PART 1

THE MAJOR DEFICIENCY SYNDROMES

Chapter 2

PROTEIN–ENERGY MALNUTRITION

E.M. DeMaeyer

CONTENTS

Introduction

No other disease compares in importance with protein–energy malnutrition (PEM) in the fields of nutrition or public health in general. This form of malnutrition is highly prevalent in young children in almost all the developing countries. Few children survive the most severe forms of PEM unless they receive medical attention; even then, mortality may still be high. The disease in its less severe forms constitutes a serious handicap and may have permanent effects on the growth and development of the child if it continues over a long period or if it is present at a very early age.

The fact that the disease is so closely associated with underdevelopment and all that the latter involves in terms of uneven distribution of wealth, poverty, illiteracy, lack of sanitation and a clean water supply, poor housing, quantitatively and qualitatively inadequate food intake, etc., explains, but does not justify, the lack of progress in the prevention of the disease. The complexity of the problem has discouraged many health authorities from undertaking measures to alleviate its gravity; this is in contrast to the great progress that has been made in the prevention and treatment of so many other health problems.

Concern over PEM has spread recently from medical circles to the political arena, as witnessed by the discussions and resolutions of the General Assembly of the United Nations and of some of its specialized agencies. Proposed plans of action, based mainly on an increased production of foodstuffs and on the development of new protein resources, may suggest to those not well informed that the solution is first of all a question of food availability. In fact, it is evident that the control of the disease will require much more than this, and that some other factors may be even more important. In view of the importance of the disease and of the great number of children affected by it, all of whom require medical treatment, it has been deemed necessary to broaden the public health approach to PEM and include in this chapter a section on prevention as well as sections dealing specifically with the nosology, biochemistry, and treatment of the disease. This seems justified because many severe cases still occur every day, and all too often diagnosis and treatment are left to general medical practitioners or medical auxiliaries who have received little or no specialized training in paediatrics. It is hoped that this chapter will help these health personnel to recognize the disease and treat it effectively, and give them confidence in the effective role that they can play in the control of this serious problem.

So much has been written about PEM that it is not easy to condense the information to a manageable size for the reader. An attempt has been made to include only essential information in this chapter; some of the more important recent publications on PEM are given in the additional bibliography at the end of the chapter for readers requiring more specialized knowledge. However, the literature is already so large that some important publications may have been overlooked. For this, we apologize to the authors and to the reader.

Terminology

PEM can be defined as a range of pathological conditions arising from a deficiency of protein and energy, and is commonly associated with infections. It occurs more frequently in infants and young children but is also observed in adolescents and adults, mostly lactating women, especially during periods of famine or other emergencies.

A number of terms have been used in the past, and some are still in use, to describe the various pathological conditions that are now recognized to be only variants of PEM, particularly of the type widely known as "kwashiorkor". While it is difficult to list all the terms that have been used in the medical literature, the following ones are used frequently: "Mehlnährschaden", "sugar baby", "sindrome pluricarencial", "culebrilla", "kwashiorkor" (*1*), "bwaki", "enfants rouges", "bouffissure d'Annam". At one time it was proposed to use the term "protein-calorie deficiency" for the disease but "protein-calorie malnutrition", which was introduced by Jelliffe (*2*) is preferred by most authors and was adopted by the Joint FAO/WHO Expert Committee on Nutrition (*3*). [a]

PEM covers a wide spectrum of pathological conditions, the extremes being nutritional marasmus and kwashiorkor (*4*, *5*). In practice, a large proportion of PEM cases occupy an intermediate position and are referred to as "marasmic kwashiorkor". The definitions of nutritional marasmus and kwashiorkor are as follows:

Nutritional marasmus: a condition characterized by very low body weight for age, loss of subcutaneous fat, gross muscle wasting, and absence of oedema. It is observed more frequently in infants and very young children.

Kwashiorkor: a condition characterized by oedema and low body weight for age. The following signs may be also present but are by no means universal or very marked: muscle wasting, dermatosis, hepatomegaly, hair changes, diarrhoea, and mental changes. The serum albumin level is low. The syndrome is most frequently observed in children aged 1–3 years and is precipitated by an infection or more commonly by a series of infections occurring successively or concurrently.

The manifestations of severe PEM vary widely according to the nature of the causative factors, the time for which they operate, and the age of the patient. Moreover, a child with nutritional marasmus may develop marasmic kwashiorkor and a child with marasmic kwashiorkor may present a picture of nutritional marasmus after the oedema subsides. From the public health point of view, it is often more convenient not to emphasize the distinctions but to use the more general term "protein–energy malnutrition". There has been a tendency in the past to underestimate marasmus and to focus attention on kwashiorkor. It is now recognized that the proportion of marasmic children in the world is increasing steadily, especially in urban and periurban areas.

Besides the children suffering from the most severe forms of protein–energy malnutrition—namely, kwashiorkor, marasmic kwashiorkor, and marasmus—a much greater number display a moderate or mild form of this

---

[a] See explanatory note on p. 10.

type of malnutrition. The main characteristics of these children is that their weight-for-age and weight-for-height ratios are low in comparison with those of well-nourished children.

Finally, some children may have a low weight-for-age ratio while their weight-for-height is normal. Although these children are small for their age, there is no apparent sign of actual malnutrition because of the more or less proportionate decrease in body dimensions. The term "nutritional dwarfism" has been used to describe this condition.

Classification

The system used to classify PEM will differ according to the objectives to be achieved. One classification may be suitable for field studies and another for clinical purposes. In the first instance, there is little need to distinguish between cases of kwashiorkor and marasmus since the number of frank cases of either condition is always small compared with the total number of children who are malnourished according to any acceptable criteria. A widely used system of classification developed from one suggested by Gomez is based on weight deficit for age but not the type or duration of the condition. The classification is as follows:

1st degree malnutrition	75–90% of expected weight for age and sex
2nd degree malnutrition (moderate form)	60–75% of expected weight for age and sex
3rd degree malnutrition (severe form)	60% of expected weight for age and sex plus all children presenting with oedema.

The expected weight for age may be based on the weight of well fed children (upper socioeconomic class) living in the same country, or, if that information is not available, on values obtained in well controlled studies in developed countries. Two widely used sets of these "reference values" are the Stuart-Meredith data for American children (Boston) and the Tanner figures for British children. This system of classification may sometimes give a misleading impression of the importance of PEM in a particular area, and for this reason more complex and apparently more adequate systems have recently been proposed; these are discussed in Annex 5.

From the clinical point of view, however, it is often convenient to group patients with the following conditions: kwashiorkor, nutritional marasmus, and the intermediate marasmic kwashiorkor. A scoring system has been devised for classifying the severe forms of PEM (*6*). Other systems of classification have been suggested more recently (see Table 1 and reference *7*; see also Annex 5). These more elaborate systems are particularly useful in clinical investigations.

