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Growth and Adiposity of Term Infants Fed Whey-Predominant or Casein-Predominant Formulas or Human Milk

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Summary: Growth, estimated composition of weight gained, and stool patterns of term infants who were fed either a whey-predominant formula or a casein-predominant formula in a random design and of breast-fed infants were compared. All infants (N = 111) were healthy, singleton products of uncomplicated pregnancies. Birth weights and other anthropometric measures in the first few days of life were not different among the three feeding groups. Formula or breast milk was the infants' principal source of energy from birth to age 16 weeks. Average energy intakes of formula-fed infants and change of intakes with age were similar in both groups at all ages. Feeding groups were not significantly different at any age in weight, length, weight or length gain, head circumference, skinfold measurements, upper arm fat area and muscle area, or estimated total body fat. Stools of infants on the whey-predominant formula differed from both the breast-fed and casein-predominant formula groups. Key Words: Growth—Adiposity—Term infant formulas—Breast fed.

If term infants are not breast-fed, they are usually fed one of several commercially available milk-based infant formulas. Breast-feeding confers nutritional, immunologic, antiinfective, endocrinologic, and emotional advantages (1). Although the nutritional advantages of human milk are not completely understood, human milk is considered the ideal food for full-term infants (2). Consequently, it has been suggested that infant formulas be formulated to reflect the composition of human milk as closely as possible (3).

Cow's milk is the protein source of the milk-based formulas. Formulas containing predominantly whey proteins from cow's milk have been developed in an attempt to mimic the whey protein-to-casein ratio of human milk. Whey proteins from cow's milk, however, differ significantly from whey proteins from human milk (4). Two types of data have shown that whey proteins from cow's milk may not be better for infants than casein. First, a recent study by Janas et al. (5) indicated that indices of protein metabolism of infants fed a whey-predominant formula were no more like those of breast-fed infants than were indices of infants fed a casein-predominant formula. In addition, common measures of growth of infants fed either type of formula were found in several studies to be similar to those of breast-fed infants (3,5,6).

Composition of weight attained during growth of infants fed the two types of formulas or breast fed, however, has not been investigated. Some studies indicate that infants fed formula may have a different pattern of growth than infants who are breast fed. Findings comparing growth of breast-fed and formula-fed infants are conflicting. Some studies show similar growth between breast-fed and formula-fed infants, whereas others suggest formula-fed infants may gain more weight than breast-fed infants (7–9). Whitehead and Paul (10), however, observed that breast-fed infants from birth to 3

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months of age grow more rapidly than growth standard rates that are based on formula-fed infants. Persson (11) also found that Swedish infants who were entirely breast fed had greater weight and length velocities to 3 months of age than infants who were formula fed. Breast-fed infants were shown in one study to have greater skinfold thickness and thus were fatter than formula-fed infants (12), whereas in another study the formula-fed infants had greater skinfold thickness (13). Differences in formula composition, differences in socioeconomic and birth characteristics of the infants, and other factors may account for the discrepancies in growth observed.

The purpose of this 16-week study was to compare growth and composition of growth of normal term infants who were exclusively breast fed or fed one of two formulas that differed primarily in whey protein-to-casein ratio. Intake of formula-fed infants and stool patterns of all infants were also evaluated.

MATERIALS AND METHODS

Design

For the formula-fed infants, the study was a blind, randomized design. Breast-fed infants were recruited throughout the study at a rate consistent with enrollment in the formula regimens. All infants were fed ad libitum. The three feeding regimens were "pure feeding groups" in the sense that the infants were either exclusively breast fed or bottle fed for the first 4 months of life. A subject was disqualified from the study if any significant source of calories other than breast milk or formula became part of the diet (>10% of total calories for >3 consecutive days). Measurements were taken 1–3 days after birth and at 2, 4, 8, 12, and 16 weeks of age.

Subjects

One hundred thirty-eight infants were enrolled. Data sufficient for analysis were obtained on 111 of these infants. Enrollment criteria were singleton birth; gestational age between 38 and 42 weeks as determined by Dubowitz et al. (14) score; birth weight >10th and < 90th percentile for gestational age in relation to local reference data given by Vaucher et al. (15); Apgar score of 7 or greater at 1 min and 8 or greater at 5 min; and apparent good health with no evidence of systemic disease. Entrance criteria also required that both parents be Anglo-American or Mexican-American, that the mother have no evidence of significant disease, and that the mother agree to exclusively breast feed or formula feed during the study period. The reasons for excluding 27 of the infants originally enrolled were failure to return to clinic for at least two of the testing periods (16 infants); excessive solid food intake (four infants); feeding changed by parent (two infants); illness not formula related (three infants); constipation (one infant), and breast-fed infant mother receiving medication (one infant). Later attrition of infants from the study was due mostly to mothers discontinuing breast feeding, missed visits, or failure to record dietary data. Three infants were removed because of reported allergic reaction to their feedings; one fed Formula A and two fed Formula B. Only the infant fed Formula A was confirmed to be allergic to the feeding.

