# PAPERS AND ORIGINALS



# Infantile Overnutrition in the first Year of Life: A Field Study in Dudley, Worcestershire

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## Summary

**A survey of feeding patterns and nutrient intake in relation to the growth of 300 normal infants up to 1 year of age in Dudley, Worcestershire, highlights a problem of overnutrition in the group; 50 (16·7%) were found to be suffering from infantile obesity and a further 83 (27·7%) were overweight.**

**During the first three months of life the daily energy intakes of 136 cal/kg body weight for boys and 149 for girls were markedly greater than the level of 120/kg recommended by the Department of Health and Social Security. This coincided with the early addition of solid foods to a full milk intake. 119 babies (39·7%) were offered solids before they were 4 weeks old and 280 (93·3%) before 13 weeks of age. Some babies had solids from the first week after birth. Protein intake was persistently high throughout the first year, and the mean intake of 32·7 g/day was much greater than the intake of 20 g for infants aged up to 1 year recommended by the Department of Health. Standards for fat and carbohydrate intake are not available but in comparison with the levels reported in breast-fed babies intake of fat and carbohydrate was high in the first three months and came closer to the desired level for the former and remained slightly high for the latter in the subsequent age quarters.**

**The relation of childhood and subsequent adult obesity to infant feeding patterns is not yet clear, but there is a high correlation between obese parents and obese and overweight babies; had these babies not been overfed the condition might have been prevented.**

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## Introduction

Major changes have taken place in the feeding patterns of young infants, especially in the past 20 years. The incidence of breast-feeding has declined (Newson and Newson, 1962) and solid food is introduced at an increasingly early age (Black, 1971). It is suspected that the present feeding practices may lead to overfeeding in babies. In recent years concern has been expressed about infantile overnutrition (Taitz, 1971) and its possible aetiological role in some resistant forms of obesity in later life (Mullins, 1958; Asher, 1966). Brook *et al.* (1972) recently showed that both the size and the number of fat cells are increased in adults and older children who were obese by the age of 1 year. The earliest age at which obesity begins is not known, nor whether it is primarily due to nutritional excess during infancy or if it starts in utero. This paper discusses the relation between feeding patterns and obesity in infants.

## Subjects and Method

Altogether 300 babies, a 10% sample of the infant population in the County Borough of Dudley, were examined. The sample consisted of white British babies aged up to 12 months whose weight at birth had been 2·5 kg or more. Only infants born normally after a normal pregnancy were included in the sample, which was stratified by the local authority clinic. Infants were

TABLE I—*Distribution of the 300 Infants by Social Class**

| | I | II | III | IV | V |
|---|---|---|---|---|---|
| Present sample | 17 (5·3%) | 34 (11·3%) | 206 (69·0%) | 38 (12·6%) | 5 (1·6%) |
| 1966 Sample Census Dudley (total population) | 3·8% | 10·9% | 60·0% | 15·6% | 9·0% |

*Registrar General's Classification.

examined in their local welfare clinics, and it was proposed to include the first 20 babies who satisfied the criteria in each of the 15 clinics in the borough; however, the number actually examined from each clinic varied. The distribution of infants by social class is given in Table I and is compared with the 1966 Census figures, which it should be noted included all races. Nine infants were excluded from the sample because the mothers were diabetic or hypertensive or the babies were premature by age of gestation or birthweight. The survey babies were classified into four groups by age and sex (Table II). No indication was obtained that the sample chosen by attendance at clinics was biased towards oversolicitous and therefore overfeeding mothers.

TABLE II—*Age and Sex Distribution of the 300 Infants*

| Age Group | Age Range (Decimal yr) | Sex | No. | Mean Age ± S.D. (Decimal yr) |
|---|---|---|---|---|
| 1 | 0·000-0·255 | M. | 45 | 0·167 ± 0·055 |
| | | F. | 43 | 0·171 ± 0·051 |
| 2 | 0·256-0·505 | M. | 49 | 0·383 ± 0·072 |
| | | F. | 50 | 0·371 ± 0·073 |
| 3 | 0·506-0·755 | M. | 45 | 0·615 ± 0·079 |
| | | F. | 24 | 0·632 ± 0·073 |
| 4 | 0·756-1·000 | M. | 20 | 0·878 ± 0·063 |
| | | F. | 24 | 0·853 ± 0·074 |

There were more male babies (159) than female (141). The decreasing number of babies in the older age group reflects the pattern of clinic attendance.

The well-known difficulties of longitudinal surveys (Thomson, 1955; Beal, 1969) such as wastage of observations owing to migration of the population and "drop-outs" and the considerable practical difficulties in follow-up made a cross-sectional method desirable. This facilitated better co-operation from the mothers and staff and also made possible the collection of more detailed information on a much larger sample within the time available. Nutritional data were collected by a 24-hour recall method based on that of Young *et al.* (1952).

The survey comprised an interview with the mother, anthropometric examination, and a record of the dietary history of the baby. Each baby was examined by one of us (A.S.), who personally performed the anthropometric measurements. All the examinations were made with the baby naked. A portable scale was used to record body weight. Supine length was measured using a Harpenden supine measuring table. Triceps and subscapular skinfolds were measured with a Harpenden skinfold calliper and mid-arm circumference with a tape measure. These measurements were estimated according to the internationally accepted techniques of Tanner (1958) and Jelliffe (1966). At the same time the condition of the napkin area was assessed and any changes in the colour or smell of urine related to the nature of feeding were ascertained from the mother. Information about the occupation and height and weight of the parents was also obtained verbally from the mother during the interview. All the babies were examined during the nine-month period July 1970 to March 1971. Information was recorded in a questionnaire designed for the purpose.

Altogether 498 different types of foods were used by the mothers for feeding the infants. Mothers described the amount of each food they gave to the baby in household measures. For calculating nutrient intake the household measures were converted to metric weights by weighing an assortment of commercial baby foods obtained on request from the manufacturers and various raw and home-cooked foods in the diet kitchen of the Children's Hospital, Birmingham. Calculations of the nutrient intake of the foods consumed were based on food composition tables obtained direct from manufacturers or the Milk Marketing Board or by referring to McCance and Widdowson (1960). Analysis of the information on dietary intake for each child was calculated using the dietary analysis program of Forsyth (1971).

## Feeding Pattern

### BREAST-FEEDING

The incidence of breast-feeding was found to be low. On the survey day no babies were receiving breast milk alone. Very few mothers attempted to breast feed the baby initially, and many of these dropped out after varying periods because they thought their babies were not satisfied. Out of 84 mothers (28%) who gave breast milk as the first food 18 (6%) gave it up within one week, 11 (3·6%) within two weeks, and 14 (4·7%) within four weeks. Only 19 babies (6·3%) received "mixed breast-feeding"—that is, including bottle and solids—up to or beyond 12 weeks of age. Early introduction of solids was common even in breast-fed babies. The earliest age when solids were given to these 19 infants was 4 weeks.

