Infantile Malnutrition in the Tropics

I-1238

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INTRODUCTION

Severe protein-energy malnutrition of the edematous type, or kwashiorkor, was first described by Cecily Williams in 1935.[1] It focused medical attention on infantile malnutrition in the tropics. Although the war and the period of political change in Africa diverted some of this attention to other issues, the interest was rekindled and by 1954 Trowell and his colleagues published a book entitled *Kwashiorkor*.[2] Classical descriptions of the various forms of protein-energy malnutrition syndromes followed: 1) the pure protein-deficient "sugar-baby" type in Jamaica; 2) the wasted, protein and energy depleted marasmic child; and 3) a spectrum of mixed types with intermediary characteristics.[3] In 1955, Gomez et al[4] proposed a classification of protein-energy malnutrition (PEM) that related deficits in weight-for-age to risk of mortality in severely malnourished children.

ETIOLOGY OF PROTEIN-ENERGY MALNUTRITION: ECOLOGICAL CONSIDERATIONS

Access to food is not the only determinant of nutritional status of children in developing countries.[5] One of the major factors in the development of severe PEM is infection. Studies from such diverse locations as Guatemala, Uganda and the Gambia implicated the number and duration of diarrheal episodes as causal or contributory factors in growth failure and malnutrition.[6,7] Upper respiratory infections[6] and malaria[7] can also cause deterioration in nutritional status. Questions about the impact of subclinical infections with intestinal parasites, specifically *A. lumbricoides*, hookworm, *E. histolytica* and *G. lamblia*, on growth and nutrition have been raised, but there is no convincing evidence of a major negative effect.

Several studies have pointed to social and environmental factors associated with poor nutritional status in children. Family size, access to land, occupation of parents and similar factors all influence nutrition of children.[8,9] Although ecological risk factors are always important, the specific ones that predominate vary with geography and culture.

Infantile malnutrition also develops in societies perturbed by change, the so-called transitional societies. As pointed out by Mata, "Increased exposure of persons living in traditional societies to the way of life of urban centers results in a measurable increase in the complexity of diets... In modern times, there has been unparalleled exodus from the rural areas throughout the world, accompanied by the mushrooming of slums in both developing countries and industrial worlds."[10] Decline in breast feeding is yet another major cause of nutritional deficiency at an early age.

FEEDING PRACTICES IN RELATION TO MALNUTRITION

Breast Milk vs. Artificial Formula in Infant Feeding

Breast milk is considered the best nutrition for infants under six months of age.[11] In addition to its nutritive value, breast milk apparently also plays a role in prevention of infections. This role may be based on the presence in milk of some immunological factors, such as antibodies and macrophages[12,13] (Table 1), which may protect the breast fed infant from infection. An additional

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TABLE 1

IMMUNOLOGICAL FACTORS IN COLOSTRUM AND BREAST MILK

Factors	Presumed Function
Soluble Components	
Immunoglobulins (s-IgA; IgM; IgG)	Act against bacterial, viral and protozoal pathogens
Complement	Promotes opsonization of bacteria
"Anti-Staphylococcus factor"	Inhibits staphylococcal proliferation
Immunoregulatory mediators	Direct the function of T and B lymphocytes
Chemotactic factors	Guide the movement of phagocytes to pathogens
Lactoperoxide	Bactericidal against enteric bacteria
Lactoferrin	Competes for iron; prevents proliferation of iron-dependent bacteria
Lysozyme	Lyses bacteria
Interferon	Inhibits viral replication
"Ribonuclease-like factor"	Acts against RNA viruses
"Bifidus factor"	Promotes colonic colonization with Bifidobacteria
Cellular Components	
Macrophages and neutrophils	Phagocytize bacterial pathogens; produce various soluble factors
B lymphocytes and plasma cells	Synthesize immunoglobulins
T lymphocyte	Regulate other cellular components
Transplantation antigens	? Govern the recognition of self and non-self

Modified from Mata L: Am J Clin Nutr *1978; 31:2058-2065; and Dayton D, Orga PL (eds):* Immunology of Breast Milk, *New York, Raven Press, 1979, pp 185-193.*

protective value of breast feeding may simply be the absence of microbial contamination, which is so difficult to avoid in the unhygienic environments that prevail in the developing countries.

