

THE ROLE OF FEEDING AND NUTRITION IN THE PATHOGENY AND PREVENTION OF DIARRHEIC PROCESSES¹

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The combined interaction of diarrhea and inadequate nutrition poses grave health problems for millions of children in the Americas. This article explores both sides of that interaction, concentrating on ways in which breast-feeding can help protect against diarrhea, and in which vulnerability to diarrhea is increased by malnutrition.

Introduction

In most countries of Latin America diarrheic processes constitute one of the most severe health problems, especially for small children. That is partly because there is a two-way relationship between diarrheic processes on the one hand and poor feeding and malnutrition on the other. Thus, while diarrhea precipitates and aggravates malnutrition, the pathogeny of diarrheic processes is likewise affected by feeding practices and nutritional status. This dual relationship, which can be classed as synergistic, together with the magnitude of both problems, helps to explain why the Inter-American Investigation of Mortality in Childhood, an undertaking sponsored by the Pan American Health Organization (1), found that diarrhea was the most important basic cause of death in the combined total of all the population samples examined. It was also observed that malnutrition was a related cause of death in 60.8 per cent of the fatalities resulting from diarrhea.

Accordingly, we would like to analyze how food, in itself, and not as a vehicle of specific

pathogenic agents, can intervene in the pathogeny of diarrheic processes. For this purpose it is especially important to study two periods of infancy: the breast-feeding period and the weaning period.

The Protective Role of Breast-feeding

The first point to consider is the protection which breast-feeding provides against the environmental factors which promote diarrheic processes. Since introduction of widespread artificial feeding with cow's milk, clinical and epidemiologic observations have revealed that the frequency and severity of diarrheic processes have been greater among bottle-fed babies than among breast-fed ones. Today we know that human milk helps protect against enteric infections in at least the following ways:

Specific Antibody Activity

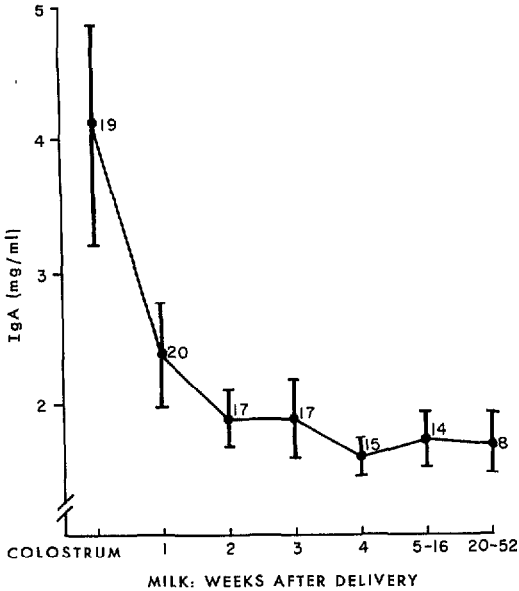
It has been shown that during the first weeks after birth a human mother's colostrum and milk contain high concentrations of immunoglobulins (especially IgA), in which antibodies against O antigens of enterobacteria have been found (2, 3).

Figure 1 shows the concentrations of secretory IgA found in the colostrum and milk of women from a rural community in Guatemala. As may be seen, the IgA concentration in the colostrum was high, and although it dropped

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FIGURE 1—Average concentrations of IgA found in the colostrum and milk of Guatemalan Indian women in Santa María Cauqué, 1968. The vertical bars show the standard deviation from the average, and the figures above the curve show the numbers of women studied.



sharply in early lactation, during the first year appreciable levels of IgA remained.

Undoubtedly, the antibodies involved do not pass through the infant's intestinal wall; but it has been observed that they do pass almost intact through the whole gastrointestinal tract. It is therefore felt that they can play a role in defense of the host by acting within the intestinal lumen. A similar defensive role has been proven in the case of antibodies against poliovirus (4, 5).

The Bifid Factor

It is well-known that the feces of infants nourished at their mother's breast differ from those of infants nourished artificially with cow's milk: the former do not have a disagreeable smell and give an acid reaction; the latter are alkaline and have a putrid smell. This is because the intestinal florae of the two are very

different. In breast-fed children the flora consists almost exclusively of gram-positive anaerobic bacilli (genus *Bifidobacterium*); in bottle-fed children it consists mainly of gram-negative anaerobic organisms (genus *Bacteroides*) which also predominate in the flora of adults.

