Do breast-feeding and delayed introduction of solid foods protect against subsequent obesity?

To correct methodologic flaws (Type II error, confounding variables, and nonblinding) in previous studies relating infant feeding to later obesity, we conducted case-control studies of 639 patients 12 to 18 years of age attending our Adolescent Clinic, and 533 similarly aged healthy children attending a Montreal high school. Each subject was classified as either obese, overweight, or nonobese based on measurements of height, weight, and triceps and subscapular skinfolds. Feeding history, family history, and demographic data were later ascertained "blindly" by telephone interview. Analysis of the raw data revealed a significantly elevated estimated relative risk of not *breast-feeding and a significant trend for rates of breast-feeding among the three weight groups. The magnitude of the protective effect appeared to rise slightly with increased duration of breast-feeding. Delayed introduction of solid foods provided little if any additional benefit. Several demographic and clinical variables proved to be confounding, but the significant protective effect of breast-feeding persisted even after controlling for confounders. We conclude that breast-feeding does protect against later obesity and attribute the conflicting results of previous studies to insufficient attention to methodologic standards.*

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FAT BABIES appear to have an increased risk of becoming obese teen-agers and adults.[1-3] Whether this stems from adipose cell, hypothalamic, or behavioral factors is unclear, but it obviously presents an opportunity for preventive intervention in the early months of life. The major focus of such intervention has been the promotion of breast-feeding and delayed introduction of solid foods; its effectiveness, however, remains highly controversial, and published studies have produced conflicting results.[4-11]

Unfortunately, methodologic difficulties in previous studies preclude attempts to resolve the conflict. One difficulty has been the long-standing problem of defining the obese state; the nutritional outcomes investigated in these studies include weight, weight percentiles, weight gain, birth weight doubling time, relative weight, and skinfold thickness. Most of the studies have used a cohort design, in which a group of newborn infants is followed to determine their later nutritional status. This approach, however, is prone to two sorts of problems. (1) Cohort studies are susceptible, by virtue of the relatively low incidence of the outcome and small sample sizes, to Type II error; i.e., they may fail to detect a positive effect that really exists. (2) The duration of follow-up has been relatively short, usually several months or years. Since most obese infants or young children (despite their increased risk) will not in fact be obese as adults,[1, 3] the significance of positive findings is also in question. Finally, despite a number of demographic and clinical variables that might serve as confounding factors, none of the studies has considered these potential sources of bias.

Abbreviation used
SES: socioeconomic status

We have attempted to overcome these previous methodologic defects by conducting an epidemiologic case-control study incorporating (1) classification of obesity

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Table I. Obesity vs breast-feeding (BF): "Raw analysis," clinic study

	Obese	*Nonobese*	*Total*
BF	13	82	95
Not BF	90	242	332
Total	103	324	427

See text for explanation of symbols and statistical analysis.
$\omega = 2.35$ (95% confidence interval = 1.25 to 4.43).
$\chi^2 = 7.273$; P = 0.007.

Table II. Weight group vs breast-feeding (BF), clinic study

	Obese	*Overweight*	*Nonobese*
BF	5 (5.3%)	8 (10.8%)	55 (18.5%)
Not BF	90 (94.7%)	66 (89.2%)	242 (81.5%)
Totals	95 (100%)	74 (100%)	297 (100%)

See text for explanation of symbols and statistical analysis.
$\chi^2_L = 11{,}102$; $P < 0.001$.

based on both relative weight and skinfold criteria, (2) inclusion of a number of cases of obesity sufficient to avoid significant Type II error, (3) focus on the adolescent age group because of the greater association between adolescent and adult obesity, (4) control for confounding variables, and (5) blind determination of feeding history.

METHODS

This study was conducted at two sites: (1) The Adolescent Clinic of the Montreal Children's Hospital and (2) Montreal West High School. The clinic site was chosen because obesity is one of the chief reasons that adolescents seek care at this clinic, thus yielding a higher prevalence of obesity than would be expected in the community at large and protecting against Type II error. Cases and controls were selected from the same clinic to equalize referral patterns in the two groups and thus ensure their comparability.

