from July 1, 1938, to June 30, 1939, and shows that the progress of these immature babies was on

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the whole good. One hundred and eighteen such babies were born; of these, one hundred and seven were surviving at ten days old. At that age they averaged approximately one ounce over birth-weight. Their average loss in weight after birth was just over three and a half ounces, or about 4.5 per cent. of birth-weight. The babies are subdivided by birth-weight, and for each subdivision the initial loss in weight is less than 4.75 per cent. of birth-weight. So that as regards these babies the use of the formula was justified by results.

The calorie intake of 43 premature babies and their progress

Though the formula was used as a guide or check in the feeding of all the premature babies, complete records of food intake were only kept in a certain number of cases. Of these hundred and seven premature babies, complete feeding records up to ten days old were kept in thirty-five cases, and up to seven days old in forty-three cases. The babies for whom the records were incomplete were nearly all the stronger and more vigorous babies, who were able at an early stage to suck direct from the breast, so that the forty-three babies whose records are available (see tables 5 and 6) included nearly all the smallest babies and the

TABLE 5

THE CALORIE INTAKE OF 43 PREMATURE BABIES IN THE FIRST TEN DAYS OF LIFE, AND THEIR PROGRESS: BABIES INCLUDED IN TABLES 4 AND 6

GROUP BY BIRTH-WEIGHT	AVERAGE BIRTH- WEIGHT		NO.	INITIAL LOSS IN WEIGHT		AVERAGE LOSS OR GAIN IN OZ.		INTAKE AS PER CENT OF FORMULA REQUIREMENT	
				AVERAGE IN OZ.	PER CENT. BIRTH- WEIGHT	AT 7 DAYS	AT 10 DAYS	0-6 DAYS OLD	0-9 DAYS OLD
	LB.	OZ.							
2½ lb. to 4 lb. . .	3	10	7	-2.29	4.7	-0.79	-1.93(7)	97	101 (7)
Over 4 lb. to 5 lb.	4	10½	28	-3.89	5.2	-1.71	-0.01 (22)	88	93 (22)
Over 5 lb. to 5½ lb.	5	4½	8	-4.81	6.0	-2.28	-0.33(6)	85	88 (6)
2½ lb. to 5½ lb. (combined) . .	4	10.0	43	-3.80	5.1	-1.67	-0.44 (35)	89	94 (35)

Figures in brackets show number of cases at 10 days old.

feeble babies. Thus, while they included fourteen out of eighteen babies weighing 2½ to 4½ lb., they included only twenty-nine out of eighty-nine babies weighing 4½ to 5½ lb. The food intake for the whole group for whom figures are available was 94 per cent. of the calculated requirement for the first ten days: for those of 4 lb. and less it was 101 per cent., for those of 4 to 5 lb., 93 per cent., and for those of 5 to 5½ lb., 88 per cent. This relatively higher feeding of the smallest babies probably reflects the attitude of the nursing staff: in the case of very small babies it is recognized that they cannot take all their milk directly from the breast and that it is of importance that they should not be underfed, consequently their intake averaged almost exactly that laid down in the schedule, and by ten days old they were approximately two ounces over

birth-weight. With bigger and stronger babies it was felt that more liberties could be taken, and in an effort to get the baby to suck from the breast, the nurses might omit to give him quite as high a feed, so that the progress of the larger babies tended to be a little slower, and they averaged almost exactly birth-weight at ten days. The average daily intake is shown in table 6. Taking the whole group of forty-three babies the average intake on the first day of life was 36 per cent. of the schedule requirement (assuming that the average period from birth to midnight was only twelve hours it would be raised to 72 per cent.), and after two days old it was always within 4 per cent. of the schedule figure. The average loss in weight after birth was 3.8 oz., or 5.1 per cent. of birth-weight (see table 5), so that these forty-three babies gained only a little more slowly than the whole group of a hundred and seven premature babies, in spite of the fact that they included nearly all the feeble babies.