This difference is due to the presence in human milk of a substance which favors the development of *Bifidobacterium*, the "bifid factor," which is not found in cow's milk (6). The bifidobacteria metabolize the sugars which have not been absorbed in the upper parts of the intestine, producing large quantities of acetic and lactic acid which are responsible for the low pH of breast-fed children's feces. The condition thus created in the intestinal lumen does not favor the growth of pathogenic enterobacteriaceae and intestinal protozoa.

These observations have been confirmed by Mata and Urrutia (7) in Guatemala, who showed that a group of breast-fed children with characteristic intestinal flora had only transitory *Shigella* infections that did not produce disease, while in older children these infections were associated with diarrhea. It has also been observed that *Entamoeba histolytica* passes through the alimentary canal of breast-fed children without colonizing the intestinal tract.

A longitudinal study of intestinal colonization by pathogenic enterobacteriaceae in small children, carried out at a village in Guatemala (8), found the pattern of *Shigella* infection shown in Figure 2. This indicates that the rate of infection was minimal during the first nine months of life, increased rapidly thereafter—especially after the first year of life when the children had begun receiving a fair amount of other food besides their mother's milk—and reached a maximum in the third year, when practically all the children had been completely weaned.

It was also found (in the same community) that even when shigellae were the bacteria most commonly associated with diarrhea in the general population, they were not frequently associated with diarrhea in the first few months of life. As Table 1 shows, shigellae were isolated from only 1.2 per cent of the diarrheic pro-

FIGURE 2—The prevalence of *Shigella* in children under three years of age in Santa María Cauqué, Guatemala (1964-1967). Upper figures show the percentage of weekly cultures positive for *Shigella*; lower figures (in parentheses) show the number of children studied during the period indicated.

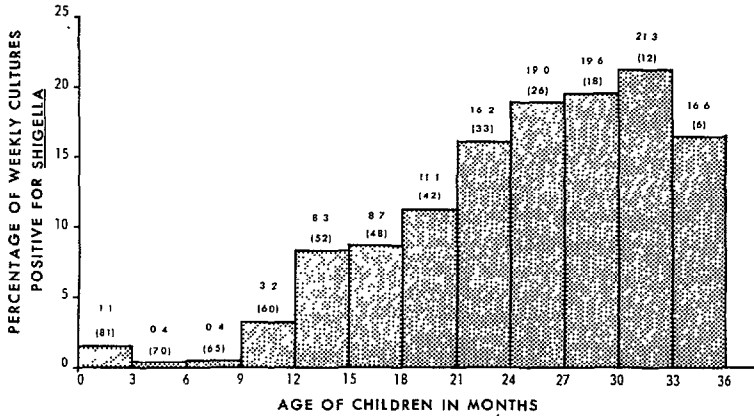


TABLE 1—Percentages of diarrhea cases associated with *Shigella* in children 0-3 years of age, by age group, in Santa María Cauqué, Guatemala (1964-1967).

Age (months)	% of diarrhea cases associated with <i>Shigella</i>
0-5	1.2
6-11	9.2
12-17	19.0
18-23	39.0
24-29	41.6
30-35	55.5

Source: Mata, et al. (8).

cesses occurring in the first months of life, while in the third year of life they were isolated in up to 55 per cent of the cases studied. We are thus led to conclude that the intestinal flora of breast-fed children protects them against enteric infections.

These two mechanisms and others that are not yet understood—involving such things as the high concentration of lysozyme (a bacteriolytic enzyme) in human milk and in the feces of breast-fed babies—help explain the reduced incidence and severity of diarrhea in these children compared with those who are bottle-fed. This protection can even be observed in

communities with highly effective environmental sanitation, though of course it is more pronounced in communities where environmental sanitation is precarious and health education is poor.

In these latter communities this disadvantage of artificial feeding is compounded by another of equal importance: the high level of contamination found in milk formulas prepared at home and in the feeding bottles and other implements used for their administration.

We therefore believe that where poor socio-economic and cultural conditions prevail, both early weaning and artificial feeding of infants are dangerous practices. They limit a child's natural defenses against enteric infections and greatly increase his exposure to an unhealthy environment. Frequent and serious diarrheic processes are the result. In support of this point, the previously mentioned Inter-American Investigation of Mortality in Childhood has confirmed that there is indeed a relationship between mortality from diarrhea and infant feeding practices.

“Weanling Diarrhea”

For breast-fed children living in an unhealthy environment, introduction of other

foods to meet their nutritional requirements and, finally, the total elimination of mother's milk, are accompanied by a marked rise in the incidence of diarrheic processes. This rise is observed regardless of the age when weaning occurs, which explains why in certain areas the greatest prevalence of diarrheic diseases is observed in the first months of life, while in others it occurs only toward the end of the first year or during the second year of life.