The most common reason given by the mothers for not breast-feeding and changing over to the bottle was personal choice (53·3%). Many mothers thought that bottle-feeding was more convenient or that the baby would be healthier. Many mothers (49%), however, believed that breast milk was superior to milk formulas, but this did not alter their decision to use bottle-feeding. Nearly a third of the mothers (30%) said that they did not have enough milk, and these included cases of hypogalactasia, mastitis, and retracted or painful nipples and also those who had received oestrogens to suppress milk secretion. A striking finding was that 81% of the mothers said that no doctor or nurse advised them to give breast milk to the baby, and to 16% this was mentioned only casually. Thus the ultimate decision on the method of feeding was left largely to the mother.

The practice of breast-feeding did not seem to be influenced by social class. Among the 19 partially breast-fed babies 17 were from social class III, one was from social class I, and one was from social class II. This reflected the general pattern of the total sample (Table I).

### BOTTLE-FEEDING

Almost all the babies were being bottle-fed on the survey day—that is, 270 (90%) were receiving bottle-feeding and solids, 12 (4%) were entirely bottle-fed, and 14 (4·8%) had breast, bottle, and solids. The mean intake of milk among the 12 exclusively bottle-fed babies was 837 ml a day. The most popular milk formulas were Ostermilk and Cow and Gate in the younger age group and later on pasteurized milk was used from bottle or cup or mixed with cereals. A total of 160 babies (53·4%) were fed on proprietary milk formulas, 71 (23·7%) had liquid cows' milk, 5 (1·7%) had evaporated milk, 59 (19·7%) had a combination of milks, and only one had National Dried Milk. It was a general practice to prepare the required amount of milk for each feed and to use a portion with cereals or instant foods. Initially the total consumption of milk remained unaltered despite the addition of solids. Depending on the age of the baby feeds from bottle or cup varied from none to six in 24 hours.

Most mothers added 1 or 2 teaspoons of cane sugar to the milk, and a few used brown sugar. There was a general tendency among mothers of bottle-fed babies to give solids even earlier than 4 weeks, in contrast to mothers of breast-fed babies.

### WEANING

Solid foods were offered to some infants from the first week after birth (Table III). Of the 300 babies 119 (39·7%) had solids by 4 weeks and 280 (93·3%) by 13 weeks of age. The commonest first solids given were from a wide range of commercial products consisting of baby rusks and instant cereals, most of which also contain high-quality proteins. These were soon followed by instant or sieved dinners. Junior foods were fed extensively in the latter part of the first year, and only a few mothers used home-cooked foods.

TABLE III—*Frequency Distribution of Age of Weaning (Introduction of First Solids) in the 300 Infants*

| Age in Weeks | Total Sample* | | Cumulative Total | |
|---|---|---|---|---|
| | No. | % | No. | % |
| 1 | 5 | 1·7 | 5 | 1·7 |
| 2 | 19 | 6·3 | 24 | 8·0 |
| 3 | 36 | 12·0 | 60 | 20·0 |
| 4 | 59 | 19·7 | 119 | 39·7 |
| 8 | 124 | 41·3 | 243 | 81·0 |
| 13 | 37 | 12·3 | 280 | 93·3 |
| 14–25 | 7 | 2·3 | 287 | 95·7 |

*13 infants were not weaned (having milk only).

## Nutrient Intake

### CALORIE INTAKE

The practice of early weaning and mixed feeding resulted in a high calorie intake in the first six months. This came closer to the recommended levels in the second half of the first year (Table IV, column 4). The level of calorie excess was highest in age group 1, which resulted from the addition of solids. The energy intake of the 12 babies who were exclusively bottle-fed on the survey day, all of whom were in age group 1, was 590 calories; this was only 40 calories above the recommended level. The energy intake of the total sample in age group 1, 93·3% of whom were receiving solids in addition to bottle-feeding, was 775 calories (Table IV, column 3). The proportion of calories from added sugar was only small.

The daily calorie intake in relation to body weight of 136 cal/kg in boys and 149 cal/kg in girls in the first three months was considerably higher than the standard level of 120 cal/kg recommended by the Department of Health and Social Security (1970) (Table IV, column 8).

### PROTEIN INTAKE

The average daily protein intake by the survey infants up to 1 year was 32·7 g, being markedly higher than the Department of Health's (1970) recommendation of 20 g/day in the first year. In relation to body weight the protein intake was also found to be much higher in all age quarters than the "minimum requirements" recommended by the Department of Health (Table V). In addition the observed results were much greater than the "advisable intake" suggested by the FAO/WHO (1965), American National Research Council Food and Nutrition Board (1964), Fomon (1967), and the Medical Research Council (1959). While it is realized that the "minimum requirements" or "advisable intakes" recommended by various bodies may not all be scientifically based, the difference between them and the intakes recorded in this study were considerable.

Stearns (1939) showed that the protein intake is greater in bottle-fed infants than in breast-fed infants. Since the infants in the present survey received bottle-feeding together with a large variety of commercially manufactured solid foods which invariably have ingredients containing high-quality proteins it is not surprising that their protein intake was excessively high.

### FAT INTAKE

The mean daily intake of fat in age group 1 was 5·7 g/kg/day in boys and 6·5 g in girls, clearly higher than the level of 3-4 g/kg/day suggested by MacKeith and Wood (1971) for breast-fed infants. In subsequent age quarters the intake ranged between 3·8 and 4·5. Thus consumption of fat was higher in the first age quarter only.

### CARBOHYDRATE INTAKE

The intake of carbohydrate per kg body weight in age group 1 was 15·3 g for boys and 15·9 g for girls, and the respective intakes for age groups 2, 3, and 4 were 14·5, 13·6, and 12·9 g for boys and 14·6, 14·4, and 13·1 g for girls. These figures, which were higher than the 12 g/kg/day for breast-fed infants recorded by MacKeith and Wood (1971), indicated overnutrition with regard to carbohydrate intake, especially in the first age quarter.