Association between feeding of human breast milk and a reduction in infections was demonstrated in a study in New Delhi. Study of in-hospital mortality and infectious morbidity among low birth weight infants fed expressed maternal milk showed a dramatic reduction in rates of infection and death compared with a cohort fed a carefully prepared sterile formula.[14]

Although it is possible to mimic the composition of human milk in the artificial preparations, bioavailability of some of the micronutrients in the human milk, eg, zinc and iron, cannot always be duplicated in the formulas.

The great majority of women are capable of successful lactation; however, exclusive breast feeding beyond six months may not always provide adequate nutrition. Whitehead and Paul[15] have demonstrated normal growth patterns in exclusively breast fed babies of well nourished, British mothers. This is not true of mothers who are not well nourished. Many women of low-income groups in tropical countries have milk outputs of only 600 to 750 ml daily and have a reduced fat concentration in their milk.[16] A decline in growth velocity of infants solely breast fed beyond three months of age by these women is a rule.

Nevertheless, the high rate of bacterial contamination of artificial feedings available in the tropics, especially liquid formulas or the watery, starchy beverages improvised in many regions, and the consequent high risk of diarrhea,[17] would still make extended lactation the better alternative.

Weaning Foods

Supplementation of breast feeding after six months of age is desirable. In the tropical countries, supplementation of protein is very important, but its sources and means for its incorporation into the diet vary with the locale.

Satisfaction of Protein and Energy Needs in Preschool Children

Foods commonly consumed by low-income families in the tropics do not fulfill the energy and protein needs (including the quantities of essential amino acids) of growing infants and toddlers.[18-20] The traditional dishes available to many weaned children in most developing countries are based on bulky vegetable foods, difficult to digest and low in energy and protein. Moreover, inadequate nutritional education, cultural constraints and misconceptions about the properties of some foods

TABLE 2

SOME MANIFESTATIONS IN PATIENTS WITH PROTEIN-ENERGY MALNUTRITION THAT GENERALLY SIGNIFY A POOR PROGNOSIS

1. Age less than six months.
2. Deficit in weight-for-height of greater than 30% or in weight-for-age of greater than 40%.
3. Extensive exfoliative or exudative cutaneous lesions, or deep decubitus ulceration.
4. Dehydration and electrolyte imbalances, specifically hypokalemia and possibly hypomagnesemia.
5. Clinical jaundice or elevated serum bilirubin concentrations with or without elevations in the transaminases.
6. Hypoglycemia or hypothermia.
7. Total serum protein concentrations less than 3.0 g/dl.
8. Severe anemia with hypoxia.
9. Generalized hemorrhagic tendencies (purpura is usually a sign of septicemia or a viral infection).
10. Intercurrent infections, particularly measles and bronchopneumonia.
11. Severe ocular lesions.
12. Persistent tachycardia and/or respiratory difficulty.
13. Coma, stupor or other alterations in mental status and consciousness.

Modified from Torun B, Viteri FE: Rev Col Med *(Guat) 1976; 27:43-62.*

prevent the inclusion of some good protein sources in the diets of children.

ASSESSMENT OF NUTRITIONAL STATUS AND RISK OF MORTALITY

Marasmus and Kwashiorkor

Marasmus is characterized by wasting of muscles, absence of subcutaneous fat, wrinkled skin, thin and sparse hair, and weakness. Protein concentration in the serum is usually above 5.5 g/dl, excretion of creatinine is reduced, and concentration of hemoglobin decreased to below 10 g/dl.

In kwashiorkor, the predominant feature is edema, which may reach the proportions of anasarca; wasting of muscles is slight and subcutaneous fat deposits may be normal; the skin glistens in the edematous regions and has dry, atrophic, hyperpigmented areas; the hair is dry, brittle, easily pluckable and is often depigmented showing a reddish tint. The liver is enlarged. Serum protein concentration is usually below 5 g/dl, creatinine excretion is as low as or even lower than that in marasmus, and hemoglobin concentration is low. The affected child is apathetic and irritable.