Table 1. Simplified classification of protein–energy malnutrition [a]

Classification	Body weight as percentage of the reference [b]	Oedema	Deficit in weight for height [c]
Underweight child	80–60	0	minimal
Nutritional dwarfing	< 60	0	minimal
Marasmus	< 60	0	++
Kwashiorkor	80–60	+	+
Marasmic kwashiorkor	< 60	+	++

[a] From an unpublished report to the Wellcome Trust, London, 1968 (see reference *34*).
[b] Reference taken as the 50th percentile of the Harvard values (see reference *8*).
[c] $\text{Weight for height} = \frac{\text{weight of patient}}{\text{weight of normal subject of same height}} \times 100.$

The Problem of Protein–Energy Malnutrition

Protein–energy malnutrition is the most widespread form of malnutrition in the world. Its prevalence is high in developing countries but is difficult to estimate accurately. The occurrence of severe cases of PEM, even in small numbers, is an indication of a much more extensive problem, i.e., the existence of a large number of mild to moderate, frequently unrecognized, forms of PEM.

Many surveys to evaluate the prevalence of the disease have been conducted over the years. Hospital record data have little significance in this respect because they are obtained from biased population samples. Only community surveys provide the information required but unfortunately most of these cover too small an area or too few children to give accurate information about the size of the problem.

Nevertheless, it is possible to obtain a rough estimate of prevalence by reviewing the published information (*9*). Taking only community surveys that cover at least 1 000 children, results from at least 25 surveys made during the last 10 years are available for study. These surveys were carried out in 17 different countries and the total number of children examined is approximately 175 000. Cases of PEM were classified according to the classification proposed by Gomez (see p. 25). The results for each continent are given in Table 2.

Table 2. Range and median of prevalence of PEM in community surveys

Area	No. of surveys	No. of children examined (thousands)	Severe forms		Moderate forms	
			Range (%)	Median (%)	Range (%)	Median (%)
Latin America	11	109	0.5– 6.3	1.6	3.5–32.0	18.9
Africa	7	25	1.7– 9.8	4.4	5.4–44.9	26.5
Asia	7	39	1.1–20.0	3.2	16.0–46.4	31.2
Total	25	173	0.5–20.0	2.6	3.5–46.4	18.9

A rough approximation, based on median values, of the total number of children affected by the disease is given in Table 3.

Table 3. Total numbers of children affected by PEM

Area	Population aged 0–5 years (millions) [a]	No. of children with protein–energy malnutrition (millions)		
		Severe	Moderate	Total
Latin America	46	0.7	8.8	9.5
Africa	61	2.7	16.3	19.0
Asia [b]	206	6.6	64.4	71.0
Total	314	10.0	89.5	99.5

[a] Averages for the years 1963–73.
[b] Excluding China and Japan.

The relative frequency of kwashiorkor and marasmus varies from one geographical area to another. Marasmus appears to be more frequent, for example, in Chile and the Middle East, while kwashiorkor and marasmic kwashiorkor are more frequently observed in Central Africa.

The importance of the problem is confirmed by the findings of the Inter-American Investigation of Mortality in Childhood (*10*), which was conducted in 13 areas of Latin America and the Caribbean islands. The causes of mortality in children aged 0–5 years were recorded in the 13 areas by means of a standardized methodology. Although conditions vary from one area to another, a similar pattern in the causes of mortality emerges. Among 7 318 deaths in children aged 1–4 years included in the study, malnutrition was found to be the underlying cause of death in 9% (range 0–18.4%) of cases and the associated cause in 48.4% (range 0–61.0%). As a whole, malnutrition was directly or indirectly responsible for the deaths of children aged 1–4 years in 57.4% of cases. There is no reason to suspect that the situation is much different in areas not included in the study.

Epidemiology

Protein–energy malnutrition results from the interaction of several factors, among which two are more or less directly responsible for the disease and act synergistically. They are (1) a quantitatively insufficient and qualitatively inadequate dietary intake, and (2) infectious processes such as gastrointestinal and respiratory infections and infectious diseases of childhood (*11*, *12*).

There has been a tendency to overemphasize the importance of either protein or energy deficiency alone, whereas in fact the two deficiencies almost always occur together. While protein deficiency has been incriminated as the major factor in areas where roots and tubers constitute the staple food, recent work in other areas, including India, has shown that the primary dietary limitation of young children is the low energy intake compared with the protein intake, which is only marginal.

It is still uncertain to what extent the clinical signs and biochemical parameters are reliable indicators of the importance of protein and energy deficiencies in PEM. Dietary studies have so far failed to provide conclusive evidence, and it is a common observation that no quantitative or qualitative differences can be detected in the previous diets of patients with a clinical picture of nutritional marasmus or kwashiorkor. It should be noted, however, that such studies do not reflect dietary intakes during and following the infectious episodes that usually precede an outbreak of PEM. Elsewhere, however, a relationship has been shown to exist between the clinical picture and the recent dietary history, and cases of typical kwashiokor have been described in children whose diets were adequate in energy but deficient in protein.

Infections experienced by children during the first years of life represent a major factor in PEM. In Zaire, childhood infections, especially measles, were traced in more than half the children in the weeks immediately preceding an outbreak of kwashiorkor (*11*). Similar observations concerning the precipitating effect of infectious processes such as measles, chickenpox, German measles, whooping-cough, primary tuberculosis, and malaria have been made in widely separated areas such as Ethiopia, Guatemala, and India. The nature of the infections may, however, vary from one area to another; in Central America and the Caribbean, for instance, the close association between diarrhoeal diseases and PEM has been repeatedly emphasized. Infectious episodes are frequent in the early life of children in developing countries; this is fully discussed in Chapter 14.

The ways in which infections adversely affect nutritional status are well known but difficult to quantify. They include a reduced food intake, which may be culturally determined or due to a decreased appetite, or to other causes such as stomatitis, an increased energy expenditure resulting from pyrexia, diminished food absorption when diarrhoea is present, and metabolic loss of nitrogen in the urine leading to a negative nitrogen balance. The level of socioeconomic development, the degree of education of the parents, the level of environmental sanitation, the underdeveloped state of agriculture, and the uneven distribution of wealth are the background factors responsible for this situation.

Children of preschool age are most seriously affected, both because their nutritional requirements are proportionally higher for body weight than those of older children or adults, and also because, for cultural reasons, they are frequently given a less nutritious diet than that consumed by older individuals. In addition, they are more often affected by intermittent infections such as measles, whooping-cough, malaria, intestinal parasites, and, particularly, diarrhoeal diseases. Furthermore, the older children and adults have a reduced body size as a consequence of an inadequate growth rate resulting from malnutrition during early childhood. Their nutritional requirements are thus lower than normal—a mechanism that permits them to adapt better to their usual diet.