TABLE IV—*Comparison between Mean Daily Calorie Intake of Sample with Recommended Allowances of the Department of Health and Social Security (1970)*

| Recommended Allowances of D.H.S.S. | | Mean Daily Calorie Intake of Sample | | | | Mean Daily Calorie Intake per kg Body Weight | | |
|---|---|---|---|---|---|---|---|---|
| (1) Age Range (Months) | (2) Total cal/Day | (3) Intake (Both Sexes) | (4) Difference between (2) and (3) | (5) Intake | (6) Difference between (2) and (5) | (7) D.H.S.S. | (8) Sample | (9) Difference between (7) and (8) |
| ≤3 | 550 | 775 | +225 | M. 790 | +240 | 120 | M. 136 | +16 |
| | | | | F. 760 | +210 | | F. 149 | +29 |
| –6 | 760 | 872 | +112 | M. 905 | +145 | 115 | M. 117 | + 2 |
| | | | | F. 839 | + 79 | | F. 117 | + 2 |
| 9 | 910 | 905 | – 5 | M. 919 | – 9 | 110 | M. 105 | – 5 |
| | | | | F. 877 | – 33 | | F. 107 | – 3 |
| –12 | 1,000 | 948 | – 52 | M. 982 | – 18 | 105 | M. 99 | – 6 |
| | | | | F. 919 | – 81 | | F. 103 | – 2 |

TABLE V—*Comparison between Sample and Available Information on Protein Intake. Results Expressed in g/kg/Day*

| D.H.S.S. (1970) | | Intake Recommended by FAO/WHO (1965) (Both Sexes) | Intake Recommended by National Research Council (1964) (Both Sexes) | Fomon (1967) | | Sample | | | M.R.C. (1959)† Mean Intake in Breast Milk |
|---|---|---|---|---|---|---|---|---|---|
| Age Range (Both Sexes) in Months | Minimum Req. (Both Sexes) | | | Age (Both Sexes) in Months | Advisable* Intake (Both Sexes) | Age Group | Sex | Mean Intake | |
| ≤3 | 2·8 | 2·3 | 2·6 | 1 | 3·0 | 1 | M. | 5·2 | 2·01 |
| | | | | 2 | 2·7 | | F. | 5·9 | |
| –6 | 2·1 | 1·8 | 2·4 | 4 | 2·3 | 2 | M. | 4·5 | 1·86 |
| | | | | 6 | 2·2 | | F. | 4·2 | |
| 9 | 1·8 | 1·5 | Not Available | 8 | 1·8 | 3 | M. | 3·9 | 1·70 |
| | | | | | | | F. | 3·9 | |
| –12 | 1·6 | 1·2 | 2·3 | 10 | 1·6 | 4 | M. | 3·6 | 1·54 |
| | | | | 12 | 1·6 | | F. | 3·9 | |

*For infants not breast-fed but receiving protein of high nutritional quality.
†Protein intake of exclusively breast-fed babies whose average calorie intake from breast milk was 100 cal/kg body weight.

## Influence of Nutrient Intake on Body Size

It is known that an intake of calories in excess of the body's requirements leads to an increase in body weight. In the present study the finding of excessive calorie intake in the first three months together with overnutrition of protein, fat, and carbohydrates seems the likely reason for the greater mean body weight and higher weight gain than expected in the survey infants. This trend continued despite a reduction in the calorie consumption in subsequent age quarters. The effect of the nutritional excess was more noticeable on the weight for length curve, which started at a much higher level than the standard curve and remained high all through the first year of life (Figs. 1 and 2). The scatter in Figs. 1 and 2 shows the large concentration of infants in the heavier weight range. This finding also indicates that body bulk or weight per unit of length calculated as "weight for length" ratio was much greater in the survey infants than would normally be expected from the standards (Table VI).

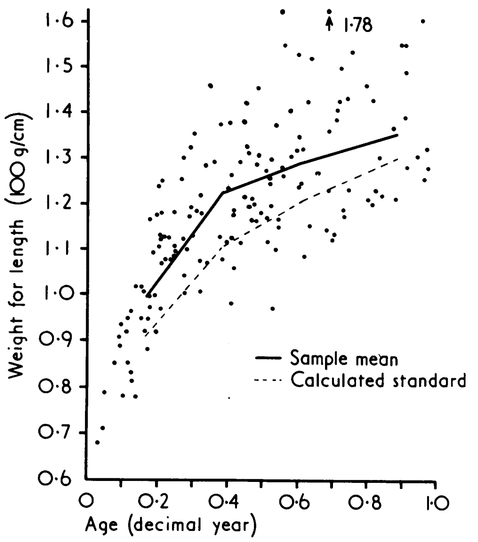


FIG. 1—Present weight for length (boys).

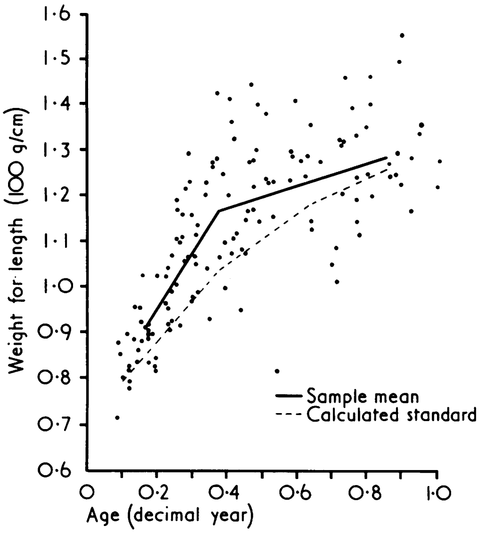


FIG. 2—Present weight for length (girls).

TABLE VI—*Observed Ratio of Weight for Length and Comparison with Standards. Results Expressed in kg*

| Age Group | Sex | Mean Wt × 100/L Sample | Calculated Wt × 100/L Tanner* |
|---|---|---|---|
| 1 | M. | 0·993 | 0·908 |
| | F. | 0·916 | 0·853 |
| 2 | M. | 1·211 | 1·103 |
| | F. | 1·162 | 1·028 |
| 3 | M. | 1·291 | 1·207 |
| | F. | 1·226 | 1·176 |
| 4 | M. | 1·375 | 1·300 |
| | F. | 1·283 | 1·256 |

*Wt × 100/L was calculated by using 50th percentile values for weight and length visually interpreted from Tanner's graphs.

## Infantile Obesity

### DEFINITION

Excessive weight was established by comparing actual weight with expected weight for age, sex, and height (Wolff, 1955). Tanner's standards (Tanner *et al.*, 1966) were used throughout for comparison. The method of calculation is as follows:

$$\frac{\text{Actual wt (kg) of infant for present age}}{\text{Actual L (mm) of infants for present age}} = A$$

$$\frac{\text{50th P expected wt (kg) for corresponding age}}{\text{50th P expected L (mm) for corresponding age}} = B$$

$A/B \times 100$ = index for survey infant; B = standard index taken as equal to 100.

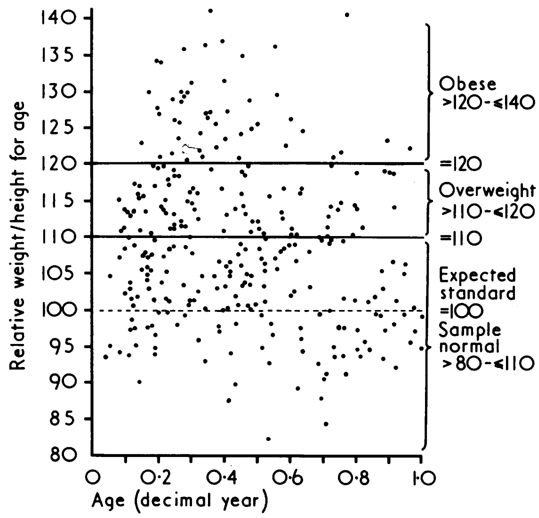


FIG. 3—Classification of infants into obese, overweight, and sample normal groups (both sexes).