The mothers were recruited from three prenatal clinics having similar economic and ethnic populations affiliated with the University of Arizona. All infants were delivered at the University of Arizona Medical Center. Informed consent was obtained from parents of each infant prior to enrollment into the study. The study was reviewed and approved by the institutional review board of the University of Arizona Health Science Center.

Feeding Regimens

The three feeding regimens were as follows: (a) Formula A: Similac With Whey + Iron 20 (60:40 whey protein-to-casein ratio), (b) Formula B: Similac 20 With Iron (whey-to-casein ratio of 18:82), and (c) human milk (breast feeding). The formulas were provided in ready-to-feed form. Mother's record of formula intake was an estimate of the volume consumed from the nursing bottle. There were 34, 36, and 41 infants, respectively, in the three feeding regimens with an approximately equal number of boys and girls in each group. The composition of formulas is shown in Table 1. Calcium and phosphorus concentrations in Formula A were lower than in Formula B. Concentrations of other nutrients were similar in the two formulas.

Growth Measurements

Birth weight was obtained from nursery admission records. At age 24 to 72 h and at each follow-

TABLE 1. *Composition of Formula A and Formula B*

	Formula A	Formula B
Protein (g/dl)	1.64	1.60
Whey-to-casein ratio	60:40	18:82
Fat (g/dl)	3.60	3.64
Source		
Soy oil (%)	60	60
Coconut oil (%)	40	40
Carbohydrate (g/dl)	7.16	7.23
Source: lactose		
Energy (kcal/dl)	67.6	68.1
Calcium (mg/dl)	511	590
Phosphorus (mg/dl)	326	432
Sodium (mEq/dl)	1.0	1.1
Potassium (mEq/dl)	1.8	2.0
Chloride (mEq/dl)	1.2	1.2
Iron (mg/dl)	1.4	1.3
Zinc (mg/dl)	0.59	0.50
Magnesium (mg/dl)	5.3	5.7
Manganese (μg/dl)	3.4	3.4
Copper (μg/dl)	80	90
Iodine (μg/dl)	10	10

Vitamins similar in both formulas and at concentrations within ranges mandated by the Infant Formula Act of 1980. Publ. Law 96–359.

up visit (2, 4, 8, 12, and 16 weeks of age), anthropometric measurements were made. All follow-up visits occurred within 3 days of the scheduled date. The measurements made were weight; supine length; circumferences of head and upper arm; and fat folds at the triceps, biceps, periumbilical, and subscapular sites. All limb and subscapular measurements were made on both sides. A Detecto beam balance was used for weighing. The balance was regularly calibrated and accurate to ± 10 g. Infant measuring boards, Fiberglas tapes, and Lange skinfold calipers were used for the anthropometric measurements. Standard procedures for quality control were observed (16).

Several outcome measures were calculated, including gains of weight, length, and head circumference; sum of eight skinfolds; midarm nonfat and fat area by an equation modified from Gurney and Jelliffe (17); and total body fat by the equation of Dauncey et al. (18). Growth data were plotted on appropriate growth charts.

Intake and Stool Records

Energy intake for the formula-fed infants was calculated from dietary records kept by the mothers on 3 randomly selected days between each visit (15 days total). A computer program was used to select the random recording days. Stool patterns were recorded on the same days as dietary records and included predominant stool color (yellow, green, brown, black, or mixed), consistency (watery, slimy, soft, formed, hard), and number. Incidence of vomiting or spitting up was noted on the dietary record. Illness history was collected by interview at each visit. Records were kept in English or Spanish depending on mother's preference.

Statistical Treatment

To assess the initial homogeneity of the feeding groups, data collected at birth were compared using one-way analysis of variance. Serial growth, estimated fat and nonfat area of the arm, and total body fat and energy intake data were analyzed by repeated measures analysis of variance. The analysis considered feeding regimen, sex, and time over which measurements of each infant were taken. Chi-square statistics were used in comparing the relative frequencies of the predominant stool color and consistency.