The high school site was chosen to minimize any potential for Berkson's bias[12] that might operate to affect the association between exposure (infant feeding) and disease (obesity), and to enhance the generalizability of the findings. The Adolescent Clinic population was skewed toward the lower end of the socioeconomic status spectrum. Montreal West High School, by contrast, draws from a segment of the community more evenly distributed socioeconomically. We recognized that the prevalence of obesity in a free-standing high school group would be far lower than that obtained at the clinic, but that if the overall trends in the results were similar in the two sites, the consistency of the findings would increase the likelihood of their validity.

For the clinic study, subjects were drawn from 639 patients age 12 to 18 years attending the Adolescent Clinic during a single calendar year ending February 1, 1980. Twenty patients refused participation, and 102 were excluded a priori for the following reasons: adopted or fostered (25) or mother otherwise unavailable to provide the infant feeding history (41), anorexia nervosa (8) or other recent extreme changes in weight (5), major psychologic problems (6), and miscellaneous conditions (17) that could affect breast-feeding or nutritional status (e.g., mental retardation, cerebral palsy, blindness).

The remaining 517 patients were enrolled by a research assistant, who performed measurements of height, weight, and triceps and subscapular skinfold thicknesses. Based on standards from the U.S. Health Examination Survey,[13, 14] patients were classified as obese if their relative weight (percent median weight for height and age) exceeded 120% *and* if either skinfold exceeded the ninety-fifth percentile or both exceeded the ninetieth percentile. They were considered nonobese if their relative weight did not exceed 110%, regardless of their skinfolds. Any patients falling between these extremes were classified as overweight. Nine nonobese subjects were unreachable, thus leaving a total of 324 nonobese, 81 overweight, and 103 obese subjects who received telephone interviews.

The telephone interview of each patient's mother was conducted by a second research assistant, who was "blind" both to the question under study and to the current nutritional status of the patients. Information obtained in the interview included ethnicity, Hollingshead socioeconomic status, and maternal and paternal age, height, and weight. The relative weight of each parent was then calculated based on standards from the U.S. Health Examination Survey.[15] The mother was also asked about the age at which solid foods were introduced and about breast-feeding (if and how long). In order to qualify as having been breast-fed, a child must have received no more than one bottle feeding per day. As soon as the child began taking more than one feeding per day by bottle, breast-feeding was considered to have terminated. The interviewer also asked the mother about her reasons for breast-feeding; this would enable us to control for any potential bias created by mothers at risk for having obese offspring who may have chosen to breast-feed specifically in order to prevent subsequent obesity. None of the mothers of our clinic adolescents breast-fed their infants for this reason.

In order to assess the certainty of the infant feeding information, vigorous attempts were made to contact the private physicians or clinics caring for each child in early

Table III. Obesity vs breast-feeding (BF): Mantel-Haenszel analysis, clinic study

	Negative family history			*Positive family history*		
	Obese	*Nonobese*	*Total*	*Obese*	*Nonobese*	*Total*
BF	5	49	54	0	6	6
Not BF	51	192	243	39	50	89
Totals	56	241	297	39	56	95

See text for explanation of symbols and statistical analysis.
R (summary estimated risk) = 3.37.
$\chi^2 = 7.165$; $P < 0.01$.

infancy. For the first 150 patients enrolled in the study, in only about one-third was such corroborating information obtainable, and in every case it confirmed the mother's history. Because this procedure required an enormous effort and proved so unhelpful, it was subsequently discontinued. Based on the results of the procedure when done, however, and on the mother's and the interviewer's confidence in the accuracy of the information, the breast-feeding and solid food data were each rated as certain, probable, or uncertain.

The procedure employed for the Montreal West High School study was virtually identical. The number of eligible 12- to 18-year-old children at the school was 553, of whom 125 did not wish to participate and 38 were excluded a priori for the following reasons: adopted or fostered (20) or mother otherwise unavailable to provide the infant feeding history (5), mental retardation or severe learning problems (8), blindness (3), or abnormally short stature (2). The remaining 390 patients were enrolled, measured, and classified as described above. One nonobese child was unreachable, leaving a total of 284 nonobese, 60 overweight, and 45 obese subjects who received telephone interviews.