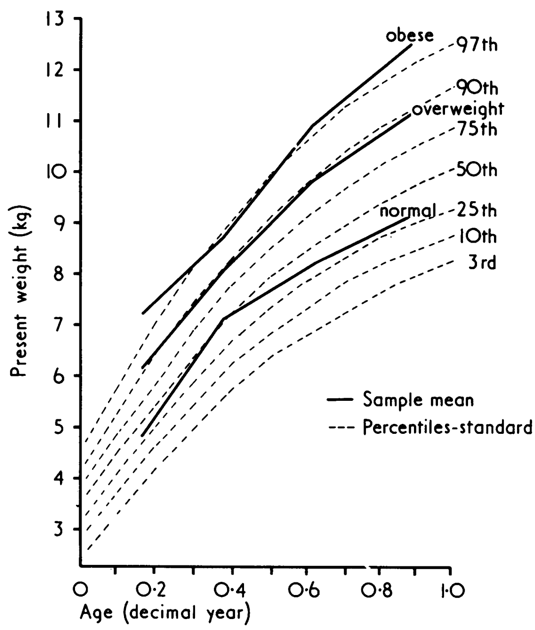


FIG. 4—Present weight (boys).

The sample was divided into the following three groups on the basis of the comparison with the standard: (1) normal, range >80 to ⩽110 or 20% below to 10% above the standard weight; (2) overweight range >110 to ⩽120 or >10% to ⩽20% above the standard weight; (3) obese, range >120 to ⩽140 or >20% to ⩽40% above the standard weight.

The scatter in Fig. 3 shows that all the infants fell within the three groups.

On plotting the mean weight of the normal, overweight, and obese groups on Tanner's weight graphs (Fig. 4) it was noticed that the curve of the overweight group ran parallel to the 90th percentile line and that that of the obese group ran parallel to the 97th percentile line. The curve for the normal group was seen to lie in the lower range of Tanner's normal—that is, between the 50th and 25th standard percentile curves. The trend of the weight curves became clearer when the curves of observed ratio of weight for length were compared with the standard for the three groups (Fig. 5). The wt/L curve for the obese group was seen to move much higher than the 97th percentile, the curve for the overweight group also moved higher but still remained between the 90th and 97th percentiles, and the sample normal curve ran parallel to the 50th percentile. This observation confirms the validity of the definitions used in this study to designate sample normal, overweight, and obese groups. Thus babies whose actual body weight is greater than 20% above the expected weight should definitely be regarded as obese if their present weight is at the 97th percentile and their ratio of weight for length is above the 97th percentile. In the same way overweight babies whose body weight is greater than 10% of the expected should be regarded as overweight if their body weight and weight for length ratio lies between the 90th and 97th percentiles.

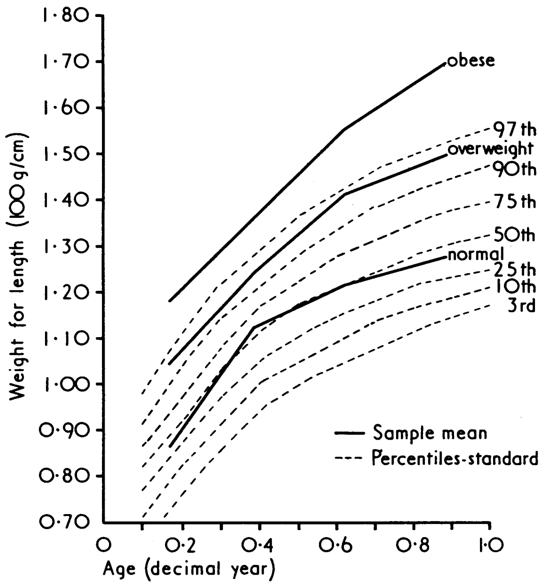


FIG. 5—Present weight for length of the three groups (boys) compared with standard percentiles.

In this study, by grouping the infants into normal, overweight, and obese groups and comparing the curves of the sample with Tanner's standards it was possible to differentiate clearly between the three groups even in early infancy. These comparisons were similar in girls except that the levels were slightly lower. This differentiation is not ordinarily possible because no convincing definition of the various grades of excessive weight exists. Another point which emerges while considering the mean curves of the overweight and obese group of the sample in relation to the percentile curves of Tanner's graphs is: What should be the upper limit of normality? If the 90th and 97th percentiles are equivalent to overweight and obese weights as shown by the present study it may be misleading to maintain these lines as part of the normal upper range in growth charts for normal children. It may be advisable to shade the area between the 90th and 97th percentiles and the equivalent area above the 97th percentile to indicate the abnormal range.

The pattern of the weight curves of the three groups also explained the reason for the higher level of body weight in the

TABLE VII—*Classification of Sample into Normal, Overweight, and Obese Groups on basis of Comparison of Actual Weight with Standard Weight for Age, Sex, and Length*

| | No. of Infants | % of Infants | Percentage of Weight in Group | | |
|---|---|---|---|---|---|
| | | | Range | Mean | S.D. |
| *Both Sexes* | | | | | |
| Sample normal | 167 | 55·7 | 72·6-110·0 | 100·9 | 6·3 |
| Overweight | 83 | 27·7 | 110·1-119·9 | 114·5 | 2·9 |
| Obese | 50 | 16·7 | 120·5-140·9 | 127·2 | 5·3 |
| *Both Sexes Age Group 1* | | | | | |
| Sample normal | 46 | 52·3 | 90·2-109·9 | 102·1 | 5·2 |
| Overweight | 31 | 35·2 | 110·5-119·9 | 114·8 | 2·8 |
| Obese | 11 | 12·5 | 120·9-134·0 | 126·6 | 4·6 |
| *Both Sexes Age Group 2* | | | | | |
| Sample normal | 45 | 45·5 | 87·6-110·0 | 102·2 | 2·9 |
| Overweight | 25 | 25·3 | 110·8-119·7 | 114·7 | 2·7 |
| Obese | 29 | 29·3 | 120·5-140·9 | 127·6 | 5·2 |
| *Both Sexes Age Group 3* | | | | | |
| Sample normal | 44 | 63·8 | 72·6-109·9 | 99·7 | 8·6 |
| Overweight | 18 | 26·1 | 110·1-119·9 | 113·4 | 2·7 |
| Obese | 7 | 10·1 | 120·9-135·9 | 125·8 | 4·9 |
| *Both Sexes Age Group 4* | | | | | |
| Sample normal | 32 | 72·7 | 91·2-109·5 | 98·9 | 4·5 |
| Overweight | 9 | 20·5 | 110·3-119·0 | 115·5 | 3·3 |
| Obese | 3 | 6·8 | 122·1-140·3 | 128·6 | 8·3 |
| *Boys All Ages* | | | | | |
| Sample normal | 87 | 54·7 | 82·3-110·0 | 110·6 | 6·1 |
| Overweight | 46 | 28·9 | 110·5-191·9 | 114·4 | 2·8 |
| Obese | 26 | 16·4 | 120·8-140·3 | 127·2 | 5·4 |
| *Girls All Ages* | | | | | |
| Sample normal | 80 | 56·7 | 72·6-110·0 | 101·2 | 6·5 |
| Overweight | 37 | 26·2 | 110·1-119·7 | 114·6 | 3·0 |
| Obese | 24 | 17·0 | 120·5-140·9 | 127·3 | 5·2 |