The term "marasmic-kwashiorkor" describes the edematous patient with muscle wasting and decreased subcutaneous fat.

Within this picture of intense PEM, there are relative degrees of severity, usually associated with a substantial risk of mortality. Table 2 lists the main clinical and biochemical characteristics that normally indicate a poor prognosis. Anthropometric characteristics of severely malnourished children have been evaluated in relationship to the risk of mortality, on the basis of the Gomez classification.[4] Other studies have also considered the association between childhood mortality and anthropometric measurements.[21-23]

Mild and Moderate PEM

The assessment or classification of the less severe forms of PEM is based primarily on anthropometric measurements. Ideally, these should be simple to obtain, independent of age, and provide reliable information on the prevalence, severity and nature of malnutrition when used in surveys or surveillance of populations.[24-26] The Gomez classification[4] relates weight to chronological age. A deficit in weight-for-age, however, may occur in a child who is truly underweight, or in one who is short in stature with a proportionate reduction in body mass. Waterlow[26] proposed a classification system that differentiates these two situations. He suggested the term "stunted" to describe a child too short for age, who may also be underweight, and "wasted" for the one truly underweight. Wasting is evidence of current malnutrition, whereas stunting is a reflection of past malnutrition, chronic malnutrition, or both. The degree of wasting can only be determined in reference to some standard of body mass for a given stature (weight-for-height), and stunting is assessed with reference to the height appropriate for a given age (height-for-age).

The World Health Organization currently recommends the use of the data from the U.S. National Center for

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Health Statistics as reference.[27] Any problems arising from the use of so-called "foreign" standards, with the possibility of genetic differences in stature, must be resolved in the interpretation of the data. The line that separates "normal" from "deficient" anthropometric measurements is a matter of value judgment, as are the further subdivisions into "mild," "moderate" and "severe" forms.[23,26,28]

Other anthropometric indices have been used, based mainly on weight, height, and mid-arm circumference. Chen et al[21] recently examined the value of such indices in predicting the risk of death among rural Bangladeshi children, 13 to 23 months old. Severely malnourished children had a higher risk of death than normal, mildly malnourished, and moderately malnourished children whose risk of death was identical. The discriminating power of anthropometric classification was enhanced when maternal weight and height and size of the household were factored into the evaluation of mortality risk.[21] Other findings in Bangladesh[22] and in the Punjab[23] correlated infant mortality rates with moderate and severe deficits in arm circumference-for-height and weight-for-age.

THERAPY AND REHABILITATION

The basic treatment of malnutrition is dietary. It provides the necessary nutrients to cure the lesions of deficiency, restore normal metabolic functions, replenish body stores, permit catch-up growth and allow the continuation of adequate growth. Attention must be paid to treatment of associated deficiencies, infections and other complications that frequently accompany malnutrition.

Severe Malnutrition

Kwashiorkor and marasmus are life-threatening conditions with case fatality rates as high as 40%.[29] Hospitalization — although essential in severe cases — may contribute to mortality rate, because of the high risk of nosocomial infections. Whenever conditions in the home allow it, the less severely malnourished patients may be treated more adequately in an ambulatory setting.

Treatment is divided into three stages: 1) attending to acute problems, 2) restoring nutritional balance, and 3) ensuring nutritional rehabilitation. The first stage consists of treating potentially life-threatening complications or metabolic disorders, such as infections, fluid and electrolyte disturbances, heart failure and severe anemia. The second stage provides nutritional replacement therapy designed to correct metabolic functions and to maintain homeostasis. There is general agreement on the principle of providing protein and energy in foods that are easily digested, and, at least during the first few days of therapy, in a liquid form administered orally or by nasogastric tube if necessary. Parenteral nutrition is rarely indicated. As the child's nutritional condition improves, the second stage gives way to the third stage. It may begin in the hospital, but must continue on an outpatient basis. In this phase other foods must be reintroduced into the diet, especially those available at home, but in combination with the energy- and protein-rich and highly digestible foods used in the hospital. Care must be taken to ensure a minimum daily intake of 3 to 4 g of protein and 120 to 150 Kcal of energy per kg. To achieve this, the patient must be fed a diet of solid foods whose energy density and protein density and quality are high. The energy density can be increased by supplementation with oil or fat; protein quality can be improved by mixtures of animal and vegetable proteins.