Breast feeding and weaning practices [a] play an important role in determining the age distribution and the type of malnutrition observed. When weaning occurs late, severe cases of malnutrition are more frequently observed during the second, third, and fourth years of life, and the kwashiorkor type of PEM appears most commonly. This applies, for instance, to the rural areas of Central America and Africa where weaning usually does not take place until after 18 months and frequently not until the age of 3 years. When weaning occurs early, i.e., before 1 year, and the infants are provided with artificial feeding (frequently overdiluted milk formulas), which is often associated with episodes of infectious diarrhoea, severe cases of PEM may occur during the first year of life and the marasmic type is most often observed. This pattern is seen frequently in the Near East, India, some countries of Latin America and Africa, and more generally in the populations of large cities. It is expected that, as a result of the increasing rate of urbanization now taking place in most developing countries and the socio-economic pressures forcing mothers to abandon breast feeding their children at an early stage, this form of PEM is likely to become increasingly frequent in the future. Marasmus is practically the only form of PEM seen in infants below 6 months. It may arise when the child is weaned immediately after birth or when the mother's milk supply is inadequate and little or no other food is given. The most common causes of inadequate breast feeding are failure of the "let-down reflex" owing to psychological factors such as anxiety or lack of confidence; various social pressures including the desire to achieve a modern "image"; the influence of advertising; improper training of health personnel; and the mother's resumption of work outside the home for economic reasons shortly after delivery, and the absence of proper facilities for breast feeding at the place of work. In urban areas, marasmus in infants commonly follows very inadequate bottle-feeding resulting from the use of poorly perforated teats, unhygienic feeding bottles, and overdiluted and insufficient amounts of sweetened condensed milk or any other milk mixtures. Solid feeding for infants is often begun too late, the amounts given are too small, and the energy and protein content of the food too low.

The prevalence in PEM is usually subject to seasonal variations that may be due to epidemics of, for example, malaria or gastrointestinal infections related to the proliferation of flies during the hot season, or to seasonal variations in the food supply, or both. In savanna areas, for instance, crops are usually planted at the beginning of the rainy season and the amount of food available decreases progressively until harvest time later in the year.

---

[a] "Weaning" means the total cessation of breast feeding. The term "weaning period" is used to designate the period during which foods other than breast milk are introduced into the infant's diet, with an accompanying decline in the provision of breast milk.

On the other hand, in the forest areas of Central Africa the food supply remains more or less constant throughout the year.

The Clinical Features of Protein–Energy Malnutrition

Protein–energy malnutrition is observed as a wide range of clinical conditions that basically indicate the degree of adaptation of the subject to a restricted diet and other superimposed stress conditions. When the nutritional deficiencies are mild to moderate and prolonged the body of the growing child "adapts" by reducing its rate of growth. For the growth required during infancy, protein and energy restrictions may be too great for the child's capacity to reduce its rate of growth; the body is then forced to consume its own tissues for metabolic purposes. When this process is prolonged the resulting clinical picture is of "marasmus". In other cases, the process is accelerated by diarrhoeal disease or other acute infections, and the PEM is then manifested as kwashiorkor or marasmic kwashiorkor.

The clinical picture varies widely from one area to another, and even within the same area. This reflects the complex interrelationships of the causative factors and is strongly influenced by the age of weaning (*13*). It is generally accepted that some clinical and biochemical changes, notably oedema, hypoalbuminaemia, a reduction of some serum enzymes, and distortion of the serum amino acid pattern, probably indicate a state of protein depletion. However, protein depletion does not usually result from dietary protein deficiency alone; energy deficiency in the diet may act as a contributory factor by promoting the utilization of protein for energy production while infections can cause protein loss. The condition of a child frequently reflects a recent infectious episode superimposed on a chronic state of malnutrition.

The main features of PEM in children are set out in Table 4. In practice, there is a continuous spectrum of signs from grossly oedematous kwashiorkor through varying degrees of marasmus associated with oedema, to marasmus and cachexia.

In kwashiorkor, oedema usually appears first above the ankles; puffiness of the dorsum of the feet and around the eyes may be seen earlier. Later, the whole body may be oedematous. Ascites is rare except in southern India, where it appears to be relatively frequent in the presence of gross oedema. There is some muscle wasting, seen particularly in the buttocks, thighs, scapular region, and upper arms, but it is hidden in the presence of extensive oedema. After resolution of the oedema, the child may be markedly underweight for age in comparison with either local or international reference weights. He is miserable, sometimes irritable, resents disturbance, and often has a characteristic moaning cry. He is inactive and usually unable to walk. The characteristic "flaky paint" or "enamel" dermatosis is seen in a minority

Table 4. Principal features of protein–energy malnutrition

Features	Marasmus	Kwashiorkor
Essential features		
(1) Oedema	None [a]	Lower legs, sometimes face, or generalized [a]
(2) Wasting	Gross loss of subcutaneous fat, "all skin and bone" [a]	Less obvious; sometimes fat, blubbery
(3) Muscle wasting	Severe [a]	Sometimes
(4) Growth retardation in terms of body weight	Severe [a]	Less than in marasmus
(5) Mental changes	Usually none	Usually present
Variable features		
(1) Appetite	Usually good	Usually poor
(2) Diarrhoea	Often (past or present)	Often (past or present)
(3) Skin changes	Usually none	Often, diffuse depigmentation; occasional, "flaky-paint" [a] or "enamel" dermatosis
(4) Hair changes	Texture may be modified but usually no dyspigmentation	Often sparse—straight and silky; dyspigmentation—greyish or reddish
(5) Moon face	None	Often
(6) Hepatic enlargement	None	Frequent, although it is not observed in some areas
Biochemistry/pathology		
(1) Serum albumin	Normal or slightly decreased	Low [a]
(2) Urinary urea per g of creatinine	Normal or decreased	Low [a]
(3) Urinary hydroxyproline index	Low	Low
(4) Serum free amino acid ratio	Normal	Elevated [a]
(5) Anaemia	May be observed	Common; iron or folate deficiency may be associated
(6) Liver biopsy	Normal or atrophic [a]	Fatty infiltration [a]

[a] The most characteristic or useful distinguishing features.

of subjects only. In this condition patches of skin typically become reddish, then purple (macules and vesicles), then dark brown, and finally they become dry and peel off, sometimes leaving raw weeping areas like burns. Hair changes are not dramatic, but dyspigmentation (greyish white, yellowish, or reddish brown) is common and the hair is sparse, silky, and easily plucked out.

In marasmus, the child is markedly underweight and has the appearance of a wizened old man. There is almost total loss of subcutaneous fat and gross muscular wasting but no oedema.

In both syndromes, the appetite may be very poor but in marasmus the child often appears hungry and eats well. Diarrhoea is common, or at least some rather frequent loose bowel motions are observed and the stools contain undigested food residues. Moderate to severe fatty infiltrations in the hepatic cells are observed in kwashiorkor and may be accompanied by hepatomegaly. The latter is not a regular feature, however, and varies considerably according to geographical area. In marasmus the liver is usually not enlarged and may show cellular atrophy; fatty infiltration is absent. Neurological manifestations such as hypertonia, muscular trembling, and convulsions have sometimes been observed in kwashiorkor; their exact cause is still unknown. Magnesium deficiency has been incriminated but without good evidence.

In summary, the clinical picture of kwashiorkor varies greatly from one geographical area to another and the only two signs that are common to all areas are the oedema and the growth retardation. Mental changes, skin lesions, and hair changes are common, but not invariable, features of the syndrome. The low body weight associated with the almost total disappearance of body fat and the gross wastage of muscles in marasmus is characteristic of the condition.