RESULTS

For the clinic, the results comparing exposure to breast-feeding in obese and nonobese subjects are presented in Table I. These results are "raw"; no attempt is made at this preliminary step to control for potential confounding variables. The odds ratio, ω , or estimated relative risk, has been inverted to reflect the risk of obesity associated with *not* being breast-fed, i.e., the inverse of the usual risk expression. A value of ω significantly greater than one can thus be taken to indicate a relative protective effect afforded by breast-feeding. Breast-feeding was associated with a significant protective effect against subsequent obesity. When only the 466 subjects whose breast-feeding data rated as certain were compared, the protective effect actually increased ($\omega = 4.09$, 95% confidence interval 1.59 to 10.54; $P = 0.002$). The remaining results pertain to these 466 subjects.

Median relative weights in the three weight groups were as follows: obese, 139.3%; overweight, 114.5%; nonobese, 96.2%. When data from all three groups were included in the analysis, the breast-feeding results (Table II) became even more striking, with a definite linear trend across the groups.

In order to determine if any relation existed between the magnitude of the protective effect and the duration of breast-feeding, we performed a regression of relative weight on the duration in months of breast-feeding. This regression revealed a small, but statistically significant, inverse correlation ($r = -0.115$, $P < 0.025$). A similar regression revealed a statistically nonsignificant inverse correlation between age at introduction of solid foods and relative weight ($r = -0.064$, $P > 0.05$). Any protection afforded by delayed solids is probably explained by the highly significant positive correlation between duration of breast-feeding and age at introduction of solids ($r = +0.261$, $P < 0.001$).

Several demographic and clinical variables, including age, sex, race, ethnicity, birth order, socioeconomic status, and family history, were next examined to see if they might represent confounding factors, i.e., if they were significantly associated with both exposure (breast-fed vs nonbreast-fed) and disease (obese vs nonobese), as determined by conventional χ^2 or t tests. Family history proved to be confounding: children of obese parents were both more likely to be obese and less likely to be breast-fed. To control for the confounding effects of family history, we performed a Mantel-Haenszel analysis, i.e., analysis after stratification of the subjects according to whether the family history was positive or negative. (A positive family history means that either or both parents were obese, or both were overweight.) The results of the analysis are shown in Table III. The protective effect of breast-feeding is demonstrated in both family history strata, indicating that a very significant protective effect of breast-feeding persists even after controlling for this confounder.

The results of the school study are essentially concordant with those obtained in the clinic. The main differ-

ences in the school, as compared to the clinic, samples were: a smaller overall sample size (389 vs 508), a lower prevalence of obesity (45/389 = 11.6% vs 103/508 = 20.3%), a more even distribution across the five Hollingshead SES classes with greater representation among the upper classes (Hollingshead I and II), and a consequently higher frequency of breast-feeding (141/389 = 36.2% vs 110/508 = 21.6%). Several of these differences lead to some decreases in statistical efficiency in analyzing the school data, but the trends are exactly the same as seen in the clinic, and most remain statistically significant.

The raw analysis revealed an estimated relative risk, ω, associated with not breast-feeding of 2.25 (95% confidence interval 1.07 to 4.73; $P = 0.029$). There was a significant trend ($\chi^2_{1.} = 4.906$; $P < 0.05$) in breast-feeding rates in the three weight groups: 22.2% in the obese (median relative weight = 129.0%), 33.3% in the overweight (113.5%), and 39.1% in the nonobese (97.6%) groups. The very small inverse correlation between relative weight and duration of breast-feeding did not reach statistical significance ($r = -0.061$; $P > 0.05$), but if breast-feeding was redefined as at least two months in duration, ω rose to 4.11 (95% confidence interval 1.57 to 10.75; $P = 0.002$). As in the clinic, there was no association with delayed introduction of solid foods after controlling for the effects of breast-feeding.

The same factors examined in the clinic study were re-examined in the school sample, and three proved to be confounding: race (blacks were more likely to be obese and more likely to have been breast-fed), SES (children from upper SES classes were less likely to be obese and more likely to have been breast-fed), and birth order (earlier born children were more likely to be obese and more likely to have been breast-fed). Because of the large number of strata that would be required in a Mantel-Haenszel analysis, these three confounders were controlled for in two other ways. (1) Forty-four of the 45 obese subjects were successful matched with one of the 284 nonobese subjects. The matched analysis resulted in no significant changes in ω (1.83 for any breast-feeding; 4.00 for breast-feeding for at least two months). (2) A stepwise discriminant function analysis revealed that breast-feeding discriminated significantly between obese and nonobese subjects ($P < 0.001$) even after controlling for race, SES, and birth order.

