The effect of diet on weight gain in infancy

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ABSTRACT Data from a longitudinal survey of 92 mothers and their female infants supported the hypothesis that the method of feeding had an effect on weight gain. Nutritionists visited the homes monthly during the first 6 months after parturition and obtained both dietary and anthropometric information. The infants were grouped according to the method of feeding at 2 months. A two-factor experiment with repeated measures on one factor as the experimental design was used to test for the effects of diet on weight gain, length increment, and weight/length pattern. The difference between group mean weights adjusted for birthweight was significant with $0.05 < P < 0.1$. One difference was between infants fed formula and solids and infants fed breast milk and food supplements but not between infants fed breast milk or formula alone. No significant differences among the feeding groups were noted in length and weight/length, but there was a tendency for higher weight in relation to height in the infants fed formula and solids. Am J Clin Nutr 33: 2635–2642, 1980.

Taitz (1) has recently questioned the use of growth standards developed for infants using a sample that was fed predominantly formula or cow’s milk with the addition of solid foods. His assertion is based on the assumption that growth differences exist between the infant who is fed only breast milk and the infant who is fed primarily formula and solid food. He assumes that the formula-fed infant is overfed because he/she is persuaded to consume substantially more milk and solid foods, and thus calories, than are needed for normal growth. The breast-fed infant, on the other hand, is assumed to regulate his own intake, to work harder to get the food (2), and to consume a smaller amount of solids. Several studies support this hypothesis (1–7); others question it (8–10), and many studies attribute no effect on weight gain or absolute weight to the method of feeding (11–12).

Conflicting evidence may appear because there is no consistency as to what duration or intensity of breast-feeding classifies an infant as breastfed. Infants fed proprietary formula are often classified with infants fed whole or low fat cow’s milk. Additionally, quantitative dietary information is not often available to test the added effect of solid foods. Differences in weight at birth, sex (13), and ethnic group of the child also affect the velocity of weight gain and, therefore, could affect outcome if these factors are not accounted for.

The variability of weight gain patterns in infancy also favors serial rather than single point data.

The purpose of this study was to investigate longitudinally a small population of female infants to determine the effects of dietary intake on growth during the first 6 months. The present analysis is based on the relationship between method of feeding in the first 2 months on weight gain to 6 months.

Materials and methods

Subjects

Pregnant women were recruited primarily through western Massachusetts obstetricians. No attempt was made to select a random sample since the aim was to develop a stable population for long-term study. The mothers were primarily multiparous (61%), in their twenties (mean age = 26 ± 4 years) and well educated (mean years of schooling = 14.5 ± 2 years). The median income was $12,500 per year.

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Procedures

Two hundred twenty-five male and female subjects were recruited. Mothers (n = 92) and their female infants (n = 92) were visited monthly during the first 6 months after parturition. Each home visit was within 4 days of the child's monthly birthday. Male infants were visited on a different schedule and data on them will be published later.

Anthropometrics

Two investigators measured 97% of the children and a third investigator measured the remaining 3%. Crying or extreme activity of the babies made some measurements difficult. Three determinations of each measurement were obtained and an average value recorded.

Recumbent length was measured by a GRAFCO Infantometer Model no. 3867-1334. The mother or caretaker held the infant's head, with the neck extended, to one end of the measuring board. The investigator extended the leg as much as possible, placed the heel flat against the boards and recorded length in centimeters.

Body weight was measured on a Continetal Pediatric Scale Model no. 322 to the nearest 100 g, with the infant nude.

Dietary

No attempt was made during the course of the study to influence the infant's diet. Dietary information was obtained monthly by use of a detailed nutrition history (14) and a 3-day food intake record. The nutrients were calculated from USDA Handbook no. 8 (15) and information obtained from baby food manufacturers. Each parent also kept a record of the date of the introduction of new foods, infant's reactions to these foods, and any other changes made in the diet.

Experimental design

In experimental studies in which diet is controlled, clear-cut differences in feeding may be set into the protocol of the study. However, with a free-living population in which pediatric recommendations and maternal practices in infant feeding are not controlled, such clear-cut differentiation is difficult. This is especially true during the first 6 months of life, when the type of milk fed is subject to change and the introduction of solid foods may be accomplished at any age. However, the data indicated that the subjects could be divided into meaningful and distinct feeding groups at 2 months. The infants at this age had been essentially the same feeding since birth.

At 2 months, the four feeding groups of the female population were 1) those fed breast milk alone (n = 40); 2) those fed breast milk with food supplements, either formula, milk, or solids in excess of 50 kcal/day (n = 12); 3) those fed formula alone (n = 10); and 4) those fed formula and solid food in excess of 50 kcal/day (n = 20). Various grouping variables were checked including parental weight, maternal smoking during pregnancy, parity, and family income. The groups did not differ statistically in any of the variables analyzed. Relationships of feeding group to weight gain, length increment, and weight/length ratio were analyzed using a two-factor experiment with repeated measures on one factor (16). This design was chosen as it takes into account the longitudinal nature of the data. The design also allowed testing for differences between diet groups and for interactions over time. The design also provided options for adjusting for covariates. The Friedman's rank sums test was used to assess the consistency in the observed pattern of growth (17).