Associated Deficiencies

Associated deficiencies vary according to the dietary patterns of the patients prior to their illness. In some areas such as southern India and Indonesia clinical vitamin A deficiency (xerophthalmia) is frequently observed and in some children it takes a severe course and leads to keratomalacia. Signs attributable to riboflavin deficiency, including glossitis, cheilosis, angular stomatitis, and perineal dermatitis, are commonly observed in many parts of the world. A moderate hypochromic anaemia is usually present in uncomplicated cases of PEM, the haemoglobin level being around 10 g per 100 ml of blood and the red cell count 3 500 000–4 000 000 per mm^3. Protein deficiency appears to be the primary cause of this anaemia but iron deficiency is usually present also. The anaemia is seldom more severe unless there is a concommittant malaria or hookworm infection. Macrocytic anaemia with megaloblastic changes in the bone marrow caused by an associated folic acid deficiency has also been observed. Sometimes, the marrow shows only fatty aplasia.

Most children ill with kwashiorkor are deficient in certain minerals but those with marasmus are generally less deficient in electrolytes. Potassium is usually deficient and magnesium deficiency has been reported in Central America, Jamaica, and South and West Africa.

Pathological Changes in Protein–Energy Malnutrition

The most striking pathological changes in kwashiorkor are the oedema and fatty infiltration of the liver. When the liver is extremely fatty, serum bilirubin levels may be raised. Atrophy of the exocrine pancreas is also characteristic. Atrophy of the jejunal mucosa is common in PEM and lesions of the central nervous system have also been reported in very young children suffering from PEM. In fatal cases there are usually signs of additional infections, especially bronchopneumonia.

Biochemical Changes

A number of biochemical changes have been described in the blood, urine, gastrointestinal secretions, endocrine functions, and tissue composition in PEM. The changes that are most important in diagnosis and treatment are summarized here. The possibility of performing the required tests without elaborate facilities has been taken into consideration.

The biochemical changes occurring in protein-energy malnutrition have been reviewed by a number of authors; some of the most recent reviews are those of Waterlow & Alleyne (*14*), Whitehead & Alleyne (*15*), and McCance (*16*).

Changes in the blood

Serum proteins and albumin

Serum albumin and serum total protein are markedly decreased in kwashiorkor. The albumin level is well below 3 g per 100 ml of blood and there is a corresponding reduction in the albumin/globulin ratio. There is still some conflict of opinion about whether this is a late event or whether it develops gradually as protein deficiency progresses, in which case it may be one of the earliest indications of protein malnutrition (*17*, *18*). In the past serum albumin was regarded as a rather insensitive index of early protein malnutrition but there is now some evidence indicating that small changes in the albumin level can already be detected in the very early stages of protein malnutrition. A reduction of 20% below the normal mean albumin level in an individual should be considered suspicious.

The serum albumin level is one of the most useful biochemical indicators of PEM because of the relative ease with which it can be measured, and it is an excellent indicator of the effect of treatment during the early stages of rehabilitation—the albumin concentration rises very rapidly, long before body weight or muscle mass are restored to normal. As far as the globulin fractions are concerned, it is interesting to note that in PEM the γ-globulins remain unchanged or there may even be an absolute increase in their quantity in the presence of infections, although there is a decrease in the β-globulin fraction. In marasmus, the total protein and albumin levels are normal or slightly reduced.

Transferrin and prealbumin (thyroxine-binding prealbumin)

It has been claimed recently that these two serum components are sensitive indicators of protein deficiency and its improvement by nutritional treatment. Their levels already show a decrease in prekwashiorkor states. Prealbumin can be measured by semitrained technicians working under field conditions in drops of blood taken from the fingertip (*19*).

Plasma/amino acid ratio

Alterations in the proportions of free plasma amino acids have been observed in children under conditions of a restricted protein intake and in kwashiorkor. The most salient change is a fall in concentration of most of the essential amino acids, particularly the branched chain amino acids, with lysine and phenylalanine being less affected. The nonessential amino acids are well maintained or even increased in concentration. The more distorted the amino acid pattern, the higher is the plasma/amino acid ratio.

The measurement of the ratio is not valid in countries where malnourished children usually present with nutritional marasmus because it seems to be of value only in areas where dietary protein deficiency is the main nutritional problem.

Changes in the urine

Hydroxyproline index

It has been shown that the urinary hydroxyproline excretion, which has been proposed as an indicator of the rate of growth of children, is markedly reduced in children with protein–energy malnutrition. In Jamaica, for instance, it has been reported that in protein-depleted infants, the hydroxyproline excretion, which was 2.6 mg per kg body weight per day, increased after treatment to 6.5 mg per kg per day. The hydroxyproline/creatinine ratio falls with age between 6 months and 5 years. Since the age of a child is very often unknown in developing countries, the *hydroxyproline index* (*20, 21*) has been introduced in order to avoid using an age-dependency factor. This index adds the parameter of weight to the hydroxyproline/creatinine ratio.

$$\text{Hydroxyproline index} = \frac{\mu\text{ mol hydroxyproline/ml}}{\mu\text{ mol creatinine/ml per kg body weight}}.$$

The index is essentially constant between the age of 6 months and about 5 years; it is low in malnourished children.

Elevated hydroxyproline levels, however, have been found in severely malnourished children with hookworm infestations or malaria; other infections may possibly have the same effect of raising the hydroxyproline level. This somewhat reduces the significance of the index.

Creatinine excretion

The urinary excretion of creatinine decreases in relation to the reduction in the muscle mass. It is low, therefore, in both the kwashiorkor and the marasmic types of malnutrition.

Water and electrolytes

Water. The total body water and especially the extracellular fluid volume are increased in all forms of protein–energy malnutrition (kwashiorkor and marasmus). At the same time, there may be clinical signs of dehydration (sunken eyes and fontanelles, loss of skin turgor, dry mucosae).

Sodium. The total sodium is increased although in some cases the serum sodium and osmolarity are seen to be reduced. This occurs particularly in patients who simultaneously have oedema and signs of dehydration.

Potassium. Serum potassium levels may be low, e.g., 3–3.5 mEq/litre, but are not necessarily so (*22*). Measurements of whole body potassium show that the total body potassium deficit may be as great as 40% (*23*). The ratio of muscle potassium to muscle nitrogen is usually also reduced, but this is not a universal finding and in some areas the ratio has been reported to be unaffected (*24*). The level of potassium deficiency seems to vary with the type of diet consumed by the child before he fell ill and the dietary potassium intake.

Magnesium deficiency. This is shown clinically by rigidity and classic convulsions, which respond rapidly to intravenous magnesium. Low serum magnesium levels have been reported in Nigeria; analysis of muscle biopsy specimens and balance studies in Jamaica and South Africa have demonstrated a magnesium deficiency and an avid retention of magnesium during recovery. Muscle appears to be the tissue most likely to be depleted of magnesium. However, it is not known how common the magnesium deficiency is elsewhere.

Acid–base equilibrium. A compensated hyperchloraemic acidosis (normal pH, low total carbon dioxide, increased chloride) is often observed in PEM (*22*).