The pattern has been clearly described by Gordon (9), who characterizes it epidemiologically as a phenomenon called "weanling diarrhea." It does not seem to be associated with a specific agent, but rather with the heavy contamination by common bacteria that results when small children are fed in an unhealthy environment.

Indeed, careful bacteriologic studies carried out in this field only reveal the presence of pathogenic organisms in the feces of about 25 per cent of the affected children; nor is there sufficient evidence to prove that these organisms are really the agents responsible for the cases observed. Epidemiologic evidence indicates, however, that this syndrome is of an infectious nature and that it probably involves a large variety of germs to which children eventually become resistant.

Table 2 summarizes the incidence of diarrhea among different age groups in four rural Guatemalan communities that were carefully

studied for a period of three years (10). It can be observed that the incidence was relatively low in the first six months of life, during which the children were almost exclusively breast-fed; it increased considerably over the next eighteen months—the weaning period—and dropped rapidly after that.

The important point here is that one must consider the age at which to recommend that breast-feeding be supplemented in communities with very low levels of environmental sanitation. The likely nutritional advantages of the solid foods introduced must be weighed against risks of infection to which they expose the child. We believe that early introduction of other foods in the diet of the nursing baby, so fashionable in some countries regardless of whether it is necessary from the nutritional standpoint, is not desirable in communities where the environment is unhealthy. In the latter case, use of breast-feeding alone must be encouraged during the first three or four months of life, and should be continued with adequate supplementation for as long as circumstances permit.

Diarrhea and Nutrition

The second matter to be considered is the possible role malnutrition can play in the pathogeny of diarrheic processes. Epidemiologic studies have shown that diarrhea is more

TABLE 2—Acute diarrhea cases in four rural Guatemalan communities, by age group, showing the number of persons and cases in each age group and the annual rate of attack (data for 1956-1959).

Age	Number of persons observed	Diarrhea cases	Rate of attack (cases/year/100)
0-5 months	92	43	46.7
6-11 months	79	87	110.7
1 year	135	162	120.0
2 years	122	129	105.7
3 years	119	66	55.4
4-6 years	406	86	21.2
7-14 years	839	69	8.2
15 + years	2,390	109	4.6
All ages	4,182	751	18.0

Source: Gordon, *et al.* (10).

TABLE 3—The relationship between nutritional status* and the incidence and severity of diarrhea in children under five years of age at Santa María Cauqué, Guatemala (1961-1962).

Nutritional status	Rate of attack (diarrhea cases/year/100)	Severe cases (% of total)
Normal	98.8	22.9
First-degree malnutrition	164.1	37.8
Second-degree malnutrition	252.5	29.1
Third-degree malnutrition	274.5	40.0

* As classified by Gómez, *et al.* (16).
Source: Gordon, *et al.* (10).

common and more severe in malnourished children than in well-nourished ones. Table 3 shows figures obtained for children in one Guatemalan village (10). As indicated, the annual attack rate among children classified as well-nourished was 98.8 cases per hundred children; this rate rose as the severity of malnutrition increased, reaching 274.5 cases per hundred in children with third-degree malnutrition. At the same time, the percentage of severe cases was higher among malnourished children than among well-nourished ones. We admit that it is not easy to tell from these observations whether the children had more diarrhea because they were malnourished or were malnourished because they had more diarrhea. Nevertheless, the interrelationship between these two phenomena is clear.

Likewise, at the clinical level it is commonly observed that severely malnourished children entering the hospital often have diarrhea. In most cases it is not possible to identify a specific agent associated with the diarrhea, and the diarrhea yields to dietary treatment as the child recovers from the severe malnutrition, without any specific medication. It is also known that even when these severely malnourished children do not have diarrhea, they invariably suffer from intestinal malabsorption, mainly of fats.

It appears, therefore, that malnutrition *per se* conditions or favors the development of diarrheic processes. We shall now consider some of the possible mechanisms that could account for this situation.

Morphological Alterations of the Intestinal Mucosa

It has been observed consistently that the intestinal mucosa of severely malnourished children shows marked morphological alterations. These are characterized mainly by marked atrophy of the villi, which appear flattened and joined together, giving the mucosa a cerebroid appearance. The thickness of the mucosa, the height of the epithelial cells, and the thickness of their brush border are all reduced. These changes are similar to those found in cases of sprue and other intestinal malabsorption syndromes.