RESULTS

Growth and Adiposity

Mean weights of male and female infants in each feeding group did not differ and were between the 25th and 75th percentiles of National Center for Health Statistics (NCHS) growth standards at every age (Fig. 1) (19). Daily weight gains, in grams, also were not different among the groups between any of the six measurement periods (Table 2). Boys, regardless of feeding group, weighed significantly more than girls at 4 weeks of age and at subsequent testing periods.

Mean lengths remained at their respective NCHS percentiles during the study period. Length gain (mm/day) was greater for boys than girls between age 2 and 4, 8 and 12, and 12 and 16 weeks (Table 3). Between 8 and 12 weeks, infants fed Formula A gained more length than breast-fed infants ($p < 0.05$), and boys gained more length than girls in this feeding group. Between 12 and 16 weeks, infants fed Formula B showed a significantly greater length gain than infants fed Formula A ($p < 0.05$).

Mean weight-for-lengths were similar among the feeding groups (Table 4). There were infants <10th and >90th percentile of NCHS curves in all three feeding groups. Mean head circumferences were

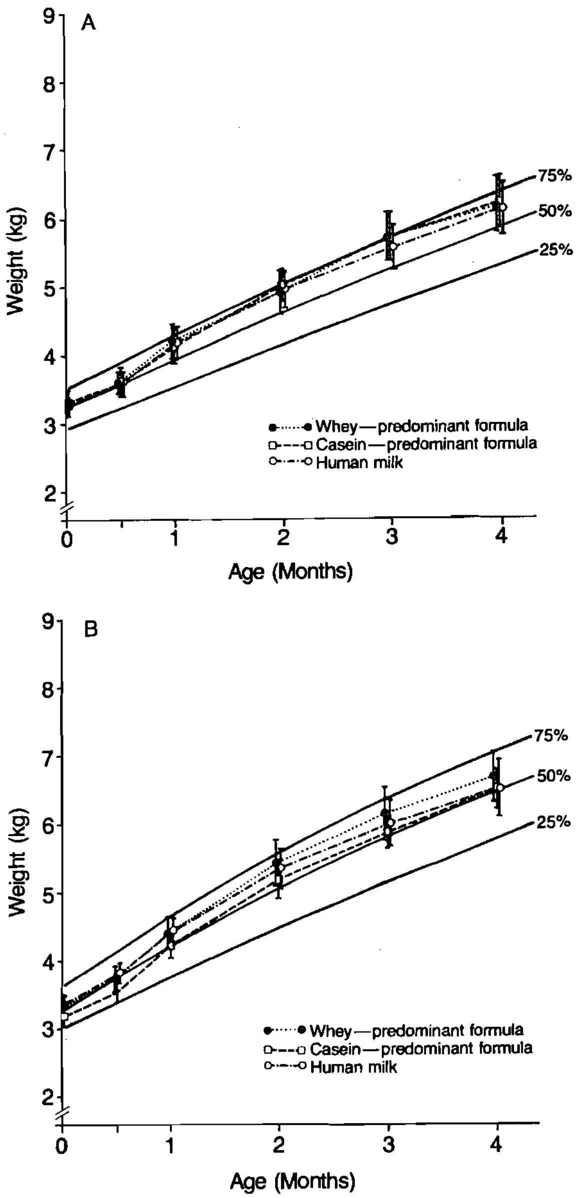

FIG. 1. A: Mean (±SEM) weights, girls. **B:** Mean (±SEM) weights, boys.

not different among the feeding groups at birth and were ≥50th percentile of the NCHS head circumference curve over the study period (Tables 5 and 6). Boys, regardless of their feeding, had significantly greater mean head circumferences than girls at all testing periods ($p < 0.01$). Head circumference gains were not different among the feeding groups or between boys or girls, except between 8

TABLE 2. *Daily weight gain (g) by age, sex, and feeding*

	Male: feeding group			Female: feeding group		
Interval (weeks)	A	B	HM	A	B	HM
1–3 days to 2 weeks						
Mean	30.9	22.6	33.4	26.4	22.0	24.4
SEM	3.5	3.9	3.1	2.8	3.1	3.5
N	15	19	23	17	15	17
2–4						
Mean	43.4	50.2	43.4	42.2	40.3	39.6
SEM	3.7	5.2	1.8	5.4	4.0	3.9
N	15	18	21	16	14	16
4–8						
Mean	37.4	34.6	30.4	24.5	30.4	30.5
SEM	3.7	3.0	2.0	2.9	2.4	2.9
N	14	17	16	15	14	14
8–12						
Mean	26.6	27.0	20.9	24.9	24.1	22.6
SEM	2.8	3.1	2.1	2.8	2.9	2.0
N	14	16	16	13	15	13
12–16						
Mean	24.1	21.5	19.1	20.1	18.8	20.2
SEM	3.3	2.6	2.4	2.1	1.5	2.4
N	14	16	16	13	15	14

A, whey-predominant formula; B, casein-predominant formula; HM, breast feeding.