Criteria of Grouping
Standard = 100.
Sample normal = 100 (range >80-⩽110) or 20% below and 10% above standard weight.
Overweight = >110 (range >110-⩽120) or >10%-⩽20% of standard weight.
Obese = >120 (range >120-⩽140) or >20%-⩽40% of standard weight.

total sample. This curve moved below the 50th percentile, as shown by the position of the normal curve in Fig. 4, after the overweight and obese groups were separated. This observation shows that the higher level of the curve of the mean body weight of the total sample was not a simple secular trend but that it was due to the presence of many babies who were overweight and obese.

### INCIDENCE OF OBESITY

The number and percentage of infants in the three groups together with their mean weight expressed as a percentage in comparison with the expected calculated standard is shown in Table VII.

Out of the total sample of 300 babies 50 (16·7%) were obese and a further 83 (27·7%) were overweight.

The influence of age on the incidence of obesity, both sexes combined, is also shown in Table VII. There was a decline with increase in age except in age group 2 where it reached a peak. The finding of a higher incidence of obesity in age group 2 may be related to early overnutrition in age group 1, but the percentage of obese babies shows a decline in the second half of the first year. Further studies beyond 1 year of age are indicated to see if this decline continues.

Sex does not seem to have much influence on obesity at this early age of life. Boys have a slightly higher incidence of both overweight and obesity but only by about 1% more than girls in the total sample up to a year. Alterations in the incidence of these two conditions in age groups 1 to 4 for both sexes separately could not be studied because the numbers of infants in the subgroups were too small for any conclusive evidence.

## Other Observations

### BIRTH WEIGHT

The mean birth weight of the total sample was similar to Tanner's standards for boys and girls (Table VIII) (Tanner *et al.*, 1966). When babies were divided into obese, overweight, and normal groups some important differences were seen in the level of mean birth weight (Table VIII). Obese babies had a significantly higher birth weight than the sample normal ($t$ = 5·67, D.F. = 215, P <0·01) and the overweight group had a slightly lower mean weight than the obese group, though this was still significantly different ($t$ = 6·14, D.F. = 248, P <0·01) from normal. The difference between the obese and overweight groups was not statistically significant (P >0·10). The mean birth weight of the obese and overweight groups was greater than Tanner's figures (Tanner *et al.*, 1966) and that of the total sample.

TABLE VIII—*Mean Birth Weight (kg) of Sample Normal, Overweight, and Obese Groups*

| | Tanner *et al.* (1966) 50th Percentile | Sample | | | |
|---|---|---|---|---|---|
| | | All Infants | Normal | Overweight | Obese |
| Boys .. | 3·50 | 3·49 | 3·33 | 3·65 | 3·75 |
| Girls .. | 3·40 | 3·36 | 3·20 | 3·57 | 3·58 |

### SUPINE LENGTH (LINEAR GROWTH)

The overall mean supine lengths of the normal, overweight, and obese infants in the sample were 633·2, 639·6, and 639·2 mm respectively (Table IX). Thus both the overweight and obese groups were about 6 mm longer than the normal group. The differences in the three groups were not significant (P >0·01) in the whole sample up to 1 year of age. In comparison with the standard percentile curves (Fig. 6) the supine length of the obese group in the first age quarter started at the 97th percentile but ended up nearer the 25th percentile, below the level attained by the overweight infants in age agroup 4. The curve for the sample normal group was much lower than the 50th percentile of the standard, lying parallel to the 25th percentile in the first six months, then sharply falling to run parallel to the 10th percentile. This finding shows clearly that normal

TABLE IX—*Anthropometric Measurements of Normal, Overweight, and Obese Infants in Sample (Both Sexes)*