Recent studies at INCAP³ (11) have shown that these alterations are more severe in malnourished children with diarrhea than in well-nourished children. But it has also been noted that these alterations are not completely reversed by nutritional rehabilitation. Indeed, they have been found among children living in the same environment who had not suffered from severe malnutrition. The question remains, therefore, as to what is the true cause of these alterations.

Functional Alterations

In the severely malnourished child the time of intestinal transit is markedly increased, and a variety of intestinal atony exists. This intestinal stagnation cannot by itself explain the increase

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in diarrhea, but it does favor the development of other alterations which result in diarrheic processes, such as changes in the intestinal flora referred to below.

Children with severe malnutrition also experience poor intestinal absorption of various nutrients, especially fatty substances. In this latter case the children have little ability to emulsify fats. This problem does not appear associated with lipase deficiency, since normal concentrations of this enzyme have been found in most of the cases studied (12).

Rather, the problem seems more related to a decline in the concentration of conjugated bile acids and an increase in the concentration of free bile acids, with a consequent reduction of the ability to emulsify fats (13). This high concentration of free bile acids could result from bacterial breakdown of the conjugated acids in the upper parts of the intestine. The free bile acids thus produced could have an irritating effect on the intestinal mucosa and could thereby cause diarrhea.

Alterations of the Intestinal Flora

Two important changes have been noted in the intestinal flora of malnourished children. The first is a marked growth of the bacterial population (both obligatory and facultative anaerobes) in the stomach, duodenum, and jejunum (14)—that is, in the upper parts of the gastrointestinal tract where the flora is normally scarcer. This invasion of the upper parts by the flora normally found in lower areas could relate to the diminution of intestinal motility referred to earlier, or to a decline in the acidity and antibacterial action of the body's gastric secretions; this in turn could be the factor responsible for breaking down the conjugated bile salts. As previously noted, all these developments contribute to intestinal malabsorption and diarrhea.

The other important microbiological alteration which has been found in malnourished children is a change in the relationship between obligatory and facultative anaerobes in the feces, involving an increase in the proportion of

the latter. This situation could also favor development of diarrhea in the malnourished child.

Conclusions

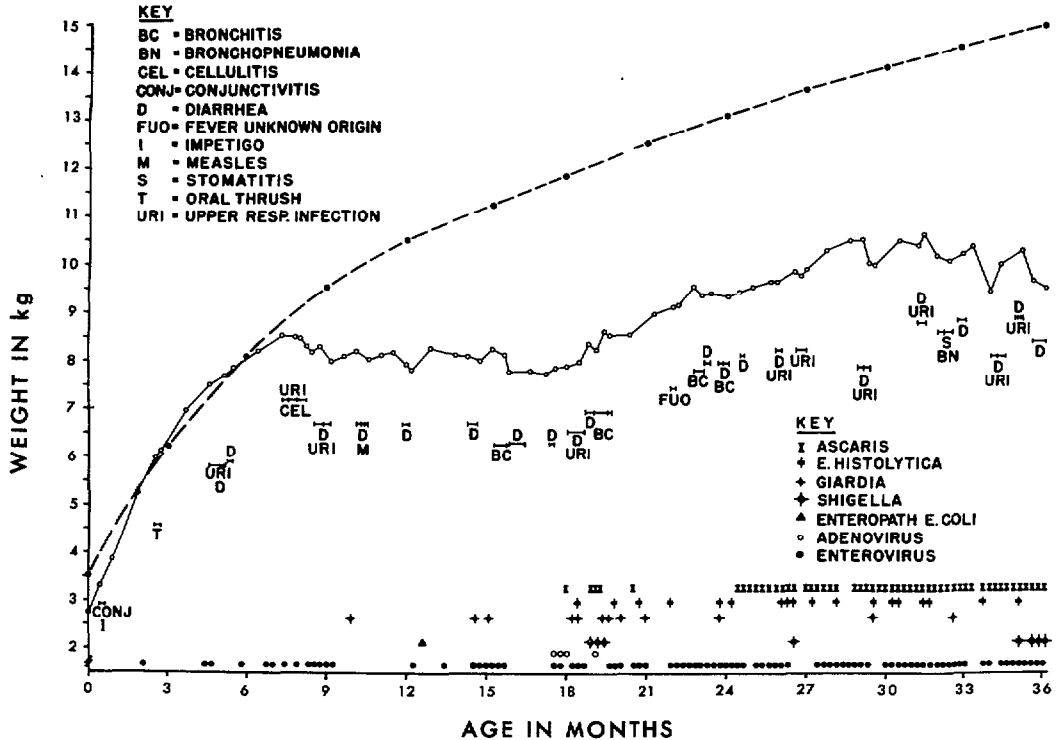
To sum up, even though we cannot clearly explain some of the physiopathological mechanisms involved, it is obvious that malnutrition favors development of diarrheic processes while, on the other hand, diarrhea in its turn precipitates and aggravates malnutrition. Children living on a marginal diet, one barely satisfying their minimum caloric and nutritional needs, fall into a state of malnutrition because of frequent infectious processes, particularly ones involving diarrhea. The latter not only reduce food intake but also increase nutritional requirements and cause an important portion of the nutrients ingested to be lost.