TABLE 3. *Daily length gain (mm) by age, sex, and feeding*

	Male: feeding group			Female: feeding group		
Interval (weeks)	A	B	HM	A	B	HM
1–3 days to 2 weeks						
Mean	1.2	0.9	1.4	1.2	1.6	1.4
SEM	0.2	0.2	0.2	0.2	0.2	0.2
N	15	20	21	17	15	17
2–4						
Mean	1.5	1.4	1.6	1.2	1.2	1.2
SEM	0.2	0.1	0.2	0.2	0.2	0.2
N	15	19	18	16	14	16
4–8						
Mean	1.1	1.2	1.1	1.1	1.1	1.2
SEM	0.1	0.1	0.1	0.1	0.1	0.1
N	14	17	14	15	14	14
8–12						
Mean	1.4	1.0	0.9	1.0	1.0	0.8
SEM	0.1	0.1	0.1	0.1	0.1	0.1
N	14	16	14	14	15	14
12–16						
Mean	0.6	0.9	0.9	0.8	1.1	1.0
SEM	0.1	0.1	0.1	0.1	0.1	0.1
N	14	16	14	14	15	14

A, whey-predominant formula; B, casein-predominant formula; HM, breast feeding.

Males in all feeding groups gained significantly more length than females between 2 and 4, 8 and 12, 12 and 16 weeks ($p < 0.05$). Formula A group gained significantly more length than breast-fed infants between 8 and 12 weeks ($p < 0.05$). Formula B group gained more length than Formula A group between 12 and 16 weeks ($p < 0.05$).

TABLE 4. *Weight for length (g/cm) by age, sex, and feeding*

	Male: feeding group			Female: feeding group		
Age (weeks)	A	B	HM	A	B	HM
1–3 days						
Mean	66.1	62.7	66.4	65.1	66.3	65.3
SEM	1.3	1.3	0.9	1.1	1.2	1.0
N	15	21	23	19	15	18
2						
Mean	71.8	68.0	72.3	69.8	69.3	69.3
SEM	1.5	1.4	1.4	1.4	1.5	1.4
N	15	19	19	17	15	17
4						
Mean	81.1	78.3	80.7	78.7	77.1	78.0
SEM	1.7	1.5	1.6	1.9	1.9	1.8
N	15	19	20	17	14	17
8						
Mean	94.4	90.6	92.3	87.0	88.3	86.7
SEM	2.5	2.1	2.0	2.6	1.6	1.8
N	14	17	26	15	15	14
12						
Mean	100.2	98.0	98.6	96.4	95.9	93.5
SEM	2.9	1.5	2.4	2.2	2.3	2.2
N	14	16	26	13	15	13
16						
Mean	108.5	103.9	103.1	100.3	99.6	98.5
SEM	3.3	2.0	2.8	2.5	2.5	2.5
N	14	16	16	15	15	14

A, whey-predominant formula; B, casein-predominant formula; HM, breast feeding.
No significant differences between groups or between sexes.

TABLE 5. *Head circumference (cm) by age, sex, and feeding*

	Male: feeding group			Female: feeding group		
Age (weeks)	A	B	HM	A	B	HM
1–3 days						
Mean	34.6	34.9	34.9	34.4	34.3	34.2
SEM	0.2	0.2	0.2	0.2	0.3	0.2
N	15	21	21	19	15	18
2						
Mean	35.8	36.1	36.3	35.7	35.4	35.6
SEM	0.2	0.2	0.2	0.2	0.3	0.2
N	15	20	21	17	15	17
4						
Mean	37.3	37.3	37.5	37.0	36.7	36.7
SEM	0.3	0.3	0.2	0.2	0.4	0.2
N	15	19	19	17	14	17
8						
Mean	39.0	39.2	39.3	38.8	38.5	38.2
SEM	0.3	0.4	0.3	0.3	0.3	0.3
N	14	17	15	15	15	14
12						
Mean	40.6	40.4	40.4	39.9	39.7	39.4
SEM	0.3	0.2	0.2	0.2	0.4	0.3
N	15	16	14	14	15	13
16						
Mean	41.5	41.7	41.4	40.8	40.9	40.4
SEM	0.2	0.2	0.2	0.3	0.4	0.3
N	14	16	14	15	15	14

A, whey-predominant formula; B, casein-predominant formula; HM, breast feeding.
Boys had significantly greater head circumferences than girls at each time point. No significant differences between feeding groups.

and 12 weeks, when boys fed Formula A had greater head circumference gain than girls.

