Association of Breastfeeding and Stunting in Peruvian Toddlers: An Example of Reverse Causality

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Background. Child feeding recommendations include breastfeeding beyond 12 months, however, some researchers have reported increased rates of malnutrition in breastfed toddlers. A negative association between growth and breastfeeding may reflect reverse causality; that is, the outcome (growth) is a determinant of the predictor (breastfeeding), and not vice versa. We examined this question with data from 134 Peruvian toddlers.

Methods. A linear regression analysis predicted length at the age of 15 months by length at 12 months, study interval, and 12–14.9-month breastfeeding, complementary food intake, and diarrhoeal incidence. This analysis defined the association between breastfeeding and linear growth. To elucidate the direction of the effect between breastfeeding and linear growth, logistic regression was used to predict the probability of weaning by the end of 14 months. Determinants included weight-for-age (W/A) at 12 months, complementary food intake at 9–11.9 months, and change in diarrhoeal incidence between 9 and 14.9 months.

Results. There was a significant ($P < 0.01$) interaction of breastfeeding, diarrhoeal incidence, and complementary food intake on length at 15 months. Increased breastfeeding was associated with a 1.0 cm decrease in length gain when dietary intake was low and diarrhoeal morbidity was high, implying that breastfeeding is harmful. The logistic analysis, however, demonstrated that the risk of weaning decreased only when W/A and dietary intake were low and diarrhoeal morbidity was high.

Conclusions. The negative association between breastfeeding and linear growth reflected reverse causality. Increased breastfeeding did not lead to poor growth; children's poor growth and health led to increased breastfeeding. Children's health must be considered when evaluating the association of breastfeeding with anthropometric outcomes.

Keywords: prolonged breastfeeding, toddlers, weaning, linear growth, stunting

Child feeding recommendations of the World Health Organization include breastfeeding for 2 years and beyond.[1] These recommendations are consistent with research that demonstrates that breastfed children over 12 months of age are less likely to become ill with some infectious agents[2] and are less likely to die[3] than their non-breastfed contemporaries.

Paradoxically, in non-industrialized societies reports of the effect of breastfeeding after 6 months on linear growth have been mixed.[4] A number of studies have reported that increased breastfeeding duration was associated with increased weight-for-age (W/A) after 6–12 months of age,[5–7] mid-upper arm circumference after 18 months of age[8] and other anthropometric measurements after 12 months of age.[7,9] Other studies, however, have found an increase in mild to severe malnutrition in children who were breastfed during the second year.[10–17] These results from less-advantaged communities are surprising. One would expect breastfed children receiving complementary foods to be protected against growth faltering from illness and poor weaning diets and, therefore, be as tall or taller than non-breastfed children. Yet this has not been observed consistently.

Several explanations have been offered for the negative association between breastfeeding and growth seen in poor communities. Some investigators have suggested that breastfeeding may reduce the consumption

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of complementary foods without an equivalent increase in human milk intake, thereby diminishing total energy intake.[11,13,15] Others discard the association as a flaw in study design or analysis.[18–20] The negative association, however, may reflect the fact that decisions to continue to breastfeed occur as a direct response to children's poor health (as reflected in low dietary intakes, frequent illness, and poor growth). Then, the negative association reflects reverse causality, where the outcome (e.g. linear growth) is a causal factor of the predictor (e.g. breastfeeding), and not vice versa. Studies not designed to detect reverse causality would conclude that breastfeeding was deleterious to growth when, in fact, breastfeeding is not responsible for poor growth but, rather children continue to be breastfed because of their poor growth.

To investigate this reported negative effect of breastfeeding on linear growth, we analysed longitudinal data from 12–15 month old children participating in a field study conducted in Lima, Peru, where breastfeeding during the second year of life is common practice. This study interval incorporates a time when breastfeeding frequency is still high, complementary food intake can be limited, and diarrhoeal morbidity is high. Unique to this study is the consideration of maternal feeding decisions as responsive to a child's needs. By examining the probability of weaning, we are able to make a strong plausibility statement concerning the direction of the effect between breastfeeding and growth.