Carbohydrate metabolism and endocrine function

Blood sugar may be low (less than 30 mg/100 ml, for example) and in some cases hypoglycaemia has been suspected as the cause of death. The administration of glucose in severe cases is, however, not always effective. Glucose absorption appears normal in most cases although the metabolism of intravenous glucose and galactose loads has been observed to be abnormal. Reduced disaccharidase activity in the intestinal mucosa is observed in a certain number of children; it usually responds to treatment.

Pancreatic secretion

Reduced enzymatic activity of the exocrine pancreatic secretion has been observed repeatedly. This reduction is transient and the enzymatic activity returns rapidly to normal during treatment, usually by the end of the second week.

Summary

In practice, and taking into consideration the limited laboratory facilities usually available for diagnosis under field conditions, the aim should be to measure as a minimum the levels of albumin and haemoglobin in the blood; a microscopic examination of the stools will also be useful for the identification of parasites. Determination of the prealbumin fraction may also become a diagnostic technique of practical importance.

Differential Diagnosis

The oedema of kwashiorkor should be differentiated from that in hepatic and renal diseases and cardiac failure. The most common condition with which kwashiorkor may be confused is nephrosis, but this disease is seen far less frequently than kwashiorkor. In nephrosis, large quantities of albumin are present in the urine; ascites is also frequently observed.

The dermatosis of kwashiorkor can be confused with pellagra but the distribution is different and in kwashiorkor it is not confined to areas of skin exposed to sunlight.

Heavy hookworm infections may be associated with kwashiorkor; the detection of a large number of hookworm ova in the stools should therefore not preclude the diagnosis of malnutrition.

Treatment of Protein–Energy Malnutrition

The treatment of mild to moderate cases of PEM requires the administration of an adequate diet and the control of infectious processes. It can be given routinely on an ambulatory or semi-ambulatory basis and should always be accompanied by appropriate nutrition and health education for the mother and other persons taking care of the child. In India, for instance, mild to moderate cases of kwashiorkor have been successfully treated on an outpatient basis by providing the children with nutritional supplements to accompany the usual home diet and giving the mother proper advice on the best way of using these supplements. For a full discussion of the various approaches to the prevention and treatment of PEM the reader is referred to Chapter 23.

The treatment of severe cases of PEM, especially if they are complicated by dehydration and electrolyte imbalances and/or infections, is better carried out in hospital since the correction of dehydration and the treatment of infections demand immediate attention. In many instances, however, hospitalization is not possible. Nevertheless, a great deal can still be accomplished in the home through simple ambulatory measures.

The basic principle of treatment is to raise the child's nutritional level as quickly as possible by providing him with sufficient amounts of energy-producing food and high quality proteins. The child may have to be tube-fed during the initial period of treatment, and the diet must therefore be in a form suitable for this kind of feeding if it proves to be necessary. The quantities of protein and energy to be provided vary according to the child's clinical condition. In kwashiorkor, it is generally agreed that 125–150 kcal (0.52–0.63 MJ) per kg per day and 3–4 g of good quality protein per kg per day will cover the child's needs. There is a tendency at present to increase the energy value of the intake as much as possible since experimental evidence indicates that weight gain depends, within certain limits, much more on energy intake than on protein (*25, 26*). Levels of 200 kcal (0.84 MJ) per kg per day are frequently administered nowadays, especially in cases of marasmus.

Milk is usually the most readily available source of good quality protein, as well as being generally the easiest form in which to administer protein to the child. Whole milk has many advantages, but for economic reasons skimmed milk, being less expensive, is usually more readily available and is therefore generally used. The disadvantage of skimmed milk, apart from its lower energy value, is its high lactose content, which may cause diarrhoea when intestinal lactase levels are low. This potential disadvantage may be partly corrected by adding casein to the skimmed milk, thereby reducing the proportion of lactose in relation to the protein.

Formulas for mixtures often used in the initial period of treatment are shown in Table 5.

Table 5. Food mixtures for the initial treatment of PEM

Ingredients	Mixtures			
	No. 1	No. 2	No. 3	No. 4
Skimmed milk, dried (g)	100	–	35	–
Whole milk, dried (g)	–	130	–	50
Casilan (calcium caseinate) (g)	–	–	25	25
Sucrose (g)	40	40	40	40
Vegetable oil, such as cottonseed or peanut oil (g)	50	20	70	55
Energy, kcal (MJ)	972(4.07)	980(4.10)	1 000(4.18)	990(4.14)
Protein (g)	35	33	35	35

These mixtures are made up to 1 000 ml with boiled water. Administered at the rate of 125 ml per kg per day, they provide approximately 125 kcal

(0.52 MJ) per kg of body weight and slightly over 4 g of protein. It is necessary to include fairly substantial quantities of fat in order to provide the child with the necessary energy without the quantity of food offered becoming disproportionately large. It should be noted that the quantity of liquid offered may be slightly below the physiological requirements of the child and it may be necessary to administer a supplement in the form of water or fruit juice. The treatment is usually started with mixtures No. 1 or 2, depending on the type of milk available.

Diarrhoea is a common sign of PEM and as such it will be observed during the early days of treatment. The pathogenesis of the diarrhoea is not well understood but it should not be regarded as a contra-indication to the initiation of the dietary treatment. The diarrhoea will usually disappear spontaneously with the restoration of the general condition of the child. Only when it persists or becomes more acute should an infectious intestinal process or a sugar intolerance be suspected and the reducing sugar content as well as the pH of stools should then be determined. If the pH of the stools (determined with special indicator paper) is lower than 6.0 and more than 0.5% of reducing substance is present (estimated with commercially available tablets), there is a serious possibility of sugar intolerance and a diet low in lactose (mixtures No. 3 or 4) should be substituted (*27, 28*). A mixture of this type (K-Mix-II) is provided on request by UNICEF. Its composition is as follows: casein, 3 parts; skimmed milk powder, 5 parts; sucrose, 10 parts. If acid, loose stools persist or excessive reducing substances are still found in the stools, fructose should be used in place of sucrose. A typical formula is as follows:

Casilan (calcium caseinate)	45 g
sucrose or fructose	50 g
vegetable oil	70 g
water	to 1 000 g

This formula, which also provides approximately 4 g of protein and 125 kcal (0.52 MJ) per 125 ml, is virtually free from vitamins and electrolytes. A mixture of minerals containing 2.0 g of sodium chloride, 2.0 g of potassium chloride, and 0.25 g of magnesium hydroxide should be added to 1 litre of the preparation. A vitamin supplement is also essential. A diet of this type is obviously inadequate in many respects and should not be continued over long periods.

It is necessary in most cases to provide the child with a potassium supplement to help replenish the reserves used up during rapid protein synthesis; this can easily be done by giving 1–2 g of potassium chloride orally every day for the first 2 weeks of treatment.

Although milk is the usual source of protein in the treatment of PEM, there is considerable evidence to indicate that vegetable protein sources alone can give satisfactory results in the treatment of mild to moderate forms of PEM or in severe forms of PEM *after* the initial stages of treatment.

A suitable vegetable protein mixture is produced and distributed by UNICEF under the code name of PKFM (i.e., prekwashiorkor feeding mixture). Its composition is as follows: cornmeal 39%, full fat soya flour 38%, dry skimmed milk 5%, sugar 15%.