Sum of the eight skinfolds (Table 7) was not significantly different among feeding regimens or between male and female infants. In all groups the mean sum of skinfolds increased over time. Percent fat area of arm (Table 8) was not significantly different among the feeding groups except at 16 weeks, at which time girls fed Formula B had significantly greater ($p < 0.05$) arm fat area than girls fed Formula A. Arm muscle area was also not different among the feeding groups (Table 9). Mean percent total body fat was not different between feeding groups at any testing period (Table 10). However, the degree of adiposity was highly variable among infants, with as much as a fivefold difference in estimated total body fat within a feeding group. Estimated percent total body fat ranged from 3 to 16% shortly after birth to 11 to 38% at 16 weeks among all feeding groups. In all feeding groups mean body fat increased ~12% over the study period.

Energy Intake

Neither the mean number of feedings per day nor the volume of feedings per day was different among the two formula groups, ranging between six and eight feedings daily.

Total energy intake from all sources was almost identical to energy intake from formula, suggesting that the feeding regimens were indeed "pure feeding groups" in the sense that the infants received very little or no supplemental food. Daily energy intakes (kcal/kg/day) were not different between the formula groups at any measurement interval (Table 11). There were no significant differences in volume of formula or energy intake between boys and girls. Intake of breast-fed infants was not measured.

Intolerance, Spitting Up, and Stool Patterns

Three infants (one fed Formula A and two fed Formula B) were considered treatment failures due

TABLE 6. *Daily head circumference gain (cm) by age, sex, and feeding*

	Male: feeding group			Female: feeding group		
Interval (weeks)	A	B	HM	A	B	HM
1–3 days to 2 weeks						
Mean	0.9	1.0	1.1	1.0	0.9	1.0
SEM	0.2	0.1	0.1	0.1	0.1	0.1
N	15	20	21	17	15	17
2–4						
Mean	1.0	0.8	0.9	0.9	1.0	0.7
SEM	0.2	0.1	0.1	0.1	0.1	0.1
N	15	19	19	16	14	16
4–8						
Mean	0.6	0.7	0.6	0.6	0.6	0.5
SEM	0.1	0.1	0.1	0.0	0.1	0.0
N	14	17	15	15	14	14
8–12						
Mean	0.6	0.5	0.4	0.3	0.4	0.5
SEM	0.1	0.0	0.0	0.0	0.1	0.0
N	14	16	14	14	15	13
12–16						
Mean	0.3	0.4	0.4	0.3	0.4	0.3
SEM	0.1	0.0	0.1	0.0	0.0	0.0
N	14	16	14	14	15	14

A, whey-predominant formula; B, casein-predominant formula; HM, breast feeding.

No significant differences between feeding groups.

TABLE 8. *Percent fat arm area by age, sex, and feeding*

	Male: feeding group			Female: feeding group		
Age (weeks)	A	B	HM	A	B	HM
1–3 days						
Mean	16.8	16.9	17.5	16.3	16.7	16.9
SEM	0.8	0.7	0.5	0.6	1.0	0.5
N	15	21	23	19	15	18
2						
Mean	20.3	21.0	22.6	21.2	20.6	21.1
SEM	0.6	0.8	0.8	1.1	0.9	0.7
N	15	20	21	17	15	17
4						
Mean	26.6	24.6	25.0	24.3	25.5	23.4
SEM	1.3	1.2	1.1	1.5	1.0	0.7
N	15	19	19	17	14	17
8						
Mean	28.2	26.6	26.7	25.5	27.5	26.6
SEM	1.4	1.2	1.5	1.3	1.2	0.7
N	14	17	15	15	15	14
12						
Mean	28.9	26.4	27.2	27.4	28.2	26.3
SEM	1.4	0.9	0.9	1.4	1.3	0.8
N	14	16	14	14	15	13
16						
Mean	27.3	26.2	26.9	24.0	29.0	25.9
SEM	1.6	1.0	1.6	0.8	1.5	0.8
N	14	16	14	15	15	14

A, whey-predominant formula; B, casein-predominant formula; HM, breast feeding.

Girls fed Formula B had significantly greater percent fat arm area than girls fed Formula A at 16 weeks, $p < 0.05$.