METHODS

Subjects

This analysis was based on data from 238 children, 12–15 months of age, who were living in a shanty town in Lima, Peru. These children were part of a persistent diarrhoeal surveillance study between 1985 and 1987.[21] The original sample was obtained from a two-stage random selection of 400 households from a census of 2886 households in the research site. All children <3 years of age in the selected homes were enrolled. Newborns were added to the study sample; children were dropped from the study when they became 3 years old. Families that moved or refused to participate were replaced with a randomly chosen neighbour. The original sample included a total of 677 children less than 3 years of age.

The present study selected only those 238 children who were between 12 and 15 months of age. Thirty-eight children did not have both 12-month and 15-month length measurements and were excluded. These 38 children did not differ from the 200 remaining

children in breastfeeding duration, diarrhoeal morbidity, or socioeconomic status (data not shown). To use the same sample of children for all analyses included in this paper, we excluded an additional 64 children who did not have all explanatory variables. During the multiple linear regression analysis, data from two children were discarded because of exceptionally high influential points caused by possible data collection errors. The final sample comprised 134 children. The 64 excluded children did not differ from those included in the final analysis by anthropometric, diarrhoeal morbidity, or socioeconomic variables (data not shown).

This project was approved by the University Committee on Human Subjects of Cornell University and the Ethical Committee of the Instituto de Investigación Nutricional.

Data Collection

Field methods for diarrhoeal surveillance have been described elsewhere.[21] Briefly, children were visited twice weekly to document symptoms of an episode of diarrhoea, defined as the excretion of three or more liquid or semiliquid stools in a 24-hr period. A new episode was defined by a ≥48-hr period not meeting the diarrhoeal definition.[21]

Weights and recumbent lengths were measured monthly. A calibrated spring balance (Salter Industrial Measurement Ltd., West Bromwich, UK) sensitive to 100 g was tared with a child's light clothing before weighing. Lengths were measured to the nearest 0.1 cm with a locally constructed length board.

A monthly food frequency questionnaire documented the frequency of intake of 29 categories of common foods and liquids. Data were recorded as not consumed, infrequently consumed, or consumed more than twice per week. Breastfeeding frequency (feeds per day) was also documented.

Variable Definition

The breastfeeding variable was determined from monthly reports of daily breastfeeding frequency averaged across the study interval. Breastfeeding as well as other continuous variables were centred at their mean. Complementary food intake values were based on the average of three food frequency surveys conducted monthly. The surveys recorded the number of 27 general food groupings (e.g. fruit, organ meats) consumed. Two items (water and vitamins) were not used as they contributed no energy. Foods were counted if consumed by the child two or more times per week. Diarrhoeal incidence rates for the 3-month study interval were calculated as the number of new episodes

per number of observed days $\times$ 91.3125. Both the complementary food intake and diarrhoeal incidence variables were categorized as above or, equal or below their mean and converted to three dichotomous indicator variables. The variables were: group 1 (low diet/low diarrhoea), group 2 (high diet/low diarrhoea), and group 3 (low diet/high diarrhoea). High diet/high diarrhoea was the base value when all three indicator variables were equal to 0.

Data Analysis

Descriptive statistics were used to define the anthropometric, dietary, breastfeeding frequency and diarrhoeal illness characteristics of the sample. The median duration of breastfeeding was determined using Kaplan-Meier estimates for survival analysis because of right censoring of the data. To estimate the association of breastfeeding frequency and other explanatory variables with linear growth, we used multiple linear regression analysis.

The *a priori* model for 12–15-month length gain included proximal biological variables reflecting intakes (complementary foods and breastfeeding), losses of nutrients (diarrhoea), and their relevant modifiers (e.g. breastfeeding $\times$ complementary foods). This model was used to develop the multiple linear regression equation for this analysis. The variables included were length at 12 months, time interval between 12- and 15-month measurements, 12–14.9-month breastfeeding frequency, and three indicator variables representing four high/low combinations of complementary food intake and incidence of diarrhoeal between 12 and 14.9 months.

With length at 12 months in the regression model for length at 15 months, the coefficients for the other variables reflected their association with 12–15-month linear growth. For example, the coefficient for the breastfeeding variable represents the increase in 12–15-month linear growth that is associated with a one unit increase in breastfeed frequency (i.e. one feed per day). Variables describing socioeconomic status, maternal characteristics, and hygiene were considered distal in our *a priori* model and presumed to function through the proximal variables (12–14.9-month complementary food, diarrhoea incidence, and breastfeeding). The distal variables did not explain additional variance beyond that explained by the proximal variables and were not included in the final regression equation.