Deficiency of Micronutrients In Severe PEM

It is important to realize that PEM also includes deficiencies of many micronutrients. Deficiencies of vitamin A and E, potassium and magnesium, and of the trace minerals — iron, zinc, chromium, and selenium — usually accompany PEM.

It is well known that vitamin A replacement is an early priority in the therapy of PEM; failure to replete the exhausted vitamin A stores prior to protein and energy rehabilitation often precipitates the severe ocular manifestations of hypovitaminosis A, xerophthalmia and keratomalacia. It has recently been shown, moreover, that some of the reduction in circulating retinol levels is due to deficiency of zinc. Zinc plays an important role in the release of retinol-binding protein from the liver. In Hyderabad, Shingwekar et al[30] showed that zinc therapy — exclusive of protein, energy or vitamin A

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TABLE 3

EXAMPLE OF A DIETARY THERAPEUTIC REGIMEN FOR CHILDREN BASED ON DRY SKIM MILK, SUGAR AND VEGETABLE OIL*

Days from Beginning of Treatment	Protein (g)	Energy (kcal)	Milk (g)	Sugar (g)	Oil (ml)	Water (ml)
1	0.8 - 1.0	80-100	3	17	2	100
3	1.5 - 2.5	100-120	6	20	2	130
5	2.5 - 3.5	140-150	9	20	4	150
7	3.5 - 4.5	150-160	12	20	4	160
12 (marasmus†)		175†			6†	
17		195			8	
22		215			11	
etc.	3.5 - 4.5	†	12	20	†	160

**All amounts per kg body weight per day. The liquid formula must be supplemented with adequate levels of vitamins, minerals and electrolytes.*

†Marasmic patients may require more than 150 to 160 kcal per kg per day. Vegetable oil to 3 ml per kg per day at five-day intervals should be added until the rate of weight gain becomes adequate.[31]

supplementation — raised circulating vitamin A levels in children with edematous PEM.

Repletion of potassium and magnesium stores is an important facet of therapy because the deficiency of these two nutrients can retard clinical recovery. Golden and Golden[31] have recently demonstrated that zinc may also be a limiting nutrient in recovery. Malnourished children achieved a greater velocity of weight gain during the period of rapid catch-up growth when zinc was added to their rations; these children also deposited a greater proportion of recovered weight as lean tissue.

Iron is one nutrient that can be conserved during periods of dietary restriction of protein and energy. Nonetheless, low hemoglobin levels are characteristic of kwashiorkor and marasmus. Viteri et al[32] determined that this was most often a "physiological" anemia due to the decreased demand for oxygen by a depleted lean-body mass, and a consequently reduced demand for oxygen transport. The low efficiency of absorption of iron seen in some children with severe PEM appears to be due to nutritional damage to the intestinal mucosa.[33] Recent studies in our laboratories suggest that this reduced absorption is the result of a functioning regulatory system for iron uptake and that it may be related to the relative adequacy of the body stores to support the decreased demand for circulating red cells (B. Caballero, N.W. Solomons, B. Torun, unpublished data, 1982).

Severe PEM as an Adapted State

A key to the treatment of children with severe malnutrition is the realization that the organism adapts metabolically to the loss of lean mass and energy reserves. On the premise that the patient has adapted fully or partially to the malnourished state, it seems reasonable to begin nutritional treatment slowly and to increase nutrients gradually, especially in the cases of edematous malnutrition.[34] In fact, a premature introduction of high-energy and high-protein formulas may be fatal.[35] Various initial regimens have been advocated.[36,37] Table 3 shows one such regimen followed by the authors, which has led to excellent results and relatively low (5% to 15%) case fatality rates.[37] The milk diet is supplemented to provide daily 6 to 8 mEq of potassium, 3 to 4 mEq of sodium, 1 to 2 mEq of magnesium per kg, 60 mg of elemental iron, 0.3 mg of folic acid, 5000 I.U. of vitamin A and other vitamins and minerals. The total daily volume of formula is divided equally into six to 12 feedings per day, depending on the patient's age and general condition. This frequent feeding of small volumes prevents vomiting and the development of hypoglycemia.