| Age Group | Normal | | | Overweight | | | | Obese | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Range | Mean | S.D. | Range | Mean | S.D. | Normal *v.* Overweight | Range | Mean | S.D. | Normal *v.* Obese | Overweight *v.* Obese |
| | | | | | | *Present Weight (kg)* | | | | | | |
| All ages .. | 3·4-10·1 | 6·9 | 1·7 | 4·4-11·8 | 7·8 | 1·8 | P <0·01 | 5·6-13·1 | 8·6 | 1·6 | P <0·01 | P <0·01 |
| 1 .. .. | 3·4- 6·0 | 4·8 | 0·6 | 4·4- 7·1 | 5·9 | 0·7 | P <0·01 | 5·6- 7·5 | 7·0 | 0·5 | P <0·01 | P <0·01 |
| 2 .. .. | 5·1- 8·0 | 6·8 | 0·7 | 6·4- 8·8 | 7·8 | 0·8 | P <0·01 | 6·5-10·1 | 8·3 | 0·8 | P <0·01 | P <0·05 |
| 3 .. .. | 5·2- 9·8 | 8·0 | 0·9 | 7·6-10·8 | 9·3 | 0·8 | P <0·01 | 9·2-11·2 | 10·6 | 0·6 | P <0·01 | P <0·01 |
| 4 .. .. | 7·4-10·1 | 8·9 | 0·7 | 9·6-11·8 | 10·7 | 0·7 | P <0·01 | 11·0-13·1 | 12·0 | 0·9 | P <0·01 | P <0·02 |
| | | | | | | *Supine Length (mm)* | | | | | | |
| All ages .. | 500-765 | 633·2 | 61·1 | 520-760 | 639·6 | 57·9 | P >0·10 | 550-740 | 639·2 | 44·6 | P >0·10 | P >0·10 |
| 1 .. .. | 500-618 | 555·7 | 24·7 | 520-650 | 583·6 | 30·5 | P <0·10 | 550-635 | 601·4 | 22·3 | P <0·01 | P <0·05 |
| 2 .. .. | 560-670 | 624·2 | 25·2 | 590-680 | 642·8 | 29·4 | P <0·01 | 565-695 | 630·2 | 28·8 | P >0·10 | P >0·10 |
| 3 .. .. | 605-765 | 671·9 | 29·9 | 620-725 | 685·3 | 26·7 | P >0·10 | 655-720 | 697·9 | 21·2 | P <0·05 | P >0·10 |
| 4 .. .. | 650-750 | 704·3 | 24·8 | 712-760 | 732·4 | 18·0 | P <0·01 | 710-740 | 728·3 | 13·1 | P >0·10 | P >0·10 |
| | | | | | | *Present Weight Length (100 g/cm)* | | | | | | |
| All ages .. | 0·7- 1·4 | 1·1 | 0·2 | 0·9- 1·6 | 1·2 | 0·2 | P <0·01 | 1·0- 1·8 | 1·3 | 0·2 | P <0·01 | P <0·01 |
| 1 .. .. | 0·7- 1·0 | 0·9 | 0·1 | 0·9- 1·1 | 1·0 | 0·1 | P <0·01 | 1·0- 1·3 | 1·2 | 0·1 | P <0·01 | P <0·01 |
| 2 .. .. | 0·9- 1·2 | 1·1 | 0·1 | 1·1- 1·3 | 1·2 | 0·1 | P <0·01 | 1·2- 1·5 | 1·3 | 0·1 | P <0·01 | P <0·01 |
| 3 .. .. | 0·8- 1·4 | 1·2 | 0·1 | 1·2- 1·5 | 1·4 | 0·1 | P <0·01 | 1·4- 1·6 | 1·5 | 0·1 | P <0·01 | P <0·01 |
| 4 .. .. | 1·1- 1·4 | 1·3 | 0·1 | 1·4- 1·6 | 1·5 | 0·1 | P <0·01 | 1·6- 1·8 | 1·7 | 0·1 | P <0·01 | P <0·01 |
| | | | | | | *Triceps Skinfold (mm)* | | | | | | |
| All ages .. | 4·6-14·0 | 9·3 | 1·9 | 7·0-16·6 | 10·7 | 2·0 | P <0·01 | 8·0-16·0 | 11·7 | 1·7 | P <0·01 | P <0·01 |
| 1 .. .. | 4·6-10·4 | 7·4 | 1·3 | 7·0-13·6 | 9·4 | 1·7 | P <0·01 | 8·0-14·4 | 10·7 | 1·5 | P <0·01 | P <0·01 |
| 2 .. .. | 6·8-13·0 | 9·9 | 1·5 | 7·2-14·8 | 11·5 | 1·6 | P <0·01 | 8·8-14·4 | 11·8 | 1·5 | P <0·01 | P >0·10 |
| 3 .. .. | 5·8-14·0 | 10·0 | 1·7 | 8·0-16·6 | 11·2 | 2·0 | P <0·05 | 10·0-15·0 | 11·7 | 1·6 | P <0·02 | P >0·10 |
| 4 .. .. | 6·4-13·0 | 10·1 | 1·8 | 8·0-15·0 | 11·4 | 1·9 | P <0·10 | 12·0-16·0 | 14·0 | 1·6 | P <0·01 | P <0·10 |
| | | | | | | *Subscapular Skinfold (mm)* | | | | | | |
| All ages .. | 4·0-12·4 | 6·9 | 1·4 | 5·0-11·8 | 8·2 | 1·5 | P <0·01 | 5·0-13·4 | 9·6 | 1·6 | P <0·01 | P <0·01 |
| 1 .. .. | 4·0- 9·2 | 6·6 | 1·2 | 5·6-10·0 | 8·1 | 1·1 | P <0·01 | 5·0-10·0 | 8·5 | 1·4 | P <0·01 | P >0·10 |
| 2 .. .. | 4·8-12·4 | 7·5 | 1·5 | 5·0-11·8 | 8·7 | 1·8 | P <0·01 | 7·4-13·4 | 10·0 | 1·7 | P <0·01 | P <0·01 |
| 3 .. .. | 4·0-10·2 | 6·5 | 1·2 | 5·0-10·0 | 7·8 | 1·4 | P <0·01 | 7·6-11·0 | 9·2 | 1·3 | P <0·01 | P <0·05 |
| 4 .. .. | 4·4- 9·6 | 6·8 | 1·3 | 5·0-10·0 | 7·4 | 1·4 | P >0·10 | 9·0-11·6 | 10·4 | 1·1 | P <0·01 | P <0·01 |
| | | | | | | *Mid-arm Muscle Circumference (mm)* | | | | | | |
| All ages .. | 64·3-134·3 | 99·9 | 11·2 | 79·2-137·3 | 105·5 | 11·9 | P <0·01 | 93·6-144·8 | 113·4 | 11·6 | P <0·01 | P <0·01 |
| 1 .. .. | 64·3-106·8 | 88·4 | 8·2 | 85·5-118·6 | 97·6 | 8·5 | P <0·01 | 94·9-115·5 | 103·1 | 7·3 | P <0·01 | P <0·01 |
| 2 .. .. | 84·2-118·6 | 100·7 | 7·3 | 79·2-121·7 | 105·2 | 9·0 | P <0·05 | 93·6-134·2 | 112·7 | 9·3 | P <0·01 | P <0·01 |
| 3 .. .. | 86·7-125·5 | 106·1 | 7·9 | 91·0-127·4 | 112·1 | 9·7 | P <0·02 | 113·0-128·6 | 123·6 | 5·1 | P <0·10 | P <0·01 |
| 4 .. .. | 88·0-134·3 | 106·9 | 10·0 | 105·4-137·3 | 119·9 | 11·4 | P <0·01 | 126·0-144·8 | 134·4 | 7·8 | P <0·01 | P <0·10 |

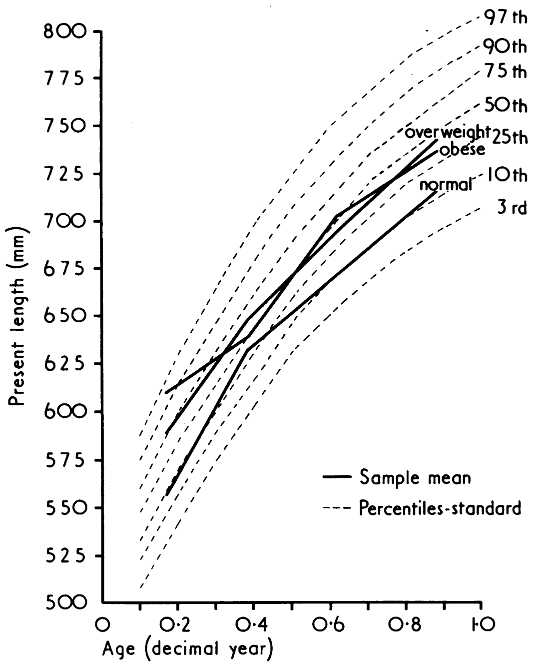


FIG. 6—Present supine length (boys).

infants in this survey of children in the West Midlands were smaller in stature than the expected norms. The differences between the means of the three groups were significant only in age group 1 between normal and overweight ($t$ = 4·42, D.F. = 75, P <0·10), normal and obese ($t$ = 5·61, D.F. = 55, P <0·01), and overweight and obese ($t$ = 1·77, D.F. = 40, P <0·05).