The two babies in the series whose percentage intake for the first ten days was smallest were two 5 lb. babies who took respectively 61 per cent. and 60 per cent. of the schedule requirement, and were half an ounce and three and a half ounces under birth-weight at ten days old. Both were ill, one had blue asphyxia, some bleeding from the nose, a shrill cry and subnormal temperature (probably haemorrhagic disease with some intra-cranial bleeding), the other had loose stools and convulsive twitchings on the seventh and eighth days of life. Of the rest of the series of forty-three, five had cyanotic attacks, nine had body temperatures of 95° F. or lower, one melaena, one a cephalhaematoma, and three vomited, so that the fact that at ten days old the average weight of the whole group was just over birth-weight must be considered satisfactory.

After the baby reached an intake of 50 calories per lb. birth-weight, subsequent increases were dependent on his appetite and on his rate of gain in weight. About 50 calories per pound birth-weight was aimed at during the second week of life until the baby showed signs of desiring more, or failed to gain adequately. The average daily intake for the second week for the twenty-six premature babies in the series for whom details are available (see table 6) was 53 calories per pound birth-weight, and the average gain for the week 5.4 oz. The intake for individual babies usually exceeded 45 calories per pound birth-weight; the highest in the group was 66 calories. After the end of the second week, a further rise in calorie intake was usually necessary.

The human milk given to the smaller premature babies in the first week was often derived from mothers in the second week of lactation, and its calorie value was therefore probably more constant than that of colostrum. When human milk was not available, sweetened condensed milk in a dilution of one in five by volume (providing approximately 20 calories per fluid oz.) was usually given, but this was seldom necessary for the smaller premature babies in the first two weeks.

During the first two to five days of life premature babies were given water between feeds in about the same volume as that taken in the feeds. Thereafter the volume of the feeds exceeded that of the plain water, and by the second week of life most babies received only one to two ounces of extra water daily, though if the baby seemed thirsty he was given more, and occasionally a baby took five or six ounces in the day.

TABLE 6
CALORIE INTAKES OF PREMATURE BABIES IN THE FIRST AND SECOND WEEKS OF LIFE:
BABIES INCLUDED IN TABLES 4 AND 5

	FIRST WEEK OF LIFE										SECOND WEEK OF LIFE			
	AVERAGE BIRTH- WEIGHT LB. OZ.	NO.	AVERAGE CALORIE INTAKE ON EACH OF FIRST 7 DAYS OF LIFE							AVERAGE TOTAL IN 0-6 DAYS, I.E. IN 1ST WEEK	NO.	AVERAGE DAILY INTAKE, 7-13 DAYS OLD	AVERAGE PER LB.	AVERAGE GAIN 2ND WEEK
			0	1	2	3	4	5	6					
Intake	4 10-0	43	12*	52	85	125	158	179	205	819 calories	26	228 calories	53 calories	+ 5.4 oz.
Formula requirement ..	4 10-0	—	33†	66	99	132	165	198	231	924 calories				
Intake as per cent. of formula requirement			36	79	86	95	96	90	89	89		106		

* This figure is the intake from birth till midnight, probably an average of 12 hours.
† This figure is the calculated requirement for 24 hours.

Test feeds: first and last feeds of the day compared with the rest

In most maternity hospitals in this country the amount of work to be got through by the nurses places a limit on the number of test feeds which can be carried out, particularly by the night staff. Hence it is desirable to know what guidance can be obtained as to the total intake from test feeds carried out by the day staff when, as is usual, the quantity taken at the first and last feeds of the day is unknown. For twenty-five babies the average volume of first and last feeds has been compared with the average volume of the rest of the feeds of the day, either five or six feeds being given in twenty-four hours. Complete records were available for eighty-eight days during which 513 feeds were given: the majority of complete records were for the first week of life. If the average of each of the three or four feeds given during the day-duty period is called 100, the average of the first and last feed came to 110 each. It must be remembered moreover, that intake was estimated only to the nearest quarter ounce. This 10 per cent. difference, if significant, would mean that if the total intake for twenty-four hours for a group of babies were reckoned on the average of the day-time feeds, the result would be too low by 4 per cent. if five feeds are given, and by 3.3 per cent. if six feeds are given, differences that are sufficiently small to make the average of the day feeds a satisfactory guide. Unfortunately, however, the individual variations are large, so that for one baby in a single day the error sometimes may be considerable. Moreover, the mother's milk supply will be affected by circumstances, such as interrupted sleep at night or an emotional upset in the day.

