Diarrhea and Growth among Children under 18 Months of Age in Rio de Janeiro[1]

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A study conducted in a periurban Rio de Janeiro community, Vila do João, sought to assess the extent to which diarrhea was influencing the growth of infants and young children. Using a prospective research design, the investigators studied a population of 159 children under 18 months of age living in the study area during the period January–September 1985. Weight and length measurements were used to calculate monthly weight and length increases. Information on diarrhea morbidity was collected at seven-day intervals by means of house-to-house visits. A multiple linear regression model was used to carry out the statistical analysis, which showed inverse and statistically significant correlations between the prevalence of diarrhea and increases in weight and length. It was estimated that the presence of diarrhea reduced increases in weight and length by averages of 13.4 g and 0.132 mm per day. These findings support the idea that control of diarrhea can improve nutritional status among children in developing countries.

It has been estimated that about a billion episodes of diarrhea occur among preschool children worldwide every year (*1*). Numerous studies have indicated that the highest incidence of diarrhea is found among children between six months and three years of age, with the annual frequency ranging from 2 to 12 episodes per year (*2*).

The most frequent immediate causes of growth retardation among preschool children living in developing countries are malnutrition, infectious diseases (particularly those that involve diarrhea—*3, 4*), and combined interactions of the two. Indeed, some authors consider that growth retardation is more closely linked to recurrent infections than to the availability of food (*5–8*).

Although diarrhea is known to have an adverse effect on growth through three interdependent mechanisms (reduced ingestion of food, metabolic changes, and poor absorption of nutrients), few studies have estimated the magnitude of this effect.

The aim of the study reported here was to determine the extent to which diarrhea affected increases in weight and length among children under 18 months of age living in a periurban area of Rio de Janeiro, Brazil. Information about these growth effects is important for better understanding the influence of diarrhea and establishing priorities for community health programs.

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MATERIALS AND METHODS

Cohort Selection and Data Collection

The study analyzed anthropometric and diarrhea morbidity data. Information for this purpose was obtained from files in the data bank of a prospective study on the epidemiologic characteristics of infectious diarrhea in the study community, Vila do João, during the period between August 1984 and September 1985. Vila do João is a low-cost urban settlement built on land reclaimed from the sea on the outskirts of Rio de Janeiro. The community has electricity, public water supply and waste disposal systems, and public services including a health post, an elementary school, a day care center, a police station, and some businesses. At the time the study was conducted, the local population consisted of approximately 8 000 inhabitants. Average income in the community was around US$ 60 a month, and most of the inhabitants had received a little formal education.

The study involved initial longitudinal monitoring of a cohort of children 0 to 6 months old. This cohort was followed over a period of 1 year by means of weekly visits. In addition, because some etiologic agents of diarrhea show cyclical or seasonal behavior, in the second half of the year we obtained a new cohort of children 0 to 6 months old that was followed for 6 months.

The necessary sample sizes of both cohorts were calculated using information from a study carried out in Brazil (9) that had found an average of three diarrhea episodes per child-year (0.25 episodes per child-month) without reporting variance. In calculating sample size, Poisson distribution was assumed.

The 95% confidence interval of the number of diarrhea episodes per child-month ($\hat{\lambda}$) is given by the following expression:

$$\hat{\lambda} \pm 1.96 \times \sqrt{\frac{\hat{\lambda}}{n}}$$

where n is the number of child-months in the study.

Using the child-month unit mentioned above ($\hat{\lambda} = 0.25$) and assuming a confidence interval of one diarrhea episode per child-year (that is, $1 \div 2 \times (1 \div 12) = 0.0415$ diarrhea episodes per child-month for each side of the estimator), the sample size was calculated as follows:

$$1.96 \times \sqrt{\frac{\hat{\lambda}}{n}} = 0.0415$$

Solving for n and rounding off yielded a sample size of 560 child-months. This meant that initially each cohort needed to include nine children in each of the 1-month age groups (i.e., nine children 0 to 1 month old, nine 1 to 2 months, etc.) from 0 to 6 months of age.

Taking into account the losses to follow-up that commonly result from high mobility and other causes among populations residing in fringe areas of cities in developing countries, it was decided to include all Vila do João children 0 to 6 months old within the cohorts studied. The resulting distribution of the two cohorts, by age group, at the outset of the study is shown in Table 1.

Table 1. Distribution by age group of the Vila do João study children initially included in each cohort.