To establish the direction of an effect, the temporal sequence of factors must be clear. This linear regression analysis uses data that occurred over the same time period: 12–15-month linear growth and 12–14.9-month breastfeeding, dietary intake, and diarrhoea incidence.

This specific analysis, therefore, can only demonstrate an association between breastfeeding and linear growth. The addition of lagged dietary, breastfeeding, and morbidity variables (9–11.9 months complementary food intake and diarrhoea incidence, and 0–5.9 months and 9–11.9 months breastfeeding frequency) did not explain additional variance, suggesting no carry-over of their effect beyond that contained in the length at 12 months. We were unable, therefore, to use these lagged variables to help establish temporal relationships between breastfeeding and linear growth.

If poor growth, however, was a determinant of maternal breastfeeding decisions and was, therefore, the reason for a negative association between growth and breastfeeding, then one would expect to find delayed weaning in those children who initially had the poorest health. We used linear logistic regression to predict the probability of weaning by the end of 14 months of age. The sample for this analysis included only those children who still were breastfeeding at the end of their 13th month and were therefore at risk of being weaned (n = 127). Determinants of weaning included 12-month W/A, 9–11.9-month complementary food intake, and change in incidence of diarrhoea between 9–11.9 and 12–14.9 months of age. The temporal order of the variables included in the logistic regression analysis (i.e. predictors [W/A, dietary intake, and change in diarrhoea incidence] occurred before the outcome [weaning]) could then lend support to the hypothesis that poor child health determined maternal breastfeeding practices.

All analyses were carried out with SYSTAT[22] and SURVIVAL, a supplemental module for SYSTAT.[23] Significance for all two-tailed probability tests was $P < 0.05$. Predicted linear growth was estimated and then plotted, using the different indicator variables for dietary intake and incidence of diarrhoea and the full range of values for breastfeeding frequency. The probability of weaning was estimated and plotted using the 25th and 75th percentile values for dietary intake and W/A, and the full range of values for change in diarrhoea incidence.

RESULTS

Sample Characteristics

Anthropometric measurements showed that 19.4% of the children were stunted (<–2 Z-scores length-for-age) at 12 months; this increased to 29.1% by 15 months of age. Only four children were wasted (<–2 Z-scores weight-for-length) at 12 months (3%); none was wasted at 15 months of age. Almost three-quarters (72.9%) of the children in the sample continued to

TABLE 1 *Descriptive statistics of anthropometric measurements, dietary intake, breastfeeding practice, and diarrhoeal morbidity of study participants (n = 134)*

Characteristics	Mean ± SD	Median
Anthropometric measurements (12 months):		
Length (cm)	72.0 ± 3.0	71.9
Weight (kg)	8.87 ± 1.2	8.8
Dietary intake (12–14.9 months):		
Complementary foods (groups)	14.3 ± 2.0	14.3
Animal products (groups)	3.4 ± 1.1	3.3
Breastfeeding (12–14.9 months; feeds/day)[a]	6.5 ± 2.9	6.3
Diarrhoea (12–14.9 months):		
Incidence (episodes)	2.1 ± 1.7	2.0
Days ill	8.2 ± 10.3	4.9
Fever with diarrhoea (days)	0.8 ± 1.5	0.0

[a] Only includes children who breastfed, n = 119.

breastfeed beyond 12 months. The median duration of breastfeeding for this sample was 16.8 months, with 13.3% of the children still breastfeeding at 24 months of age. Incidence of diarrhoea was high in this age group, with a median of 2.0 episodes/study interval, or 8.0 episodes/child-year (Table 1). Although the number of episodes was high, the median prevalence of diarrhoea was only 5.4% of days ill. Between 12 and 15 months, complementary food intake varied. The most common food groupings consumed regularly throughout the study interval were broths (94%), bread (95%), rice (90%), noodles (90%), potatoes and tubers (92%), and vegetables such as tomatoes (87%). Animal protein was obtained primarily as milk (60%) and meat (56%). Many children still had not tried some common adult foods by 15 months, including whole grains (65%), fish (50%), legumes (51%), organ meats (24%) and eggs (18%).