SUBCUTANEOUS FAT

The mean triceps skinfold values for the whole sample were 11·7 mm for the obese group, 10·7 mm for the overweight group, and 9·3 mm for the normal group (Table IX). Obese infants appeared to end up with much higher levels of fat by the end of one year, and the curve in Fig. 7 shows a distinct increasing trend, which specifically points towards the tendency for continued accumulation of adipose tissue. This appears to be responsible for the increase in body bulk determined by the weight for length ratio, which showed a smiliar trend in obese

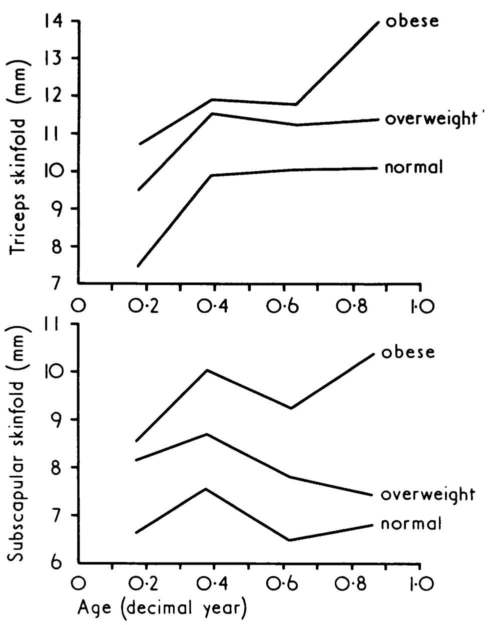


FIG. 7—Mean triceps and subscapular skinfold thicknesses (both sexes).

groups. The difference between all the groups was statistically significant for all infants aged up to a year for normal and overweight ($t$ = 51·6, D.F. = 248, P <0·01), normal and obese ($t$ = 7·83, D.F. = 215, P <0·01), and overweight and obese ($t$ = 3·07, D.F. = 131, P <0·01). The difference between the three groups was also statistically significant in all the age quarters, P ranging from <0·10 to <0·01 except in age groups 2 and 3 for overweight *v.* obese groups, where it was not significant at P >0·10.

The subscapular skinfold also followed the same pattern in the obese group (Fig. 7, Table IX). The curve for the overweight group tended to show a decreasing trend from age group 3 continuing in age group 4. Except for the overweight *v.* obese groups in age group 1 and the normal *v.* overweight groups in age group 4 the differences in all the groups were statistically significant.

Fat measurements showed strong correlations with all the anthropometric measurements in the range 0·84 to 0·98 except for length. They also correlated strongly with fat intake (0·99) and had good correlation with other nutrients (0·81) in the overweight and obese groups only.

Mean values in the obese and overweight groups were similar for boys and girls, indicating that fat measurements tend to be the same when infants have excessive weight. In the normal group, however, boys had slightly more fat than girls, which is to be expected owing to the natural sex differences in body dimensions. The difference between boys and girls, however, was not statistically significant at P >0·10.

MID-ARM MUSCLE CIRCUMFERENCE

The mean mid-arm muscle circumference was highest in the obese infants at all ages. Muscle growth was taking place much faster in the obese group than the sample normal and overweight groups with increase in age, as shown by a total increase of 31 mm in obese, 22 mm in overweight, and 18 mm in sample normal groups from age groups 1 to 4 (Table IX, Fig. 8). Boys had higher mean values in all the three groups than girls, which may explain the larger size of boys.

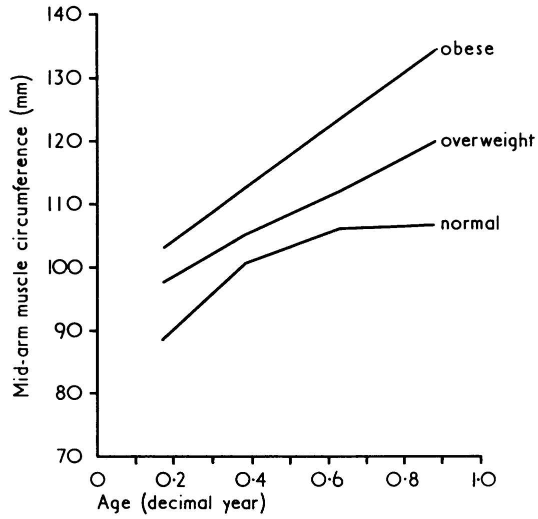


FIG. 8—Mean mid-arm muscle circumference (both sexes).

The differences in the means of the three groups were highly significant (P <0·01) in all infants (Table IX). Muscle circumference was significantly correlated to protein intake (1·0), and other correlations with nutrients and all the anthropometric measurements except length (0·54) were good—that is, in the range 0·68 to 0·98.

RELATION TO SIZE OF PARENTS

There was high correlation between the weight and height of the obese parents and obese (0·96) and overweight infants (0·74).

This suggests that hereditary influences were also related to excessive weight in the sample.

## Discussion

The results of this study indicate that overnutrition in the first 13 weeks of life leads to an increase in the level of the weight attained, which is maintained throughout the first year. Furthermore, of the group studied 50 infants (16·7%) were obese and a further 83 (27·7%) were overweight, which is similar to the 16·7% and 26·7% observed by Eid (1970). The total proportion of overweight plus obese infants in this study (44·3%) was also in accordance with that (44%) reported by Asher (1966). The incidence of excessive weight gain in 59·6% of young infants reported by Taitz (1971), however, was much higher than the total incidence of overweight and obese groups in this study. This difference appears to be due to differences in the nature of the sample and also to the fact that height was not taken into account; also the infants were not differentiated into overweight and obese groups in the Sheffield study.

A low incidence of breast-feeding with a corresponding greater dependence on bottle-feeding and early weaning appears to encourage overnutrition. The present concept of giving early solids may have originated from the idea that babies can digest most types of food shortly after birth (Sackett, 1956). The optimal age of weaning is disputed. Douglas (1950) suggested 6-9 months of age, Ellis (1947) 4-6 months, the Medical Research Council (1959) 5 months, and the American National Research Council Food and Nutrition Board (1964) 2-3 months. The recommended age of giving solids has thus successively declined. Since the 1950s the concept of weaning appears to have altered from a gradual change-over from breast-feeding to solid foods to the introduction of solid foods at an early age without appreciably reducing the milk intake.

This study appears to show a causal relation between nutrient intake and the high level of body weight as seen in the pattern of the weight for length curve. Any increase or decrease in the weight for length ratio is known to be directly related to the nutritional intake and was designated as the "nutritional index" by Paton and Findlay (1926). An increase in this ratio indicates accumulation of soft tissues which make up the body bulk. Although in the present study fat cell number and size was not investigated it is probable that cellular changes similar to those observed in animals by Knittle and Hirsch (1968) were initiated in the critical period of the first 13 weeks in the sample, which was specifically related to excessive calorie intake caused by early weaning. The high protein intake and the increase in muscle measurements suggests the possibility of similar multiplication of cells in the muscle tissue also.