TABLE 7. *Sum of eight skin folds (mm) by age, sex, and feeding*

	Male: feeding group			Female: feeding group		
Age (weeks)	A	B	HM	A	B	HM
1–3 days						
Mean	26.5	26.0	27.7	26.3	26.6	27.6
SEM	1.2	1.1	1.2	1.2	1.1	0.9
N	15	21	23	19	15	18
2						
Mean	35.3	35.2	36.6	38.5	36.8	36.4
SEM	1.1	1.7	1.7	1.1	1.7	1.6
N	15	20	22	17	15	17
8						
Mean	52.9	50.4	50.3	49.1	49.1	47.5
SEM	2.6	3.0	2.7	2.9	2.1	1.6
N	14	17	16	15	14	14
12						
Mean	57.9	53.0	53.1	55.0	56.0	50.2
SEM	2.7	2.7	3.6	3.4	3.9	2.2
N	14	16	16	14	15	13
16						
Mean	60.6	58.9	53.3	54.8	60.1	54.4
SEM	3.4	2.7	2.9	3.4	3.7	2.4
N	14	16	16	15	15	14

A, whey-predominant formula; B, casein-predominant formula; HM, breast feeding.

to adverse gastrointestinal symptoms that were assumed to be formula-related by the child's physician. In only one case (Formula A) was the relationship confirmed by a challenge with the formula. Thus, the incidence of intolerance did not differ among groups. Spit-up and vomiting incidents were not significanly different among feeding groups.

Stools of infants fed the whey-predominant Formula A differed noticeably from both the breast-fed and casein-predominant formula groups. Green was the predominant stool color throughout the study of infants fed Formula A. Most infants fed Formula B initially passed yellow stools with an increase in infants passing green stools at subsequent periods. Stools of most breast-fed infants were yellow throughout the study. Stool consistency was significantly different between the breast-fed and all formula-fed infants at 4 and 8 weeks only. Consistency of stools from most formula-fed subjects was rated by the mothers as "soft," whereas the stools of most breast-fed infants were rated "slimy" or "watery."

TABLE 9. *Nonfat arm area (cm²) by age, sex, and feeding*

	Male: feeding group			Female: feeding group		
Age (weeks)	A	B	HM	A	B	HM
1–3 days						
Mean	7.9	7.2	8.0	7.7	8.1	8.0
SEM	0.3	0.2	0.3	0.2	0.4	0.3
N	15	21	23	19	15	18
2						
Mean	8.3	7.6	8.0	8.1	8.2	7.9
SEM	0.3	0.3	0.3	0.3	0.4	0.3
N	15	20	23	17	15	17
4						
Mean	8.6	7.8	8.3	8.2	7.5	8.3
SEM	0.5	0.3	0.2	0.3	0.4	0.4
N	15	19	21	17	14	17
8						
Mean	9.7	9.3	9.8	9.0	8.8	8.5
SEM	0.5	0.4	0.3	0.4	0.4	0.2
N	14	17	16	15	15	14
12						
Mean	10.8	10.4	10.3	10.0	9.6	9.6
SEM	0.5	0.3	0.4	0.4	0.4	0.3
N	14	16	16	14	15	13
16						
Mean	12.8	12.0	11.4	11.7	10.7	11.2
SEM	0.6	0.5	0.7	0.5	0.4	0.5
N	14	16	16	15	15	15

A, whey-predominant formula; B, casein-predominant formula; HM, breast feeding.
No significant differences between groups.

TABLE 10. *Body fat (%) by age, sex, and feeding*

	Male: feeding group			Female: feeding group		
Age (weeks)	A	B	HM	A	B	HM
1–3 days						
Mean	6.9	6.6	7.9	6.9	7.7	8.1
SEM	0.6	0.6	0.6	0.7	0.7	0.5
N	13	21	23	19	14	17
2						
Mean	11.6	12.3	12.7	13.8	13.2	12.7
SEM	0.7	0.9	1.0	0.6	1.0	0.8
N	15	19	19	17	15	17
4						
Mean	17.3	14.2	14.8	15.7	15.9	14.1
SEM	1.1	1.1	1.0	1.4	1.1	0.7
N	15	19	19	17	14	15
8						
Mean	18.8	17.8	18.0	16.9	18.7	16.5
SEM	1.2	1.2	1.4	1.5	1.6	0.9
N	14	17	16	15	15	14
12						
Mean	20.6	18.5	19.9	19.2	20.0	17.4
SEM	1.4	1.2	1.9	1.6	1.8	1.1
N	14	16	15	13	15	13
16						
Mean	21.0	21.4	19.1	18.6	22.5	19.3
SEM	1.7	1.1	1.4	1.6	1.7	1.0
N	14	16	14	15	15	14

A, whey-predominant formula; B, casein-predominant formula; HM, breast feeding.
No significant differences between groups.