In the first days of treatment it is often necessary to divide the diet into a large number of small meals to be given every 2 hours by spoon. This feeding is time consuming, and if the mother is not present or cannot assist with feeding the almost constant presence of the nursing staff is required. The expression "tender loving care" (TLC) is more than ever appropriate here, and its fulfilment has a direct bearing on the results that can be expected from the treatment.

If the child's anorexia is severe, gastric intubation at the rate of 10–15 drops per minute may be necessary. Polyethylene or flexible Nylon tubing (size 2; 1 mm internal diameter) should be used; the end of the tubing is smoothed with sandpaper or placed in a flame for about a second. Generally, tube feeding can be stopped after a few days since the child soon regains enough appetite and strength to take nourishment himself.

In severe cases, it is often advantageous to increase the intake of protein and energy progressively rather than start with the full formulation (*29*). The child may, for example, receive 50% of the recommended intake prepared in the standard volume of water (125 ml/kg) on the first day, 60% on the second day, 75% on the third, 90% on the fourth, and 100% on the fifth and subsequent days. The rate of increase should be determined according to the clinical status of the child.

After 2 weeks on the milk diet, and often sooner, the child has generally recovered sufficiently to allow the regimen to be supplemented with meat, fish, and the traditional ingredients of the local diet, such as beans, rice, plantain, cornmeal, and palm oil. This supplementation can be started earlier if the child's appetite permits it and the stools are normal.

The administration of vitamins is indicated during the early stages of treatment, whether or not there are signs of avitaminosis, before the child is placed on a mixed diet, and especially when Casilan is substituted in whole or in part for the milk. A prophylactic multivitamin preparation should be used. In order to prevent the serious ocular lesions associated with vitamin A deficiency that may develop suddenly in areas where vitamin A deficiency is prevalent, the administration of a large dose (about 100 000 international units) of a water-miscible preparation of this vitamin by intramuscular injection is recommended on the day of admission. This should be followed by daily oral administrations of about 10 000 IU of a water-miscible or oil-soluble preparation until the child is receiving, and tolerating, a diet providing adequate amounts of this vitamin.

An iron supplement of 30 mg per day of elementary iron in the form of oral ferrous sulfate (or any other well-absorbed iron salt) is also required after the first few days of treatment to correct any iron deficiency that may be present or develop in the presence of intense erythropoiesis. Folic acid (1 mg/day) is indicated in the case of macrocytosis.

The need to administer supplementary potassium at the rate of 1–2 g per day has already been mentioned. Some fruits (bananas) and vegetables (carrots) are particularly rich in potassium and may therefore make a useful contribution to the diet in this respect. Magnesium therapy may also be necessary in severe cases of kwashiorkor in regions where associated magnesium deficiency has been reported to occur. Because of the danger of high magnesium levels following parenteral administration if kidney function is impaired by dehydration or hypotension, care must be taken to correct any dehydration before parenteral magnesium is administered. A 50% sterile solution of magnesium sulfate ($Mg\ SO_4 . 7\ H_2O$) can be given intramuscularly during the early days of treatment as follows: 250 mg for a child under 7 kg in weight; 500 mg from 7 to 10 kg; 750 mg between 10 and 15 kg, and 1 g above 15 kg. After 1 week, or after the child has recovered sufficient appetite, the magnesium is administered orally.

Complications may arise, especially in the early stages of treatment, that require special therapeutic measures, but it cannot be overemphasized that a suitable diet is the mainstay of treatment. After the initial stages, in which some special dietary items may be necessary, the diet should, as far as possible, be related to local foods and cultural practices and to the diet likely to be available in the child's home. The opportunity must be taken to ensure that the parent or guardian of the child understands how to feed the child when he returns home.

Hypothermia and shock

In severe cases of PEM (children with a serum albumin level below 1.5 g per 100 ml of blood) hypothermia and shock are frequently observed. It is important under these circumstances to keep the child warm, and care should be taken that this temperature does not fall below 36.6°C. This can be achieved either by placing the child in a warm cot or by putting him in bed with his mother. The state of shock must be treated as promptly as possible by continuous intravenous injections of saline–dextrose solution (normal saline + 5% dextrose; 200 ml of fluid per kg during the first 24 hours). In the most severe cases plasma or whole blood may also have to be administered. Intravenous administration of potassium (5 mEq/kg per day) is also indicated if the child is in a depleted condition.

The administration of whole blood is indicated when the child has severe anaemia. Such cases are rare. The use of packed red cells rather than whole blood may be preferable to avoid precipating congestive cardiac failure.

The administration of saline–dextrose solution may also be indicated if the child loses his oedema very rapidly under treatment. As a practical rule, it should begin as soon as the child loses more than 10% of his weight per 24 hours. However, care should be taken to see that there is no overdosage of fluids because more deaths are caused by overadministration of fluids (leading to cardiac failure and pulmonary oedema) than by underadministration.

Hypoglycaemia

Hypoglycaemia may develop without the child showing the typical signs of restlessness, shivering, and sweating. It is usually prevented by offering the child frequent small feeds, but in some cases intragastric glucose or, better, continuous intravenous infusion of glucose might be indicated. It should be recognized, however, that in some instances these measures are not particularly effective.

Heart failure

Heart failure has been reported as one of the complications that may arise, especially during the second half of the first week of treatment. It is diagnosed by the usual signs—namely:

(1) a sudden rise in weight although oedema is being lost;

(2) an acute and alarming increase in the respiratory rate;

(3) a rapid and considerable enlargement of the liver, which becomes tender;

(4) the frequent appearance of a triple rhythm.

Its occurrence appears to be much less frequent when the dietary sodium intake is low.

Pulmonary and gastrointestinal infections

Pulmonary diseases can develop extremely rapidly and soon cause death; the routine administration of antibiotics has therefore been adopted by some medical practitioners during the first days of hospitalization. Although good results have been reported, it is difficult to assess accurately the advantages of this procedure. As children ill with PEM are very susceptible to infection, routine treatment with antibiotics is probably advantageous when close surveillance is not feasible or when diagnostic facilities are limited.

Diarrhoea is a common feature of PEM. In most cases no infective agent can be identified and the diarrhoea responds well to dietary therapy. Occasionally it may be due to a specific infective enteritis, in which case the administration of antibiotics may be necessary. In the great majority of cases, the presence of diarrhoea is not a justification for postponing the institution of dietary treatment. However, if the diarrhoea is really profuse or there is intensive vomiting, it may be necessary to postpone dietary treatment for 1 or 2 days; in this event, the child should be given adequate liquid such as Darrow's solution[a] in 2.5% glucose, either by the intravenous or the intragastric route; the intraperitoneal route may also be used. The volume administered will depend on the child's state of hydration and the severity of diarrhoea. After 24 hours of this treatment, it will usually be possible to start the feeding.

Finally, strict hygienic measures must be taken during hospitalization, including semi-isolation of the child, prompt changing of soiled linen, daily baths, the preparation of clean food, and the control of flies.