If the progressive advancement of the protein and energy content of the diet is moderate, as previously described, one can expect a gradual loss of weight, corresponding to the diuresis of interstitial edema, followed by a phase of compensatory or "rapid catch-up growth," in which the child replaces the lean-body and adipose tissue appropriate to stature (Figure 1). This velocity of weight gain is often 15 times that in a healthy child of the same age. Finally the growth velocity

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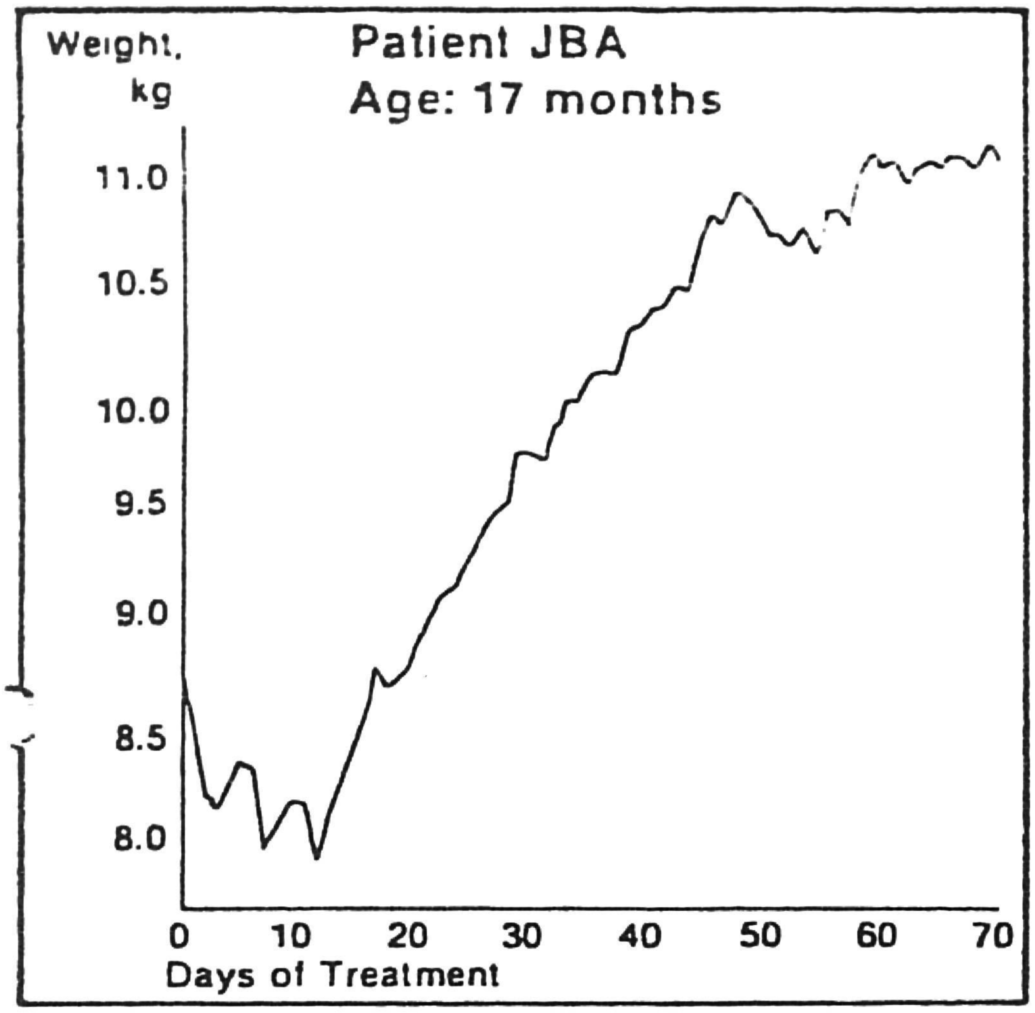

Figure. The graphic record of the daily weights of a preschool child admitted to the Clinical Research Center of INCAP with severe PEM of the edematous type. During the first ten days, there was a diuresis of the edema, this was followed over the next 27 days by a phase of rapid catch-up growth during which time the child gained 7.6 g/kg daily; finally, the growth velocity moderated to assume that expected for a child of this height.