Age group (months)	Cohort 1	Cohort 2
<1	11	26
1	9	15
2	12	7
3	10	14
4	11	8
5	12	13
6	3	8

Before the study began, a meeting was held with the Vila do João Residents' Association in order to discuss the aims and feasibility of the research, and informed consent was obtained from the participating mothers. In addition, personnel who would be serving as interviewers were given training in standard techniques of weight and length measurement and in administration of the questionnaires to be employed.

An initial interview was conducted with the mother of each cohort child in order to obtain information about her obstetric history and living conditions (i.e., presence or absence in the home of a drinking water supply system, wastewater disposal system, and domestic animals; refuse management practices; and family composition).

Thereafter, each mother was interviewed on a weekly basis to determine her child's history of diarrhea morbidity. The interviewer noted the dates when each diarrhea episode began and ended, based on the mother's report of changes in stool consistency and the frequency of bowel movements. (In exclusively breastfed children, diarrhea was defined as more than eight liquid bowel movements per day, while in totally or partially weaned children it was defined as more than three bowel movements per day.) In cases of diarrhea, the clinical characteristics of the ailment, use or nonuse of health services, and the mother's attitude toward her child were determined.

In addition, beginning in January 1985, each participating child's weight and length were measured monthly. The child was weighed, without clothing, on an ITAC scale, model 800, with a 25 kg capacity and 100 g sensitivity. Length was measured with an anthropometric device having a 150 cm limit and 0.1 cm graduations.

Statistical Analysis

The unit of analysis used was growth per child in a given time interval. In order to characterize the growth of the children studied, the weight and length measurements were converted to increases in weight and length between two consecutive measurements and were converted into standardized 1-month intervals. (This was accomplished by dividing each increase by the number of days in the interval and multiplying the result by the quotient $365 \div 12$.) The percentile distributions of the standardized monthly increases in weight and length, by age group and by sex, were compared with two reference standards: the reference standard of the United States Center for Health Statistics (NCHS) (*10*) for children under 12 months of age and the standard established for British children (*11*) 12 months of age and over.

It was assumed that the relationships between weight increase and age and length increase and age were linear within the age groups studied. Therefore, in order to provide a basis for comparison, the reference populations were regrouped by age and sex, and the mean monthly increases in weight and length for selected percentiles and each age group were calculated. The resulting values for the regrouped reference populations are shown in Tables 2 and 3.

The diarrhea prevalence for a particular child in a particular period was calculated by dividing the number of days with diarrhea by the number of observation days between two consecutive measurements of weight and length (*12*).

In order to determine whether or not a relationship existed between diarrhea prevalence and growth (in weight and length), a multiple regression model was used to compare the increase in weight and length of the children with and with-

Table 2. Average monthly increases in weight (grams per month) of reference standard children in the indicated percentiles, by sex and age group.

Age (months)	Monthly weight gain in grams of indicated percentile (P)						
	P3	P5	P10	P25	P50	P75	P90
Girls:							
0–3	—	520	600	765	940	1 125	1 325
4–6	—	390	423	470	527	597	640
7–9	—	287	303	340	373	417	460
10–12	—	227	240	270	300	340	383
13–18	96	—	136	177	219	281	339
Boys:							
0–3	—	705	835	915	1 065	1 265	1 450
4–6	—	433	463	503	563	630	697
7–9	—	287	310	343	387	433	483
10–12	—	227	230	270	310	350	400
13–18	100	—	143	178	219	280	327

Sources: For the group aged 0–12 months, adapted from Roche and collaborators (*10*); for the group aged 13–18 months, adapted from Tanner and collaborators (*11*).

out diarrhea during each interval between two consecutive measurements. Two factors were associated, separately, with the increase in weight and length during each child-interval: the prevalence of diarrhea and the child's age at the end of the interval. The first factor is consistent with the hypothesis that the greater the prevalence of diarrhea, the smaller the increase in weight and length. The other factor (age at the end of each interval) was used as a covariable, since the same child at different ages would be expected to have different increases in

Table 3. Average monthly increases in length (centimeters per month) of reference standard children in the indicated percentiles, by sex and age group.