DISCUSSION

We detected no important differences in the rate of growth of term infants fed casein-predominant Formula B, whey-predominant Formula A, or breast fed. Mean weight and length of each feeding group followed the 50th or greater percentile of NCHS growth curves.

Weight gain and mean length gain of our subjects were similar to those observed by Fomon et al. (7). These authors, however, observed that between 8 and 112 days breast-fed infants gained less in weight and length than formula-fed infants. Only between 8 and 12 weeks did breast-fed infants in our study show slower growth and this was in length only. Duncan et al. (20) found that breast-fed infants dropped in growth velocity at ~3 months when compared with NCHS curves. In our study, mean weight and length for age of breast-fed infants and of formula-fed infants did not drop relative to NCHS percentiles over the 4 months of the study.

Weight-for-length data suggest that there were

TABLE 11. *Daily formula intake (kcal/kg) by age, sex, and formula*

	Male: Formula		Female: Formula	
Interval (week)	A	B	A	B
0–2				
Mean	111	97	97	99
SEM	5	5	7	7
N	15	17	16	14
2–4				
Mean	111	112	113	102
SEM	5	6	8	8
N	15	18	15	14
4–8				
Mean	101	109	106	94
SEM	5	6	8	8
N	13	17	15	14
8–12				
Mean	95	113	106	106
SEM	6	5	7	5
N	13	14	13	14
12–16				
Mean	89	102	100	97
SEM	4	5	7	5
N	13	14	13	14

No significant differences between formula groups.

lean and fat infants in all three feeding groups. As Dewey and Lönnerdal (21) observed and contrary to general belief, a breast-fed infant may become relatively fat. Measures of body composition, i.e., skinfold thickness, midarm fatfold, estimated percents of arm fat and nonfat areas, and estimated total body fat as percentage of body weight were also similar among the groups and similar to percentage body fat values estimated by Dauncey et al. (18). Although mean percent body fat was slightly less 1–3 days after birth in our study than these researchers observed (8 versus 13%), by 16 weeks of age the percent body fat of infants in all three groups was ~20% and similar to values obtained by Dauncey et al. (18). There were infants with relatively high (>20%) and relatively low (<15%) body fat in each of the feeding groups by this age.

This study suffers from the same difficulty as other studies in which one infant cohort is being breast fed: the lack of true randomization between formula- and breast-fed groups. The percent of breast-fed infants who completed the study period was only 66%, similar to that experienced by others (7), whereas 77% of infants in each of the formula groups remained in the study. Infants were removed from the breast-fed group mostly because they missed scheduled clinic visits, not because they grew poorly. Unlike most other studies comparing formula-fed and breast-fed infants, the infants in our study were very similar. Their mothers were of similar ethnic and socioeconomic backgrounds and were recruited from the same health care centers. All mothers received the same standard prenatal care provided by that center and were healthy. Also, each mother had firmly decided before delivery either to breast feed or to formula feed her baby. Birth weights were not different among the feeding groups. In similar studies formula-fed infants have had lower birth weights than the breast-fed infants (8). Thus, the breast-fed and formula-fed infant cohorts in our study were likely more homogeneous than similar cohorts in other feeding studies.

Energy intake was similar between the two formula groups. Mean daily energy intakes were <115 kcal/kg recommended by the National Academy of Sciences for infants for the first 6 months of life (22) and the 120 kcal/kg reported by Fomon et al. (7) in 1-month-old formula-fed infants. Unlike the observations of these authors, formula-fed infants in our study did not significantly decrease their energy consumption per kg body weight between birth and 4 months of age by our method of recording intake.

In the study of Sickles et al. (23) female infants fed a whey-predominant formula consumed significantly more formula than female infants fed the casein-predominant formulas. We found no such difference between infants fed whey- or casein-predominant formulas over the 4 months of the study. Although the whey-predominant formula contained less calcium and phosphorus than the casein-predominant formula, both formulas provided sufficient concentrations of these nutrients to meet a term infant's estimated needs (22). Both formulas also contained more of these minerals than typically found in human milk.

Stools of the infants fed the whey-predominant Formula A were predominantly green, whereas those of infants fed the casein-predominant formula were yellow or green and thus more like stools of breast-fed infants. These findings are similar to those of Malacaman et al. (24) who also found that stools of most infants fed whey-predominant formula containing 12 mg iron/L were green, whereas those fed iron-fortified casein-predominant formula were yellow or brown. The green stools were thought to result from an interaction between whey protein and iron.