Discussion

Considerations governing the giving of supplements. The start given the baby in the first fortnight of life plays a large part in his progress for the next few months. Very many of the 'feeding difficulties' of infancy originate in mismanaged feeding during the early weeks. As already stated, this formula for calculating a baby's requirements should not be adhered to rigidly, but should simply be used as a guide. The sixty-three babies, full term and premature, at the Mother's Hospital, whose records are analysed in this paper, include seven getting about 20 to 30 per cent. under the formula requirement for the first ten days, who nevertheless made normal progress. The probable explanation is that the calorie value of the breast milk they received was higher than the average, so that their actual calorie intake was greater than that calculated. Four babies received 10 per cent. or more above the schedule requirement in the first ten days, and these averaged six ounces over their birth-weight at ten days old.

In deciding whether an individual baby, whose gain is inadequate, should have a supplement, various factors should be taken into consideration besides the actual volume intake, and the problem is often complicated by other factors. A baby getting insufficient food may become or remain lethargic, and suck badly; if given a supplement, he may suck better. On the other hand, a baby given too liberal a supplement may simply go to sleep when put to the breast. The psychological effect on the mother is also important, and some psychological insight is necessary to arrive at a right decision. For example,

a mother's worry over her baby's failure to gain may result in a poor milk secretion, or, on the other hand, some mothers finding that their babies are gaining well on breast-milk and supplement conclude there is no good reason for persevering in breast feeding. When ordering supplements, information is always needed, not only as to the amount taken in test feeds, but also as to the amount of milk, if any, remaining in the breasts, as to the baby's behaviour during the feed, as to the mother's management of the feed and her attitude to the problem of feeding. Much of this work in a maternity hospital must devolve on the ward sister, and balanced judgment and skilled handling on her part are essential if good results are to be obtained. Speaking generally, if the mother's stay in hospital can be extended, supplements can often be withheld, and lactation may increase satisfactorily, whereas if the baby is underfed and has to be discharged early it is safer to supplement before discharge. To send out babies wholly on the breast, but underfed, is to court trouble for mother and baby, and is probably the commonest reason for breast-feeding being abandoned.

Every paediatrician and medical officer in charge of a welfare centre is familiar with the common remark that the mother's milk failed after her discharge from the maternity hospital, and the baby was consequently wholly bottle-fed. Those who have the opportunity of tracing the past history, find time and again that in such cases the mother's lactation before discharge was inadequate, and the baby underfed, so that it is scarcely surprising if the mother, deprived of the help she might have been given in hospital, is unable to cope alone with the often difficult task of adjusting the baby's feeds satisfactorily. Parents and hospital authorities, therefore, need to realize that inadequate lactation often necessitates a longer stay in hospital in the interests of the baby. If this cannot be achieved, as must often happen in the present time of war, the supplements on discharge should be fully adequate, and the mother's co-operation should be sought in reducing the supplements as and when possible, and she should be told that subsequent omission is very often possible. Brennemann (1938) has lent the weight of his authority to the claim of the new-born baby to be given enough food, and states boldly, 'The new-born baby that is on the breast alone, that is not vomiting and has no diarrhoea and is not gaining in weight after the third day of life, is not getting enough to eat and should be given more.'

Overfeeding. The formula for the calculation of feeds has also its uses in picking out the baby that is taking too much from the breast and vomiting or having loose stools as a result. The chief risk of overfeeding is, however, to the hand-fed baby, and the use of a formula should prevent sudden increases in food as well as the giving of excessive quantities: always remembering that caution is needed in giving the full schedule requirement if breast milk is not available.