Association of Breastfeeding with Growth

Linear growth between 12 and 15 months had a complicated relationship with breastfeeding, diarrhoea and dietary variables (Table 2). The presence of a significant interaction term in the equation demonstrated that, in this population, it is inappropriate to consider the direct association with breastfeeding alone. That is, the slope of the line for the association of breastfeeding with growth was not the same for the different subgroups of dietary intake and diarreal morbidity (Figures 1 and 2).

When complementary food intakes were above the mean, breastfeeding frequency was not associated with a significant increase in length gain regardless of the

TABLE 2 *Multiple linear regression coefficients for length at 15 months, predicted by length at 12 months, interval period, breastfeeding frequency, and indicator variables for high/low combinations of complementary food intake and incidence of diarrhoea (n = 134)*

Variable	β	SE	P
Constant	74.674	0.165	0.000
Length at 12 months (cm)	0.976	0.024	0.000
Time interval (months)	0.860	0.244	0.001
Breastfeeding (feeds/day)	0.043	0.044	0.338
Group 1[a]	–0.044	0.212	0.835
Group 2[b]	–0.006	0.203	0.978
Group 3[c]	–0.340	0.233	0.147
Breastfeeding × Group 1	–0.039	0.059	0.505
Breastfeeding × Group 2	–0.033	0.054	0.542
Breastfeeding × Group 3	–0.157	0.059	0.009

[a] Low diet and low incidence of diarrhoea; n = 37.
[b] High diet and low incidence of diarrhoea; n = 46.
[c] Low diet and high incidence of diarrhoea; n = 27.
NB High diet and high incidence of diarrhoea was the value when groups 1, 2, and 3 were all set to 0; n = 24.
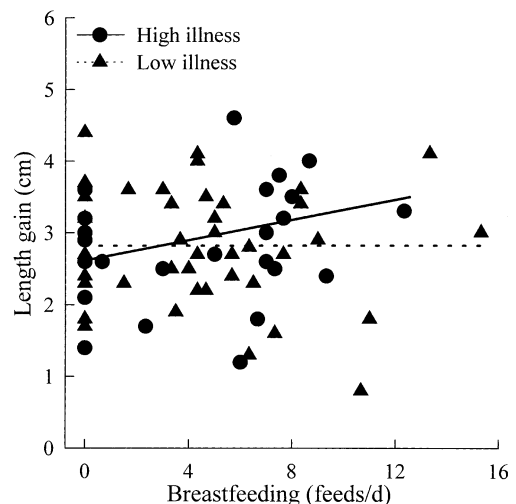

FIGURE 1 *Association of 12–15-month length gain with breastfeeding by degree of diarrhoea, in toddlers with high complementary food intakes. Estimated regression lines are shown for the high (circles, solid line) and low (triangles, dotted line) illness groups. Low refers to less than or equal to the mean value and high refers to greater than the mean value for both complementary food intakes and diarrhoea. Time interval between measurements and length at 12 months were both set to their mean*

incidence of diarrhoea (Figure 1). The association of breastfeeding with growth, however, was very different when complementary food intake was low. When diarrhoeal incidence and complementary food intakes were
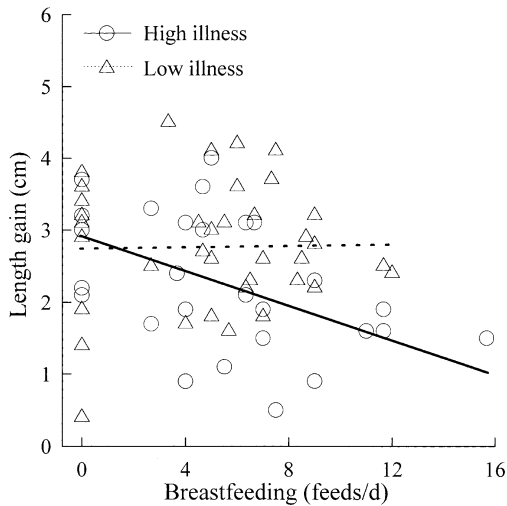
FIGURE 2 *Association of 12–15-month length gain with breastfeeding by degree of diarrhoea, in toddlers with low complementary food intakes. Estimated regression lines are shown for the high (circles, solid line) and low (triangles, dotted line) illness groups. Low refers to less than or equal to the mean value and high refers to greater than the mean value for both complementary food intakes and diarrhoea. Time interval between measurements and length at 12 months were both set to their mean*