Whether excessive dietary protein is harmful to babies is uncertain at present. The urine of breast-fed babies was reported by the mothers as colourless, which soon changed to light or dark yellow with a strong ammoniacal smell on bottle-feeding plus solids. There was a high incidence of napkin rash in the survey babies. Could these symptoms be related to the excretion of concentrated urine due to excessive protein metabolites? In what way will this affect the distribution of water and solutes in the infant's body? Can this be associated with the increased occurrence of hypernatraemic dehydration during infections or with urinary infections and enuresis later on? It appears that excessive protein consumption as shown in this study should be a greater cause for concern, especially in view of the findings in animals of speedy growth but shortened longevity on high protein intake (MacKeith and Wood, 1971). These problems require further investigation.

Studies are also needed to set up standards for fat and carbohydrate intake because the requirements for these are not known. MacKeith and Wood (1971) suggested 3-4 g/kg/day as the critical level, beyond which fat from cows' milk cannot be absorbed. Widdowson (1969) suggested that if fat intake is above the critical level less calcium will be absorbed as more cows' milk is given to the baby. The observed fat consumption of 5·7 g/kg/day in boys and 6·5 g/kg/day in girls in age group 1 was higher than the critical level, and this may explain the shorter supine length in age groups 2, 3, and 4. Further investigations are needed to study growth and composition of weight gain in relation to the nature of feeding and its long-term effects.

Relation of length with age in this study is interesting. The finding that obese babies end up shorter than overweight babies in age group 4 supports the observation in animals that overnutrition, while leading to increase in weight, is not necessarily associated with accelerated linear growth.

Reports concerning the relation between weight at birth and subsequent development of obesity are conflicting. Bauer (1929) found a higher birth weight in obese children, which was suggestive of a constitutional tendency towards overweight. Bruch (1939), however, thought that there was no difference between birth weights of obese children compared with normals. The sample studied by Wolff (1955) also did not show any difference between the birth weight of obese infants and standards. The results of the present study agree with Bauer's (1929) opinion, indicating the possibility of some constitutional influence in the obese and overweight groups in the sample which may be related to factors operating during the antenatal period.

Since the size of the parents was obtained verbally from the mother the measurements may not be accurate, but the results did show that 18·7% of the mothers and 8·4% of the fathers were obese. The high correlation between obese parents and obese and overweight infants (0·96 and 0·74), together with the finding of greater birth weight in these babies, indicates that such infants may be "at risk." It is quite possible that the obese and the overweight groups had a potential tendency to gain excessive weight, but if they had not been overfed the condition might have been prevented.

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# Significance of milk pH in Newborn Infants

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## Summary

**Bottle-fed infants do not gain weight as rapidly as breast-fed babies during the first week of life. This weight lag can be corrected by the addition of a small amount of alkali (sodium bicarbonate or trometamol) to the feeds. The alkali corrects the acidity of cow's milk which now assumes some of the properties of human breast milk. It has a bacteriostatic effect on specific *Escherichia coli* in vitro, and in infants it produces a stool with a preponderance of lactobacilli over *E. coli* organisms. When alkali is removed from the milk there is a decrease in the weight of an infant and the stools contain excessive numbers of *E. coli* bacteria.**

**A pH-corrected milk appears to be more physiological than unaltered cow's milk and may provide some protection against gastroenteritis in early life. Its bacteriostatic effect on specific *E. coli* may be of practical significance in feed preparations where terminal sterilization and refrigeration are not available. The study was conducted during the week after birth, and no conclusions are derived for older infants. The long-term effects of trometamol are unknown. No recommendation can be given for the addition of sodium bicarbonate to milks containing a higher content of sodium.**

## Introduction

Cow's milk differs from human milk in many respects. It has a high protein and phosphate content and produces a firm stool with a preponderance of *Escherichia coli* organisms. Breast milk, with its high lactose, low phosphate, and low protein load, produces a stool with a relatively low *E. coli* count (Bullen and Willis, 1971). In addition, it affords protection against gastroenteritis.

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A consistent difference has been noted in the weight patterns of normal full-term breast-fed and bottle-fed infants at Mowbray Maternity Hospital, Cape Town. Breast-fed babies regain birth weight a day earlier than bottle-fed infants despite their larger initial weight loss (Table I). The delayed weight gain in bottle-fed babies can be corrected or prevented by the addition of sodium bicarbonate to the milk. A pattern of delayed gain in weight has been described in premature infants who manifest late metabolic acidosis (Kilderberg, 1964). Sodium bicarbonate given by mouth produced a gain in weight as well as a correction of the acidosis. The full-term bottle-fed infants did not show signs of acidosis during the phase of growth lag. Nevertheless, they gained weight within 24 hours after the addition of alkali to feeds. Further investigations indicated that cow's milk was more acid than human breast milk.

This study was undertaken to determine the significance of these observations. It is concerned with the effects of a pH-corrected cow's milk on the early growth pattern of newborn infants and on the nature of their stool flora. The investigations were conducted on similar groups of breast-fed and bottle-fed babies.

## Material and Methods

*Breast Milk pH*.—The pH was measured daily for seven days on the colostrum and milk of 92 lactating mothers. Milk was expressed directly into a sterile test tube at a fixed time each day. This was done before a feed. In 10 cases a second sample was collected under anaerobic conditions in a capillary tube. The ends were immediately sealed with wax. The pH was measured within five minutes by the Astrup technique, using a capillary electrode (Radiometer G297/G2).

*Cow's Milk pH*.—Twenty-four milks of varying strengths and makes were reconstituted with water (pH 7·80) to a volume of 75 ml. They were then sterilized at 110°C at 15-lb (6·8-kg) pressure for 10 minutes and then refrigerated. Each feed was re-warmed to 38°C and the pH measurements were done in triplicate. These milks were prepared on five separate occasions for pH readings.

*Milk Titration*.—Titratable acidity was determined on all samples submitted for pH measurement. A 6-ml volume of

TABLE I—*Birth Weight and Percentage of Birth Weight of 50 Breast-fed and 50 Bottle-fed Full-term Infants. Mean ± S.D.*

| | Birth Weight (in grammes) | Days after birth (% of Birth Weight) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 3 | 4 | 5 | 6 | 7 | 8 |
| Human breast .. .. .. | 3,304 ± 352 | 97·3 ± 2·1 | 98·3 ± 2·5 | 99·3 ± 2·7 | 100·2 ± 3·0 | 101·5 ± 3·9 | — |
| Cow's milk .. .. .. | 3,345 ± 386 | 97·9 ± 2·2 | 98·5 ± 2·8 | 98·9 ± 3·2 | 99·3 ± 4·1 | 100·0 ± 4·5 | 100·9 ± 4·7 |