Age (months)	Monthly weight gain in cm of indicated percentile (P)						
	P3	P5	P10	P25	P50	P75	P90
Girls:							
0–3	—	2.16	2.39	2.73	3.12	3.44	3.76
4–6	—	1.74	1.79	1.89	2.05	2.17	2.27
7–9	—	1.35	1.40	1.48	1.57	1.65	1.72
10–12	—	1.13	1.18	1.25	1.32	1.40	1.46
13–18	0.70	—	0.79	0.89	1.00	1.10	1.20
Boys:							
0–3	—	2.43	2.63	3.05	3.37	3.73	4.06
4–6	—	1.79	1.84	1.96	2.08	2.21	2.35
7–9	—	1.35	1.40	1.48	1.56	1.65	1.73
10–12	—	1.11	1.15	1.22	1.30	1.37	1.45
13–18	0.62	—	0.72	0.87	0.92	1.03	1.12

Sources: For the group aged 0–12 months, adapted from Roche and collaborators (*10*); for the group aged 13–18 months, adapted from Tanner and collaborators (*11*).

weight and length. No significant difference was found between the two sexes, and interactions found between the observed variables and sex were not statistically significant.

Graphic representation of the observed increases in weight with age and length with age revealed a quadratic relationship between the variables. The presence of colinearity between the variables was not detected. Accordingly, the following models were proposed:

$$Y_1 = b_0 + b_1x_1 + b_2x_2 + b_3x_3^2$$
$$Y_2 = b_0 + b_1x_1 + b_2x_2 + b_3x_3^2$$

where Y_1 is the standardized monthly increase in weight; Y_2 is the standardized monthly increase in length; b_0, b_1, b_2, and b_3 are the partial regression coefficients, x_1 is the prevalence of diarrhea, x_2 is age, and x_3^2 is age squared. The coefficient b_1 in each of the above regression lines represents the average increases in weight (Y_1) and length (Y_2) associated with each increase in the prevalence of diarrhea relative to an infant who had no diarrhea during the study period.

When child-interval was employed as the unit of analysis, the multiple regression model used to estimate the effect of diarrhea on the standardized monthly increases in weight and length had certain potential causes of imprecision. One of these was that the model did not consider the conglomerate effect in estimating standard deviation. In other words, it may be assumed that observations of the same child were probably correlated. If the conglomerate effect were not taken into account, the standard deviation, and consequently the confidence interval, could be biased.

Nevertheless, applying a correction factor to take account of the conglomerate effect within the model showed that the degrees of statistical significance achieved with and without the correction factor were very similar (*13*). Therefore, the multiple regression model results presented here are those obtained without the correction factor using child-interval as the unit of analysis.

RESULTS

Of the 159 children monitored between January and September 1985, 69% completed all of the months of observation (8 months for the first cohort and 4–6 months for the second). During this period 18 children (11%) were lost to the study. Thirteen of these moved away, two could not participate because they had to accompany their mothers to work, one was withdrawn from the study, and two died (one of bronchopneumonia, dehydration, and severe malnutrition and the other of bronchopneumonia).

Diarrhea Prevalence

As Table 4 shows, diarrheal disease was found on 8.43% of the observation days. The percentage of days with diarrhea was lowest in the youngest (0–3 month) group, somewhat higher in the 4–6 month group, and both considerably higher and relatively constant in the older groups.

From January to September 1985, 374 episodes of diarrhea were noted, at least

Table 4. Diarrhea prevalences by age group in the 159 Vila de João study children 0–18 months of age, showing the number of child-days and the average percentage of days the children in each group had diarrhea.

Age group (months)	Child-days	Percentage of days sick with diarrhea
0–3	2 596	5.51
4–6	4 934	6.85
7–9	6 385	9.33
10–12	6 227	9.38
13–18	5 170	9.15
Total	25 312	8.43

one episode being noted in 81.0% of the children. Taking both sexes and all age groups together, around 70% of the diarrhea episodes lasted 7 days or less, while 8.3% appear to have lasted between 14 and 35 days.

Description of Growth

The intervals between the "monthly" measurements of weight and length of the study children ranged from 14 to 46 days but averaged 32. The proportion of children with low birthweight (a birthweight under 2 500 g), making no distinction between those born prematurely and those born at term, was approximately 12%. This percentage is close to the average figure for institutional births in developing countries (*14*).

The standardized monthly weight increases of the study children were subsequently compared to the aforementioned reference standards (*10, 11*) (Tables 5 and 6). This comparison revealed that 56% of the weight increases in both boys and girls were below the tenth percentile of the reference standard. In other words, for both sexes and all ages, the percentage of weight increases below the tenth percentile of the reference standard was 46% higher than expected. A slight downward trend in the percentage of weight increases under the tenth percentile was noted as age increased, especially among the boys.