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moderates to assume the pattern characteristic of a normal child of the same height.

Choice of Protein Source in Recovery Diets

Severe PEM is associated with changes in gastrointestinal ecology and function. In part, these alterations are due to nutritional injury and adaptation to the semi-starved condition; they are also attributable to infectious enteritides that commonly accompany clinical malnutrition.[38,39] Therefore the patient may not be able to tolerate a normal diet.

Many clinical reports have made note of the reduction of mucosal disaccharidases and consequent impairment of the absorption of lactose in children with severe PEM. We recently reviewed the literature related to the use of milk in malnourished children[40] and performed a retrospective survey of records from 24 children receiving a diet based on milk, delivering 3 to 4 g/kg of protein from milk and >120 Kcal of energy for from 20 to 49 days (Table 4). Our analysis has cast substantial doubt on the reported difficulties with diets containing cow's milk.[40] We conclude that, for routine treatment of severe PEM, it is not necessary to remove lactose from the diet.

Other animal protein sources, such as meat and meat extracts, or powdered eggs are generally well accepted and have excellent nutritional characteristics. They are not as widely available, however, as milk, and their cost is a limiting factor. Fish protein concentrates are relatively inexpensive, but they are not usually accepted in non-fish eating societies. Combinations of animal foods and other proteins, eg, K-mix (a mixture of calcium caseinate, skim milk powder, sucrose and vegetable oil), are quite adequate to treat severe PEM.[41] However, such products are generally less available and more costly than milk or other single animal proteins.

Soy protein is of particular interest because of its high biological value in man,[42] but there is concern about possible interference with the biological availability of minerals that the high phytic acid content of the soybean might impose. Marasmic Jamaican children fed a soy-protein formula experienced a fall in plasma zinc and reduced synthesis of lean tissue compared with those on a milk-based ration.[43] Whether other minerals are also made less available by soy, and what the compensatory supplementation of soy-based recovery formulas should be, remains to be clarified by future research.

Vegetable-protein mixtures with good essential amino acid complementation have become popular dietary supplements in the developing world. Many are suitable for nutritional rehabilitation diets for children with moderate or severe PEM. They are prepared in many countries, usually from locally available grains and legumes, and are enriched with vitamins, minerals and energy sources (lipids or carbohydrates). Protein in these mixtures is 10% to 20% less digestible than are animal proteins. This makes it necessary to feed large amounts of the mixtures to meet protein needs. The bulkier consistency of some vegetable mixture preparations makes it difficult to provide 4 to 5 g protein per kg per day to small, severely malnourished children. Three grams per kg can usually be consumed comfortably by children recovering from malnutrition. These considerations are pertinent to the present strategy to educate mothers in the preparation of weaning foods from blends of locally available vegetable protein sources.

Mild and Moderate Malnutrition

The less severe forms of PEM should be treated in an ambulatory setting by supplementation of the child's home diet with easily digested foods that contain proteins of high biological value and a high energy density. The quantity of food will vary, depending on the degree of malnutrition and on the relative deficit of proteins and energy. As a general guideline, the goal should be to provide a total intake — including the child's home diet — equal to at least twice the protein and 1.5 times the energy requirements. For preschool children, this would mean daily intake of 2 to 2.5 g of high quality protein and 120 to

TABLE 4

CATCH-UP GAINS OF 24 CHILDREN WITH PROTEIN-ENERGY MALNUTRITION TREATED AT INCAP'S CLINICAL CENTER WITH COW'S MILK FORMULAS FOR 20-49 DAYS*