Malaria, like bacterial infections, must be treated immediately (half a tablet of chloroquine daily for 3 days). On the other hand, it is preferable to wait until the child has recovered sufficiently before administering anthelminthics against intestinal parasites. When there is *severe* hookworm infection, however, it may be necessary to treat the child at an early stage in view of the heavy demands in terms of iron and protein imposed on the body by the infection. Heavy ascariasis is another infection where early treatment may be indicated.

To sum up, the principles of treatment are simple. However, the importance of correct and vigilant nursing care and of strict hygiene cannot be overemphasized as essential prerequisites for the success of the treatment. It may be opportune to stress here the need for an adequate nursing staff to take care of the children. Most of the nursing staff do not need extensive training or much technical knowledge since their main, and almost only, function is to feed the children properly, to keep them clean, and to provide TLC. Young adolescent girls after a short period of training can easily discharge these duties under the supervision of trained nurses.

In some parts of the world, the sick child is usually hospitalized with his mother. This practice provides an excellent opportunity for educating the mother on the consequences of inadequate diets, the importance of proper feeding, and how this can be achieved within the cultural and socioeconomic condition of the family. Rehabilitation centres (see Chapter 23) treating uncomplicated third-degree malnutrition might offer similar opportunities. The hospitalization of mothers with their sick children should therefore be recommended whenever the local situation and cultural conditions permit it.

Ideally, the length of hospitalization of patients with severe PEM should be kept to a minimum. If infectious episodes can be controlled, 2–4 weeks is usually long enough for the large majority of children to be out of danger and well on their way to recovery. Afterwards, they should receive treatment on an ambulatory or semi-ambulatory basis. A general paediatric ward is not the best place for children already in the "consolidation of cure" stage when the only treatment being provided is an adequate diet. The children are subject to the risk of cross-infection, which delays recovery,

---

[a] An aqueous solution of 240–280 mg of potassium chloride, 380–420 mg of sodium chloride, and 550–630 mg sodium lactate per 100 ml.

and they also occupy hospital beds that are badly needed for other children. When the patients cannot be followed up properly after discharge they should be transferred from the hospital ward to a nutrition rehabilitation centre, where the cost of treatment is much lower. This reduces the length of hospital treatment and therefore liberates beds in the paediatric wards. The speed of rehabilitation varies widely from one child to another but usually between 2 and 4 months are needed for full recovery.

Results of treatment

With the treatment as described above and at the indicated levels of energy and protein intake, the child, after losing his oedema (7–10 days) may gain 10–15 g per kg per day—a rate of growth 20 times faster than that of a normal child of the same age. Nitrogen balance studies and measurements of total body potassium indicate that the tissue gained is of normal composition. It is of great importance to secure these rapid weight gains and a child can only be considered nutritionally cured when he is free from symptoms and has achieved the expected weight for his height, although he may still be below normal height for his age.

Mortality during treatment is difficult to assess accurately because it depends on the severity of the condition, the age of the children, the type of malnutrition, the intercurrent infections, and the association of complications such as dehydration at the time the children are admitted to hospital. These factors, together with differences in the quality of the hospital services (diligence, patience, and availability of staff), probably explain the great differences in death rates reported from various places; they range from 5% to 40%, with an average of 10–15%. It is suspected that the high figures reported in some hospitals may be due to the large number of cross-infections occurring when strict sanitary conditions are not maintained throughout the treatment, and the poor training of the personnel handling these patients. The frequency of relapses depends to a large extent on the socioeconomic environment to which the children return after treatment. Relapse rates of 5–30% have been reported. Follow-ups conducted over several years show that surviving children may be as tall and heavy as their siblings who were never admitted to the hospital for malnutrition (*30*); it does not necessarily follow, of course, that they or the sibblings are normal.

Mild Protein–Energy Malnutrition

Growth retardation is common in the developing countries and this is shown particularly by the available data on average weight and height for age. Growth performance is relatively good up to about 6 months of life but thereafter there is a lag, which is especially marked in the first 3–4 years of life. Curves of average weight-for-age are commonly below the tenth percentile and very often close to the third percentile of American or European weight curves. Closer study suggests that growth is probably sub-optimal even from about the fourth month. This may be the result of an impaired nutritional condition from birth. Maternal diets are often borderline or below, with little increase during either pregnancy or lactation by comparison with those of nonpregnant, nonlactating women. This is probably partly responsible for the low birth weights observed in some areas and some of the slower rates of growth seen in childhood. The general contributing causes are the same as those in frank malnutrition. Insufficient energy and protein intake coupled with intercurrent infections are responsible for this retardation of growth.

The child who is undernourished or malnourished and retarded in growth is more prone to infections, which produce higher mortality rates in such children, particularly toddlers (1–4 years), than in well nourished children. Underlying the high mortalities caused by many childhood diseases and the almost universal growth retardation are both energy and protein deficiencies. Although poverty is the main contributing cause, it is aggravated by lack of proper dietary knowledge. The importance of the latter has been brought out in areas of India such as the Punjab, where dramatic increases in food production resulting from the introduction of new varieties of high-yielding cereals have failed to reduce the high level of malnutrition owing to poor feeding practices.

Mild malnutrition appears to be extremely frequent. In a recent survey of the Central American countries, for instance, frank cases of PEM were observed in only 0.1 to 0.9% of the children below 5 years of age, depending on the country. On the other hand, 50–73% of the children below 5 years were suffering from mild to moderate forms of PEM, judging by the weight deficit for age. In India, a very large number of children below 5 years of age belonging to the poorer socioeconomic groups suffer from mild to moderate forms of PEM.

Prevention

The factors responsible for PEM are multiple and some of them act synergistically. All the causative factors are related to underdevelopment; they include poverty, lack of education, poor environmental sanitation and personal hygiene, qualitatively and quantitatively inadequate food supply, poor housing, too many children, insufficient spacing between births, poor distribution of food within the family, and a disrupted family life. Prevention of PEM must take all these factors into consideration. A number of action programmes may thus be devised to help in changing the ecosystem in which the child is hardly able to survive and where PEM is frequent. Besides these general measures, which, in view of their character, require many years to exert any noticeable effect, a number of specific measures can be taken that, although they will not eradicate PEM, will help to improve the situation fairly quickly (see Table 6). These measures include those for:

(1) maintaining the nutritional status of the child at the highest possible level,

(2) reducing the risk of infectious diseases and correcting diets that are deficient,

(3) minimizing the effects of infectious diseases on the nutritional status of the child, and

(4) rehabilitating the malnourished child when he is still in the early stages of PEM.

The definition of a preventive programme in any particular area must be based on an analysis of the factors responsible for the existence of PEM; only this approach will permit limited resources to be correctly utilized.

Maintenance of the nutritional status of the child

Programmes designed to maintain the nutritional status should start when the child is still *in utero*, almost from the time of conception. There is considerable evidence to indicate that premature or light-for-dates babies are handicapped in terms of future growth and physical development. A poor state of nutrition of the mother during pregnancy will definitely affect the offspring. Improvement of the nutritional status of the mother through food supplementation whenever there are indications that it may be unsatisfactory is therefore a prerequisite. There is now good evidence to show that supplementation of malnourished women during pregnancy is beneficial, at whatever time it is given.