TABLE 3 *Logistic linear regression coefficients for 14-month weaning, predicted by 12-month weight-for-age (W/A), 9–11.9-month complementary dietary intake, and change in incidence of diarrhoea between 9 and 15 months (n = 127)*

Variable	β	SE	P
Constant	−3.303	0.644	0.000
12-month W/A (Z-score)	−0.024	0.446	0.958
9–11.9-month diet (foods)	0.093	0.267	0.733
Change in illness (episodes)	0.542	0.322	0.095
Change in illness × 12-month W/A	0.336	0.179	0.064
9–11.9-month diet × change in illness	−0.143	0.144	0.323
12-month W/A × 9–11.9-month diet	0.046	0.211	0.833
9–11.9-month diet × 12-month W/A × change in illness	−0.202	0.096	0.038

both below their mean values, breastfeeding frequency was associated with no increase in linear growth (Figure 2). Under the worst health conditions of low intake of complementary foods and high diarrhoeal illness, however, breastfeeding was associated with a significantly lower linear growth. Under these circumstances, the mean breastfeeding practice would be associated with 1.0 cm less in linear growth than that associated with weaned toddlers over the 3-month interval. This would be equivalent to over 1 SD if this difference were to be continued during all of the second year. We looked to see whether this negative relationship could be explained by reverse causality.

Understanding the Negative Association as Reverse Causality

The results from the linear logistic equation showed that the three predictor variables functioned together to determine weaning at 14 months (Table 3). When children's complementary food intake was high in late infancy (9–11.9 months), neither 12-month W/A nor change in incidence of diarrhoea made a significant difference in the probability of being weaned by the end of the 14th month (Figure 3). In contrast, when 9–11.9-month complementary food intake was low, 12-month

W/A and change in morbidity both affected the probability of being weaned in the 14th month. When 12-month W/A was high, a subsequent increase in diarrhoea illnesses was associated with increased weaning at 14 months. The opposite was true when 12-month W/A was low; increased morbidity was associated with decreased probability of weaning at 14 months. Therefore, mothers of children with recent poor health indicators (low dietary intake, low W/A and increased incidence of diarrhoea) made different decisions about weaning than those made by mothers of children with good health indicators (high dietary intakes, high W/A or low incidence of diarrhoea). Under worse child health conditions, mothers were less likely to wean their children.

DISCUSSION

The negative association between breastfeeding and growth has frequently been reported in the literature.[4,10–17] Although reverse causality has been mentioned as a possible explanation for these results, only two previous studies have provided evidence to support this hypothesis and that only for infants under 12 months of age.[24,25] One may not expect that the same associations exist between breastfeeding and growth in these two age groups because of different nutrient requirements and environmental exposures. Our results, however, argue plausibly for the reverse causality hypothesis in older children. In this poor peri-urban community, increased frequency of breastfeeding was associated with poorer growth only in children with low
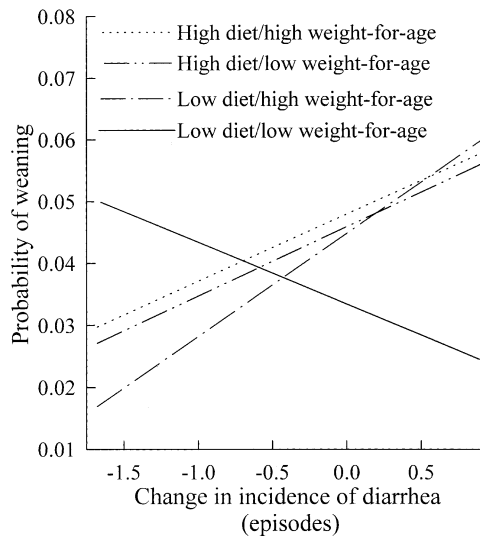
FIGURE 3 *Estimated risk of weaning at 14 months of age, by 9–11.9-month complementary food intake (diet), 12-month weight-for-age, and change in incidence of diarrhoea between 9–11.9 and 12–14.9 months. For complementary food intake and weight-for-age, low and high refer to the 25th and 75th percentile values, respectively*

complementary food intake and high diarrhoeal morbidity. If reverse causality were to account for these negative findings, then the probability of weaning for those children with the poorest nutritional status, lowest dietary intake, and highest diarrhoeal morbidity should be decreased. This did occur in our study.