DISCUSSION

Our results suggest that breast-feeding provides a significant protective effect against subsequent obesity that persists at least through adolescence. The degree of protection afforded appears to rise slightly with increased duration of breast-feeding. Delayed introduction of solid foods, on the other hand, seems to offer little if any additional benefit. Breast-feeding probably has a far weaker effect than do genetic, racial, socioeconomic, and behavioral factors, but all else being equal, it appears to afford a two- to fourfold benefit. Because obesity is not a "rare" condition, however, the odds ratios reported here may not be good estimates of the true relative risks,[16] and the exact magnitude of this protective effect should not be interpreted too literally.

The dose-response relationship between duration of breast-feeding and degree of protection, though statistically significant, is of low magnitude and suggests that duration may be far less important than other clinical and demographic factors, or that the early weeks and months of life may be more critical for expression of the protective effect. Furthermore, a mother's ability to remember whether or not she breast-fed probably far exceeds her memory of how long she did so, and the increased variance associated with inaccurate recall of duration will diminish the magnitude of the measured trend.

The lack of agreement of our findings with several recently published studies[8-10] is probably explained by the failure of the latter to control for confounders and the susceptibility of their cohort designs to Type II error. Furthermore, recent studies may have failed to demonstrate an effect of breast-feeding because of current awareness, publicity, and caution about obesity, so that perhaps even bottle-feeding mothers today are careful not to overfeed their infants.

We must, however, consider other potential explanations for our findings. Is there some bias in the selection of the case or control groups that might lead to a false association between breast-feeding and obesity? In the clinic, we deliberately chose cases and controls from the same sampling frame in order to equalize referral patterns and thus ensure comparability of the two groups. Although some of the adolescents came to the clinic for treatment of their obesity, our classification of patients as obese, overweight, or control was based solely on their heights, weights, and skinfolds, and was independent of the reason for the clinic visit. It seems unlikely that patients coming to the clinic for care of their obesity should, a priori, have different infant feeding histories from those attending for other reasons. Furthermore, similar results in the free-standing, healthy high school group argue strongly against Berkson's bias[12] or patient selection as a likely explanation of the findings, and further enhance their generalizability.

It might be argued that mothers of adolescents are not

able to recall accurately what they fed them as infants. Unreliable feeding histories (when unbiased) should, however, increase the variance in exposure rates and therefore make it statistically more difficult to detect true associations. We cannot, therefore, attribute our consistent positive findings to this factor. Our procedure for verifying the mothers' histories indicated that they were in fact very accurate, and restricting the analysis to patients whose feeding histories were considered certain enhanced the strength of the associations.

The observed association between breast-feeding and subsequent obesity, even if valid, does not prove that the association is causal. It is possible, and even likely, that substantial differences exist between mothers deciding to breast-feed and those choosing artificial feeding. By testing and controlling for confounding factors, we have attempted to minimize the effects of such differences, but perhaps the mothers who chose to breast-feed their infants were more nutritionally "aware," and more vigilant not to overfeed their babies. Such vigilance might have been responsible for the protective effect of breast-feeding, rather than the breast-feeding itself. Since breast-feeding is a self-selected maneuver and cannot be feasibly "assigned," we cannot dismiss the importance of this psychologic factor of nutritional vigilance. The fact that the infant feeding for our study subjects occurred 12 to 18 years ago, before the current publicity and concern about obesity, would seem to argue against it. Furthermore, it must operate independently of race, ethnicity, socioeconomic status, and the mother's stated reasons for breast-feeding. Finally, the linear trend seen across the three weight groups and the dose-response effect observed with increasing duration would be consistent with a causal association between breast-feeding and protection against obesity. However, the nutritional vigilance factor might also express itself in a graded, dose-response fashion, and thus causality remains unproved.

In any case, these results provide the strongest evidence accumulated to date that breast-feeding may be a potent maneuver for preventing obesity, and that the protective effect is long-lasting. This evidence should add theoretical weight to the efforts of pediatricians and other health care professionals to promote the initiation and continuation of breast-feeding by new mothers.

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