Similar analysis of the standardized monthly length increases in the study boys and girls (Tables 7 and 8) showed that over 70% of these increases (71.9% of those in boys and 72.5% of those in girls) were below the tenth percentile of the reference standard. Hence, a 60% excess was observed in the percentage of length increases below the tenth percentile of the reference standard.

Effect of Diarrhea

As Table 9 indicates, the prevalence of diarrhea (the percentage of days a child had diarrhea) exhibited a significant ($p < 0.05$) inverse relationship with the standardized monthly increase in weight. It is estimated, with 90% confidence, that the study subjects' mean increase in weight decreased between 2.9 g and 5.2 g for each percentage increase in days ill with diarrhea.

In the children studied, diarrhea reduced the increase in weight by an average of 13.4 g a day for a child of average age. This implies that a study child without diarrhea at the age of 8.7 months (the mean age of the children providing data over the course of the study) could have gained an average of 37.8 g a month more than another child of the same age who experienced the same average percentage of days sick with diarrhea (9.33%) as study children in the 7–9 month age group (see Table 4).

Table 5. The distribution of standardized monthly weight increases for study population boys, showing the proportions falling into specific percentile ranges of the reference standards (*10, 11*). N = number of Vila de João study child weight increases in each percentile range.

Reference standard percentile range	N	% of weight increases within each age group					
		0–3 mo.	4–6 mo.	7–9 mo.	10–12 mo.	13–18 mo.	Total
<10.0	322	79.4	64.1	53.8	54.1	33.9	56.3
10.0–74.9	97	13.0	14.5	16.7	20.5	19.3	17.0
≥75.0	153	7.6	21.4	29.5	25.4	46.8	26.7

Table 6. The distribution of standardized monthly weight increases for study population girls, showing the proportions falling into specific percentile ranges of the reference standards (*10, 11*). N = number of Vila de João study child weight increases in each percentile range.

Reference standard percentile range	N	% of weight increases within each age group					
		0–3 mo.	4–6 mo.	7–9 mo.	10–12 mo.	13–18 mo.	Total
<10.0	218	58.0	66.7	52.7	54.9	44.8	55.8
10.0–74.9	76	28.0	20.2	15.5	18.3	19.0	19.4
≥75.0	97	14.0	13.1	31.8	26.8	36.2	24.8

Table 7. The distribution of standardized monthly length increases for study population boys, showing the proportions falling into specific percentile ranges of the reference standards (*10, 11*). N = number of Vila de João study child length increases in each percentile range.

Reference standard percentile range	N	% of length increases within each age group					
		0–3 mo.	4–6 mo.	7–9 mo.	10–12 mo.	13–18 mo.	Total
<10.0	404	79.8	85.1	77.3	72.5	43.9	71.9
10.0–74.9	41	11.2	3.5	6.1	5.0	12.2	7.3
≥75.0	117	9.0	11.4	16.6	22.5	43.9	20.9

Table 8. The distribution of standardized monthly length increases for study population girls, showing the proportions falling into specific percentile ranges of the reference standards (*10, 11*). N = number of Vila de João study child length increases in each percentile range.

Reference standard percentile range	N	% of length increases within each age group					
		0–3 mo.	4–6 mo.	7–9 mo.	10–12 mo.	13–18 mo.	Total
<10.0	282	83.6	87.8	73.7	65.9	48.4	72.5
10.0–74.9	19	5.5	3.7	2.7	2.4	13.3	4.9
≥75.0	88	10.9	8.5	23.6	31.7	38.3	22.6

Table 9. Regression coefficients of the multiple regression models used. Vila do João, Rio de Janeiro, 1985.

	Dependent variable					
	Weight (g)[a]			Length (mm)[b]		
Independent variable	Coefficient	Standard error	p	Coefficient	Standard error	p
Diarrhea prevalence	−4.05	0.70	<0.0001	−0.04	0.02	0.0420
Age	−153.44	11.89	<0.0001	−4.51	0.38	<0.0001
Age^2	6.21	0.62	<0.0001	0.17	0.02	<0.0001

[a]$R^2 = 0.3119$
[b]$R^2 = 0.3303$

Similarly, the percentage of days with diarrhea exhibited a significant inverse relationship with the standardized monthly increase in length (see Table 9). Specifically, it was found that this standardized monthly increase was reduced by 0.014–0.07 mm for each increase in diarrhea prevalence.