Whether or not mothers modified their child feeding practices varied according to the child's health circumstances. This suggests that reverse causality may be important under certain health circumstances and not others. These results showed that diet alone was not sufficient cause to alter the likelihood of weaning; but the additional conditions of low initial weight and increased diarrhoeal disease did reduce the likelihood of weaning. Qualitative field results from the same Lima community support these findings.[26] This complementary field work included repeated interviews with mothers concerning child feeding decisions. These results demonstrated that the primary reason for weaning was the mother's own health; if the mother perceived the child's health as not adequate, however, weaning was postponed.

Changing a child's dietary intake or breastfeeding status is a means by which mothers could respond to their children's poor health or nutritional status. In reality, some mothers could not improve their child's

diet because of economic constraints; therefore, breastfeeding was the one means by which they could actively respond to their children's needs. The results from the logistic regression, as well as qualitative data from the community,[26] suggest that mothers consciously did just this. Mothers reported weaning their children, only to breastfeed them again if the child's perceived health deteriorated. These types of reversal patterns in breastfeeding have been reported previously in infants,[27,28] but only briefly mentioned in toddlers.[27]

Inconsistent published results on the association of breastfeeding with growth may partly reflect the variation in the effect that breastfeeding has depending on levels of diarrhoeal morbidity and dietary intake. Studies[6,7] that have shown positive associations with breastfeeding have been carried out in communities reporting low dietary intakes. In the Cebu area (Philippines), the effects of breastfeeding on ponderal growth varied by dietary intake and diarrhoeal morbidity.[6] When the present analysis was run with only continuous variables, we could compare our results[26] for the two-way interaction terms of breastfeeding × dietary intake and breastfeeding × diarrhoeal morbidity (data not shown) with those of the Cebu study. Both studies found a negative coefficient for the interaction term of breastfeeding and diet, suggesting that there was a decreasing benefit of human milk with higher dietary intake. This would be expected; the contribution of human milk to growth would be less important when more energy and nutrients were provided by the complementary diet.

The coefficients for the interaction term of diarrhoeal morbidity and breastfeeding, however, were negative in the Lima study and positive in the Cebu study. This suggests that in Cebu breastfeeding was effective in ameliorating growth retardation associated with diarrhoea. Similar results were seen in the high-diet subgroup in Lima, but not in the total sample.

This difference is surprising because rates of diarrhoeal morbidity were higher in Cebu that in the Lima sample. This may reflect the fact that weight is more responsive to recuperation than length. Studies showing no difference in growth between breastfed and non-breastfed toddlers may reflect the fact that intra-study variation in diet and diarrhoea was not taken into account. In the present study, for example, breastfeeding had no effect on linear growth when all diet and diarrhoea morbidity groups were considered together (i.e. only the main effect of breastfeeding was included).

All other reports of a negative association between breastfeeding and growth in toddlers living in low-income countries are probably not examples of reverse causality. In middle and upper class communities in Brazil,

where health conditions are good, mothers gave no indication that feeding decisions were driven by child health.[13] It may be that continued breastfeeding in this small group of women reflected concurrent child feeding habits that did not promote adequate growth (e.g. low-fat diets). Detailed dietary intake data are needed to clarify the negative association noted in this community.

This study demonstrated that there was no overall association of breastfeeding with growth for those toddlers with high intakes or low diarrhoeal morbidity. Further analyses presented elsewhere,[26] however, demonstrate that for some subgroups of children, specifically those with low intakes of animal protein, breastfeeding is associated with improved linear growth. This significant association becomes apparent when the analysis excludes the subgroup of children whose poor health influences maternal breastfeeding behaviour.

In summary, in communities with poor dietary intakes and high morbidity from diarrhoea, researchers must consider the possibility that poor child health causes mothers to continue breastfeeding rather than prolonged breastfeeding leads to increased prevalence of malnutrition.

ACKNOWLEDGEMENTS

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