The influence of feeding on the neonatal death rate. In the Registrar's General's Statistical Review for the year 1936, the infant mortality per 1000 live births during the years 1906 to 1910 is compared with that of 1936, about thirty years later. In this country in that period the mortality of infants under twenty-four hours old had dropped by only 7 per cent., of those one to fourteen days by 22 per cent., whereas that of infants aged fourteen days to twelve

months old had fallen by 62 per cent. It is generally accepted that among the many factors at work, improved feeding has played an important part in bringing down the death rate of infants over fourteen days old to a little over one-third of the old figure; but improvement in feeding cannot be expected to lessen materially the death rate in the first twenty-four hours of life. What of the next thirteen days? Better feeding will not save the lives of babies dying as the result of gross malformations or gross trauma, but what of the premature babies and twins, the babies ill with infections, the babies of mothers with poor lactation, the babies who, for one reason or another, have to be fed by hand in the early weeks? Many such are potentially healthy children. Though feeding difficulties do not figure in the death certificate, there is no doubt that they contribute to death in many instances, and that the neonatal death rate could be materially lowered by better feeding. And just as knowledge of how to calculate quantitative needs has vastly improved the feeding of older babies, so it should help in the feeding of the new born.

Summary

The day-to-day calorie needs of new-born babies is a subject which has been much neglected and about which text books provide the most diverse statements. In this paper the calorie value of colostrum and early human milk is discussed. Its value is taken in the author's calculations as 20 per fluid ounce.

A formula is suggested whereby the food intake of new-born babies may be regulated. According to this the baby should receive on the first day of life calories equivalent to $\frac{1}{2} \times 50 \times$ birth-weight in pounds, and his feeds should increase by this same amount each day of the first week, so that by the seventh day of life he would be given 50 calories per pound birth-weight. It is pointed out that the formula over-estimates the intake of normal breast-fed babies during the first two days when breast secretion is scanty. In the second week of life 50 calories per lb. birth-weight was taken as the usual requirement. The importance is emphasized of using these figures simply as guides and not to enforce a rigid system of feeding.

The calorie intake of twenty healthy breast-fed babies at the Mother's Hospital, Clapton, has been compared with the quantities calculated from this formula. The average intake on any one day after the first two days of life, of those who regained their birth-weight by ten days old, was found to be within 3 to 12 per cent. of the schedule. Three other series of full-term babies making good progress, whose average food intake for the first ten days has been recorded by different workers, received in these ten days a total quantity within 1 to 8 per cent. of the formula requirement: those who took larger quantities in the first days of life tended to take less than others in the latter part of the first ten days, and vice versa.

Calculations from test feeds on twenty-five full-term babies showed that estimates of total intake based on the feeds given during the duty-periods of the day staff gave, on the whole, a fairly accurate figure for the twenty-four-hour intake, hence three or four test feeds in the twenty-four hours should generally provide an adequate check on a baby's intake.

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One hundred and seven consecutive premature babies at the Mother's Hospital who had their food intake checked and guided by the formula, made good progress and averaged one ounce over their birth-weight at ten days old.

For a group of forty-three premature babies in this series complete figures are available. Their birth-weights varied between $2\frac{1}{2}$ lb. and $5\frac{1}{2}$ lb., and their intake for the first ten days was within 6 per cent. of that allowed by the formula. During the second week of life, the intake averaged 53 calories per pound birth-weight per day, i.e. again within 6 per cent. of the formula requirement.

All artificial feeds were given in a strength to provide approximately 20 calories per fluid ounce. Dilute feeds were not given. The fluid intake was augmented by giving water to full-term babies during the first three to five days of life or longer, to premature babies generally during the first fourteen days. Premature babies during the first two to five days received water between feeds in about the same volume as provided in their feeds.

It is hoped that wide adoption of a scheme for calculating the approximate calorie needs of new-born babies would bring about a fall in the neonatal death rate, as well as improved health in the subsequent months, by contributing to better management in the most critical period of life.

The author is much indebted to Sisters and nurses at the Mothers' Hospital for their generous help, and for the extra work they have given to enable this investigation to be carried out. The credit when good results are obtained with premature babies in hospital must always belong primarily to those who undertake the skilled and exacting work of nursing. To the resident medical staff who have shared with the author the medical care of the infants and supervision of feeds, she tenders sincere thanks for their constant co-operation.

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