Results

Before analysis to test the effects of feeding was performed, the data were examined to see if this population followed a normal growth pattern. Because of the known skewness of most anthropometric data, goodness of fit tests were performed on all data using the Kolmogorov-Smirnov procedure (18).

Weight and length percentiles from birth to six months for the infants are presented in Tables 1 and 2. Comparisons of weight and length with the newly developed standards of the National Center for Health Statistics (NCHS) (19) are presented elsewhere (20).

Shifting of percentile position

Infants were placed according to their weight in percentile ranges of < 10th; 10th to 25th; 25th to 50th; 50th to 75th; 75th to 90th, and > 90th. Using cross-tabulations, it was found that only 22% of the infants did not change percentile ranking for weight in the first 6 months. By far the most frequent change of percentiles was noted from birth to 1 month, when 78% of the infants changed percentiles. From 1 to 2 months, 58% of the infants changed percentiles. From 2 to 3 months, the percentage increased slightly to 62% and from 3 to 4 months, the percentage was 59%. From 4 to 5 months and from 5 to 6 months, the percentage change stabilized at 52%. There was no consistent trend, either upward or downward in the shifting of percentiles. Individual children followed different patterns.

Age at doubling of birth weight

Thirty subjects (33% of the population) did not double birth weight by age 6 months. Of these 30, 21 (70%) were breastfed and the remaining nine formula-fed after discharge from the hospital. Only three subjects doubled birth weight by 3 months of age. These three each weighed less than 3.00 kg at birth and all were started on commercial formula but changed to cow's milk.
TABLE 1
Percentiles for weight (kg) for female infants, age 0 to 6 months

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TABLE 2
Percentiles for length (cm) for female infants, age 0 to 6 months

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Weight patterns of infants obese at birth

From the literature, one might conclude that the use of weight alone as an index of obesity has the highest validity in infancy because at this age, weight and length are not independent factors. However, weight alone as an index may tend to underestimate the true incidence of obesity in infants (21). At birth, 16 of the 92 infants (17%) had weights which exceeded the 95th percentile of the NCHS standard, a level which Garn and Clark (22) define as "super obese." At 1 month, six of these infants were still above the 95th percentile. By 6 months, six (37%) of the original 16 heavy infants were between the 25th and 50th percentiles; three (19%) between the 50th and 75th percentiles; four (25%) between the 75th and 90th percentiles; two (13%) between the 90th and 95th percentiles; and only one infant remained above the 95th percentile. Twelve of these infants were breast-fed for at least 2 months and four were formula-fed from birth. These numbers are too small for comparison of the effects of breast or bottle feeding on the changes in weight percentile position. The one infant who was above the 95th percentile both at birth and 6 months was fed formula.

Feeding group analysis

The four feeding groups used for analysis have been outlined in "Materials and methods". Mean birth weights did not differ significantly from group to group (F = 0.39, df = 3.90, P = 0.76), and therefore, should not affect the validity of the grouping variable. Maximum difference in birth weight means was 0.14 kg. Infants who were breast-fed (group 1) had a mean birth weight of 3.45 ± 0.41 kg. Infants who were breast-fed with food supplements (group 2) had a mean birth weight of 3.44 ± 0.59 kg. Infants who were given only formula (group 3) had a mean birth weight of 3.31 ± 0.38 kg. Infants who were given formula and solid food (group 4) had a mean birth weight of 3.38 ± 0.35 kg.

Differences in weight gains of feeding groups at 2 months

The analysis of absolute weight at each month showed a significant difference at the
0.10 level but not the 0.05 level among the group means adjusted for birth weight ($F = 2.37, \text{df} = 3.71, P = 0.081$). Birth weight was an important covariate, its slope being significant ($p < 0.001$). In all diet groups, a significant month-to-month interaction between means adjusted for birth weight was also noted. This was expected since this interaction is an indication of growth or month-to-month change in values ($P < 0.001$). Six infants had a missing weight during the 6-month period, and rather than estimate the mission values they were excluded from the analysis.

Since the difference in the group means adjusted for birth weight was significant, possible sources of significance were determined by using multiple comparison procedures based on Duncan's multiple range test (16). Using the Duncan procedure a significant difference between group 4 (formula and solid food) and group 2 (breast milk with food supplements) was noted. Group 1 (breast milk alone) and group 3 (formula

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**FIG. 1.** Adjusted mean weight gain since birth of four feeding groups classified at 2 months.
alone) were not significantly different from groups 4 or 2. The Friedman's ranks sums test procedure was used to assess the consistency of the rankings of the four group means at each month. This consistency is easily noted by the fact that the polygons for each group in Figure 1 are parallel for the most part, i.e., that infants fed formula and solids were consistently heavier than infants fed in any other manner. The results were significant with the following order observed: mean weight group 4 > mean weight group 3 > mean weight group 1 > mean weight group 2.