The result of the synergism between an inadequate and unsuitable diet and frequent infections is illustrated in Figure 3. This chart summarizes the history of a child studied longitudinally by Mata, *et al.* (15) at INCAP; it is representative of what happens to a large majority of children in poor communities.

As may be seen, the child made good progress in terms of weight during his first six months of life. In this period his mother's milk was enough to satisfy his needs and the infections he suffered were relatively few. But from then on he did not receive the foods needed to supplement breast-feeding, and he began to suffer frequent attacks of infectious diseases, especially diarrhea. The result was a rapid deterioration of his nutritional state, reflected in the complete flattening of his weight curve for one full year (up to the age of 18 months) plus inadequate and irregular growth after that.

We believe that this illustrates very clearly the sad story of millions of children in Latin America. Many of them die from the synergistic action of malnutrition and diarrhea, and the survivors do not attain their full genetic potential for physical and functional development and growth. Control of diarrheic infections, by

FIGURE 3—Weight, infectious agents, and infectious diseases of a child studied longitudinally by Mata, *et al.* (15). The upper (broken) line shows standard median weights for children in this age range (0-3 years). The lower (solid) line shows the weight of the child studied. His diseases are represented by capital letters and by horizontal bars indicating their duration. Infectious agents are represented by symbols, each one indicating a week positive for the particular agent involved.



itself, would greatly improve their nutritional status. On the other hand, breast-feeding during the early months, duly supplemented later and followed by a sound diet after weaning, would considerably reduce the danger caused by enteric diseases.

Ideally, the application of both these measures at the same time—that is, improved feeding and improved control of enteric disease

through environmental sanitation—would cause the greatest possible advancement available to our people through application of existing knowledge, in terms of lower death and disease rates and reduced physical and functional damage, and would thus create a more promising outlook for future generations of citizens of the Americas.

SUMMARY

Diarrheic processes pose a grave health threat in much of Latin America, especially for small children. One reason for this is the close connection between diarrhea and lack of proper nutrition. The present article seeks to explore this connection by examining two of its main

components: the protection against diarrhea resulting from breast-feeding and the increased vulnerability to diarrhea created by malnutrition.

Breast-feeding helps prevent enteric infections in several ways. For one thing, the

mother's colostrum and milk contain antibodies against some enterobacterial antigens. For another, the so-called "bifid factor" in human milk helps discourage growth of pathogenic enterobacteria in the intestinal lumen. Furthermore, children living in unhealthy surroundings become heavily exposed to common bacteria when breast-feeding stops, a circumstance deemed largely responsible for "weanling diarrhea."

Proper nutrition in general is also important, since diarrhea tends to be more common and severe among malnourished children. Several processes that could contribute to this problem have been suggested. These include morphological alterations of the intestinal mucosa in malnourished children, poor intestinal absorption of fats and other nutrients, irritation caused by increased concentrations of free bile

acids, and changes in the composition of the intestinal flora. Though not all these processes are well understood, it is clear that malnutrition favors development of diarrhea, while diarrhea in its turn precipitates and aggravates malnutrition.

The sad plight of millions of children in the Americas is the result of this combined interaction. Many of those who experience it die, and the survivors fail to achieve their full potential growth and development. The control of diarrheic infections alone would greatly improve these children's nutritional status. Likewise, breast-feeding in the early months of life, duly supplemented later and followed by a sound diet after weaning, would considerably reduce the danger and damage caused by diarrheic infections.

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EDITORIAL NOTE

The author, who has served as Director of the Nutrition Institute of Central America and Panama (INCAP) for 13 years, was named Chief of the Nutrition Section of WHO in December 1974. Dr. Béhar assumed his new duties at the beginning of January. Succeeding him as Director of INCAP is Dr. Carlos Tejada, who previously headed the Institute's Education Division.