Overall, it was found that diarrhea reduced the increase in length of the study children by an average of 0.132 mm a day. This implies that a study child without diarrhea could have gained an average of 0.81 cm more in 2 years than another child of the same age who experienced the same average percentage of days sick with diarrhea (8.43%) as did the study children (see Table 4).

DISCUSSION

Most of the children in Vila do João exhibited slow growth in terms of weight and length because of a number of acute adverse factors. In this analysis, the prevalence of diarrhea was studied as one of the possible acute factors that might explain this phenomenon.

The prevalence of diarrhea in the children of Vila de João, though quite high (Table 4), is lower than diarrhea prevalences generally observed among poor populations in the developing world (*3, 4, 15–17*). As in other areas, this "quite high" prevalence in Vila do João could be attributed to high levels of environmental contamination and transmission of pathogenic organisms, possibly as a result of poor personal hygiene and food habits.

The results of the study reported here indicate that the prevalence of diarrhea is inversely related to increases in weight and length. These findings are similar to those of studies conducted in Guatemala (*3*), Bangladesh (*16*), and Taiwan (*18*).

Our data also indicate that diarrhea was more closely related to reduction of weight increases than to reduction of length increases. As other authors have suggested (*4*), this difference may be attributable to the fact that weight increases were measured over short intervals, and so the affected children did not have time to make up the weight deficit. Moreover, the length deficit is cumulative; so if the interval between measurements were increased, the inverse correlation between length and diarrhea prevalence would probably be more marked, to the point where a biologically important effect would be seen.

The observed magnitude of diarrhea's impact upon weight and length increases in this study is not strictly comparable to the findings of other studies (*3, 4, 15, 16, 18, 20*) owing to differences in age, diarrhea prevalence, nutritional status, and food consumption. Nevertheless, it is noteworthy that the observed magnitude of diarrhea's impact upon monthly weight gains in this study was similar to that found in another study (*19*). The difference between our results and those of other investigators who found that diarrhea had a more marked impact on weight and length (*4, 20*) could be due to the fact that the children involved in this study were better nourished and consumed a larger quantity of food.

It is possible that the observed impact on weight and length appeared greater than it was because the children experienced compensatory growth during infection-free intervals, as has been affirmed by other authors (*19*); but it is unlikely that this substantially altered the inverse relationships described.

CONCLUSIONS

Our data associate diarrhea with a reduction in weight and length increases in the children of Vila de João similar to that observed in rural populations of other developing countries. The magnitude of this effect is probably due to a relatively high prevalence of diarrhea which, together with decreased food consumption following each episode, leads to weight loss and slows linear growth. These findings support the conclusion that control of diarrhea can improve the nutritional status of children in developing countries.

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Governmental Actions Encourage Breast-feeding

In response to an initiative promoted by the World Health Organization and UNICEF, 122 developing countries have now taken action to end the dangerous practice of distributing free or low-cost infant formula to maternity wards and hospitals. This marketing practice has been demonstrated to contribute to the cycle of infant infection and malnutrition by discouraging women from initiating or continuing breast-feeding.

In some of the 122 countries, governments and members of the infant-food manufacturing industry have entered into written agreements to end the practice; in others, legislation has been adopted or administrative action taken by the health authorities. Although there have been some failures to comply with government bans on supplying free or low-cost infant formula, WHO and UNICEF expect that global monitoring and industry cooperation will lead to full enforcement in developing countries by mid-1993. The next step will be to address this practice in industrialized countries.

In a related initiative, 90 developing and 14 industrialized countries have begun to evaluate and certify hospitals as "baby-friendly" based on recently established international criteria. The WHO/UNICEF Baby-Friendly Hospital Initiative seeks to protect, promote, and support breast-feeding in maternity wards and hospitals by removing such obstacles as routine bottle-feeding (which is facilitated by free or low-cost formula) and the separation of healthy babies from their mothers. Some 767 hospitals, located in over half of the countries that have taken up the challenge, are working toward or have already achieved "baby-friendly" status by providing optimum support to breast-feeding. WHO estimates that 1.5 million infant deaths every year could be averted through effective breast-feeding.

Source: "Governments take action to protect breast-feeding," Press Release WHO/10, published jointly by the World Health Organization and the United Nations Children's Fund, 2 February 1993.