Similar analyses were performed on measurements of length and weight/length$^2$ (Fig. 2). In both, birth weight was used as a covariate and in none was a significant difference among groups noted. In all, strong linear trends were noted, and as expected, a significant month-to-month interaction, an indication of growth, was noted.

Although no significant differences emerged from the length and weight/length$^2$ analyses, interesting patterns did develop. Adjusted groups means for length for all groups were almost identical ($F = 0.47, \text{df} = 3.71, P = 0.71$). In fact, the plotting of the adjusted length means was so overlapping that there appeared to be only one line. How-
ever, since the weights of the groups differed, the data showed a tendency for higher weight in relation to length among the infants in the group fed formula and solids. When length is coupled with weight as in weight/length² (F = 1.46, df = 3.71, P = 0.23). Indeed, the graph of the weight/length² ratio (Fig. 2) clearly shows that the values were higher for the group fed formula and solids. Although the distance between the lines was not statistically significant, the Friedman test shows that this consistency is statistically significant.

Discussion

Comparison with published growth standards

The subjects of this study demonstrated growth patterns comparable to those used as national reference standards (19). Both the NCHS standards and the Stuart Meredith Standards (24) assume a doubling of birth weight at approximately 5 months. This is later than the 3.8 months noted by Neumann and Alpaugh (6) in California.

Birth weight doubling is largely controlled by size at birth—the smaller the infant, the faster the weight gain; the larger the infant, the slower the weight gain. Indeed, the recent work of Holmes et al. (25) has further distinguished between those infants who are merely underweight for length and those infants who are innately small. These small infants have no leeway and must increase weight rapidly whereas the larger infants have flexibility in choosing their developmental pattern. Such a weight gain pattern was observed in infants in the present study. Those infants who were small at birth (under 3.00 kg) gained weight more rapidly. Weight gain of most of the heaviest infants was less rapid and their percentile positions for weight were lower at 6 months. The fact that over 75% of these large infants were breast-fed may have been a factor in regulating their own appetites. Certainly the potential for infantile obesity was present in this population because of the high percentage (17%) of heavy babies at birth.

Effect of the method of feeding on growth rate and pattern

Weight is generally thought to be the best measure of nutritional intake in the immediate past because of its potential to change quickly (26), whereas body skeletal measures such as height and head circumference are thought to be a better measure of past nutritional experience because they do not respond as quickly to a calorie deficiency as does weight (27). In the present study, where significant relationships among repeated measurements were found, the greatest change in weight percentile was noted from the 1st to the 2nd month for the two feeding groups where significant differences were noted. We do not know whether this change is the result of fetal or postnatal nutrition.

Since we cannot identify the actual time lag between nutritional intake and growth effects, we must examine these data circumspectly. When the weight gain values for the two feeding groups that were significantly different were compared with the NCHS percentiles (19), adjusted means for both groups started between the 50th and 75th percentiles, but then the groups took divergent paths as shown in Figure 3. The group fed formula and solids stayed within the channel, whereas by 3 months the group breast-fed with food supplements has lost position and their mean was between the 25th and 50th NCHS percentiles. Fomon (28) warned that the addition of solids to the diet of the breast-fed infant may reduce the percentage contribution of protein to total calories to undesirable levels, which may affect the growth rate. An alternative explanation may be that lactating mothers introduce supplementary feeding when the volume of breast milk is inadequate. In the present study, the patterns of weight gain demonstrated by these feeding groups were different. The observation that infants who were fed either formula or breast milk without the addition of solid foods for the first 2 months had similar weight gains implies that the solid food addition may be affecting weight gain.

There were no significant differences in the lengths of infants in these feeding groups. However, since the weights of the groups differed, there was a tendency for higher weight in relation to length among the infants in the group fed formula and solids, as shown in the graph of the weight/length² ratio (Fig. 2). Since this anthropometric index is not totally appropriate for infants, further work is needed to develop indices that can more accurately define overweight in infants.

From these data, it appears that infants
who were fed formula with solids added before 2 months of age, gained weight significantly faster than infants fed breast milk with the addition of solids. Their gain was also faster (but not significantly) than that of infants fed either formula or breast milk without added solid foods. Weight gains of infants fed either breast milk or formula without added solids for the first 2 months did not differ.

**Summary and conclusions**

The method of feeding had an effect on weight gain in 92 female infants followed from birth to 6 months in western Massachusetts. The weight and length percentiles of these infants were comparable to accepted United States standards.

When the data for the 2-month feeding groups were analyzed (the two-factor experiment with repeated measures on one factor) using absolute weight of each infant at each month, a significant difference was found between the 0.10 level and 0.05 level among the group means for weight adjusted for birth weight. Infants fed formula and solids weighed significantly more than those infants fed breast milk and food supplements.

Although no significant differences among the feeding groups were noted in length and weight/length, there was a tendency for higher weight in relation to height in the infants fed formula and solids. The Friedman test confirmed this.

These data support the theory that early introduction of solid foods may affect weight gain in infancy. The data do not support the hypothesis of differences in weight gain between breast- and formula-fed infants during the first 6 months.

**References**