Severity of PEM at the beginning	Number	Age, months	Initial weight-for-height percent of expected†	Weight gain, g/day	Weight gain, g/kg/day
Weight-for-height					
<80% of expected†	12	26 ± 6‡	76 ± 2	76.6 ± 15.5	8.7 ± 1.7
		(14 - 37)	(70 - 79)	(58.1 - 100.0)	(6.3 ± 11.4)
Weight-for-height					
≥80% of expected†	12	29 ± 13	84 ± 3	79.0 ± 32.1	7.8 ± 2.3
		(18 - 66)	(80 - 88)	(39.5 - 151.9)	(4.1 - 12.1)
Total	24	28 ± 10	80 ± 5	77.7 ± 24.7	8.2 ± 2.0

*The diets provided 3 to 4 g protein, 5 to 6 g lactose and 150 Kcal/kg/day, and they were fully consumed by the children.
†Relative to 50th percentile of well-nourished standards; weights after disappearance of edema.
‡Mean ± SD. Range within parentheses.
Reproduced with permission from Torun B, Solomons NW, Viteri FE: Arch Latinoam Nutr 1979; 29:445-494.

150 Kcal per kg of body weight.

Two important factors should never be overlooked in the treatment of mild and moderate PEM: 1) ensuring the intake of the food supplements by the target (the malnourished child) and 2) avoiding a major substitution effect on the household diet (ie, a decrease in the usual food intake). The ingestion of the food supplement by the malnourished child is more likely to occur if it is appetizing to both the child and the mother, if it is ready-made or easy to prepare, if additional amounts are provided to feed the siblings, and if it does not have an important commercial value outside the home that would make it easy and profitable for the family to sell the item for cash. A substitution effect on the home diet is almost unavoidable, but it can be reduced to a minimum by using low-bulk supplements of high protein and energy densities. Special attention should be given to maintenance of breast feeding. The supplements for breast fed infants should be paps or solid foods, which will not quench the infant's thirst and thus not change the infant's demand for breast milk (Table 5).

As in severe PEM, the diets should be supplemented with minerals and vitamins, as needed, and infections should be treated.

PREVENTION AND CONTROL OF INFANTILE MALNUTRITION

The main goal of nutritional programs is the eradication of infantile malnutrition through preventive measures. They include the availability and rational use of foods that optimize utilization of nutrients; control or reduction of infections that decrease appetite, reduce intake, increase nutrient losses, and tax the child's reserves; and education programs relating to nutrition.

Availability of Food

Food may be unavailable because of poverty, cultural food taboos, cyclical climatic conditions, and natural and manmade disasters. Solution of some of these conditions is beyond our control; however, the pediatrician, nutritionist, public health worker and educator can play an active role in ameliorating or solving those that are. Among these, one can provide instruction about more nutritious combinations of foods available to the household and about better infant feeding practices.

It will often be necessary to convince the child's parents about the safety of using foods that, in some cultures, are fed only to adults and older children. This is especially true in the case of weaning foods. Trials have shown that it is feasible to feed pablums based on legumes, a cereal and vegetable oil, to babies as young as three months without causing intestinal discomfort, and *without decreasing intake of breast milk* (Table 5).

Presence of a malnourished child in a family is an indicator that other members of the household might also be malnourished. Therefore, nutritional and health education must not be restricted to the rehabilitation of the index case, but to prevention of nutritional deterioration of other family members, especially siblings and pregnant and lactating women. Similarly, a high

TABLE 5

PAPS TO COMPLEMENT BREAST MILK, USING COMMON FOODS AND BASED ON COMBINATIONS OF A LEGUME, A GRAIN AND VEGETABLE OIL

	A	B	C	D
Cooked beans*	25†	20	20	25
Vegetable oil	12	7	7	10
Corn dough‡	20	—	—	—
White bread**	—	10	—	—
Boiled rice	—	—	22	—
Boiled potatoes	—	—	—	31
Protein, g/100g††	5.6	7.1	6.1	5.5
Energy, kcal/100g††	312	268	269	232

*Black beans (Phaseolus vulgaris), cooked and strained according to Guatemalan customs.
†Amounts of ingredients in grams.
‡Cooked, lime-treated corn dough.
**Moistened with about 50% water.
††Protein and energy content of 100g of pap, ready to eat.

prevalence of children with malnutrition (wasted) or growth retardation (stunted) indicates that their entire community is at some risk of impaired nutrition. Consequently, education programs must also be devised for community leaders, civic action groups and the community as a whole.

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