In summary, growth and estimated body fat and lean body tissue of term infants fed casein-predominant or whey-predominant formulas were similar to those of breast-fed infants during the first 4 months of life. Stool patterns of infants fed the two formulas differed, with stools of infants fed casein-predominant formulas being more like those of breast-fed infants. Evaluation of growth suggests that a whey-predominant formula offers no nutritional advantage as judged by these parameters over a casein-predominant formula for term infants.

REFERENCES

1. Jelliffe DB, Jelliffe EFP. *Human milk in the modern world.* Oxford: Oxford University Press, 1978.
2. Ogra PL, Greene HL. Human milk and breast feeding: an update on the state of the art. *Pediatr Res* 1982;16:266–71.
3. Järvenpää AL, Räihä NCR, Rassin DK, Gaull GE. Milk protein quantity and quality in the term infant: I. Metabolic responses and effects on growth. *Pediatrics* 1982;70:214–20.
4. Hambraeus L. Proprietary milk versus human breast milk: a critical appraisal from the nutritional point of view. *Pediatr Clin North Am* 1977;24:17–36.
5. Janas LM, Picciano MF, Hatch TF. Indices of protein metabolism in terms infants fed human milk, whey-predominant formula, or cow's milk formula. *Pediatrics* 1985; 75:775–84.

6. Volz VR, Book LS, Churella HR. Growth and plasma amino acid concentrations in term infants fed either whey-predominant formula or human milk. *J Pediatr* 1983;102:27–31.
7. Fomon SJ, Thomas LN, Filer JL Jr, et al. Food consumption and growth of normal infants fed milk-based formulas. *Acta Paediatr Scand* [*Suppl*] 1971;223:1–36.
8. Ritchie CD, Naismith DJ. A comparison of growth in wholly breast-fed infants and in artificially fed infants. *Proc Nutr Soc* 1975;34:118A.
9. Salmenperä L, Perheentupa J, Siimes MA. Exclusively breast-fed healthy infants grow slower than reference infants. *Pediatr Res* 1985;19:307–12.
10. Whitehead RG, Paul AA. Growth charts and the assessment of infant feeding practices in the western world and in developing countries. *Early Hum Dev* 1984;9:187–207.
11. Persson LA. Infant feeding and growth—a longitudinal study in three Swedish communities. *Ann Hum Biol* 1985;12;41–52.
12. Oakley JR. Differences in subcutaneous fat in breast- and formula-fed infants. *Arch Dis Child* 1977;52:79–80.
13. Roberts DW. Growth of breast and bottle fed infants. *NZ Med J* 1980;92:45–6.
14. Dubowitz V, Dubowitz L, Goldberg C. Clinical assessment of gestational age in the newborn infants. *J Pediatr* 1970;77:1–10.
15. Vaucher YE, Harrison GG, Udall JN, Morrow G III. Skinfold thickness in North American infants 24–41 weeks gestation. *Hum Biol* 1984;56:713–32.
16. Branson RS, Vaucher YE, Harrison GG, Vargas M, Thies G. Inter- and intra-observer reliability of skinfold measurements in newborns. *Hum Biol* 1982;54:137–43.
17. Gurney JM, Jelliffe DB. Arm anthropometry in nutritional assessment: nomogram for rapid calculation of muscle circumference and cross-sectional muscle and fat areas. *Am J Clin Nutr* 1973;26:912–5.
18. Dauncey MJ, Gandy G, Gairdner D. Assessment of total body fat in infancy from skinfold thickness measurements. *Arch Dis Child* 1977;52:223–7.
19. Hamil PVV, Drizd TA, Johnson CL, et al. Physical growth: National Center for Healthy Statistics percentiles. *Am J Clin Nutr* 1979;32:607–29.
20. Duncan B, Schaefer C, Sibley B, Fonseca NM. Reduced growth velocity in exclusively breast-fed infants. *Am J Dis Child* 1984;138:309–13.
21. Dewey KG, Lönnerdal B. Milk and nutrient intake of breast-fed infants from 1 to 6 months: relation to growth and fatness. *J Pediatr Gastroenterol Nutr* 1983;2:497–506.
22. National Research Council, Committee on Dietary Allowances, Food and Nutrition Board. *Recommended Dietary Allowances*. 9th rev ed. Washington, DC: National Academy of Sciences, 1980.
23. Sickles VS, Tuley RJ, Bader P, et al. Growth and tolerance studies of a new infant formula. *Clin Pediatr* 1984;23:617–22.
24. Malacaman EE, Abbousy FK, Crooke D, Nauyok G Jr. Effect of protein source and iron content of infant formula on stool characteristics. *J Pediatr Gastroenterol Nutr* 1985;4:771–3.