After birth and during the first months of life, usually up to the fourth, depending upon the lactation performance of the mother, breast milk should be the mainstay of the infant's diet. No additional foods are necessary provided sufficient breast milk is available, and there may even be a risk of infection when they are given other food in addition to the breast milk. After 4 months, semisolid foods should be introduced gradually in increasing quantity and range. The first food to be offered is very often a gruel made of the staple indigenous food. The latter may be poor in some nutrients and there is thus a need to develop combinations of local foods that might be adequate from the nutritional point of view and acceptable economically. The concept of village-level multimixes has been developed by Jelliffe (*31*) for this purpose. These mixtures, which are nutritionally balanced, constitute an adequate supplement to breast milk when the latter becomes insufficient to cover the nutrient requirements of the young child during the transitional process of weaning. Some examples of these multimixes are shown in Table 7 and others are given by Cameron & Hofvander (*32*) and Jelliffe (*33*).

Table 6. Summary of objectives and activities in the control of malnutrition in young children [a]

Levels of intervention	Objectives	Activities
I. General	Establishment of a food and nutrition policy and agricultural development. Expansion of education. Improvement of environmental sanitation. Raising of standards of living.	Establishment of a coordinated food and nutrition policy Food production programmes including development of agricultural industries Fundamental education Socioeconomic measures directed to the less privileged groups and development of opportunities for employment Food prices and minimum wage policies, etc.
II. Specific Health promotion	(*a*) Improvement or maintenance of nutritional status	(1) Measures directed to pregnant and lactating women (education, distribution of supplements, etc.) (2) Promotion of breast-feeding (3) Development of low-cost weaning foods (4) Measures to improve family diet, including food distribution programmes; demonstration kitchen (5) Nutritional education in cooperation with health and agricultural extension services, schools, social services, and home economics (6) Spacing of births
Health protection	(*b*) Control of infectious and diarrhoeal diseases	(7) Expansion of immunization programmes (8) Food and personal hygiene (9) Promotion and provision of more suitable domestic utensils for infant food preparation and feeding
Treatment and rehabilitation	(*c*) Minimizing the effects of infectious diseases	(10) Early diagnosis and treatment of all infections (11) Development of programmes for early rehydration of children with diarrhoea (12) Development of supplementary feeding programmes during epidemics (13) Deworming of heavily infested children
	(*d*) Early detection and management of mild cases of malnutrition	(14) Periodic surveillance of population at risk (15) Food supplementation and fortification
	(*e*) Improved treatment, early and complete rehabilitation of moderate and severe cases of malnutrition	(16) Ambulatory treatment; nutrition rehabilitation services (17) Hospital treatment (18) Follow-up care through supplementary feeding and nutrition education

[a] Adapted from the eighth report of the joint FAO/WHO Expert Committee on Nutrition (*3*).

Table 7. Village-level multimixes

Mix	Ingredients
Double mix	Staple + legume or Staple + animal protein [a] or Staple + dark green leafy vegetable (DGLV)
Triple mix	Staple + legume + animal protein or Staple + legume + DGLV or Staple + DGLV + animal protein
Quadrimix	Staple + legume + DGLV + animal protein

[a] Mixtures with animal protein are preferable in all mixes.

These multimixes can easily be prepared at home by the mother.

Industrially processed weaning foods are also a useful supplement to the diet of the infant and the young child, especially in urban areas. In the industrialized countries these weaning foods are usually based on cereals and the concentration of protein varies widely from one preparation to another. This is usually of little consequence since they are meant to be mixed with milk at the time of final preparation or to supplement a diet based on milk. In the developing countries, milk may be rare or relatively expensive, and there is therefore a need to develop weaning foods rich in energy and proteins, which do not need an additional source of protein in order to constitute a nutritious supplement to the diet of the young child. The development of these "protein-rich weaning food mixtures" is described in Chapter 27.

In many human cultures spacing of births is a customary practice, and breast-feeding, possibly by retarding the initiation of ovulation after delivery, may be a factor in the prolongation of the birth interval. Unfortunately, there is a tendency for these practices to be less frequently followed, with the result that pregnancies may succeed one another at short intervals and jeopardize the chances for full rehabilitation and restoration of the mother's reserves, and also affect the offspring, whose feeding at the breast may be curtailed. Spacing of children through family planning is therefore desirable for maintaining the health of the mother and for the optimum development of the child.

Control of infections and diarrhoeal diseases

The poor sanitary condition of food and utensils in contact with it are to a large extent responsible for the high frequency of diarrhoeal diseases observed in children in developing countries. Health education may partly remedy this situation. Changes in the types of utensil may also be helpful. There is no doubt, for instance, that the bottle and teat used in bottle-feeding are difficult to clean and to keep clean; a small saucepan may be a much more convenient container for feeding infants and young children. Immunization programmes are particularly effective against childhood diseases, especially measles and whooping cough, which are responsible for outbreaks of severe forms of malnutrition in many areas. Protection against tuberculosis and malaria is also important.

Minimizing the effects of infectious diseases

Diarrhoea—dehydration and early rehydration

In areas where diarrhoea is endemo-epidemic, dehydration is frequently a result of the diarrhoeal episodes, especially in young children and is often accompanied by some degree of protein–energy malnutrition. It is therefore important to prevent outbreaks of diarrhoea by improving environmental sanitation and food hygiene. However, in the absence of these primary preventive measures, the dehydration should be treated as early as possible in order to prevent a severe form of malnutrition in the affected children. An excellent measure, the value of which has now been proved repeatedly, is the establishment of centres for early rehydration therapy at the village, or equivalent local, level.

In the presence of diarrhoea, there is a loss of fluids and electrolytes resulting in saline depletion (extracellular fluid deficit), metabolic acidosis (base deficit), and potassium deficiency.

Saline depletion.

(1) This accounts for most of the clinical signs of severe diarrhoea.

(2) It is first detectable when about 4–5% of the body weight has been lost.

(3) The maximum acute loss compatible with life is 10–12% of the body weight.

(4) The clinical signs are as follows:

(*a*) mild (loss of 4–5% of body weight)—thirst, slight loss of skin turgor, tachycardia;

(*b*) moderate (loss of 7–8% of body weight)—tachycardia, weak pulse, restlessness, moderate loss of turgor;

(*c*) severe (loss of 9–12% of body weight)—poor skin turgor, sunken eyes, sunken anterior fontanelles, radial pulse absent, hypotension, stupor, cold extremities, cyanosis, muscle spasms of extremities, hoarseness.

Metabolic acidosis.

(1) This is a result of bicarbonate loss in the stools.

(2) The serum pH may be as low as 7.1, and the serum bicarbonate (HCO_3^-) as low as 5 mEq/litre.

(3) The consequences of acidosis are as follows:
(*a*) respiratory compensation;
(*b*) impaired cardiac function; congestive heart failure may develop during rehydration if the acidosis is not corrected;
(*c*) the serum potassium may initially be falsely elevated, in spite of the whole body potassium deficit.

Potassium deficiency.

(1) This is present in all patients with acute diarrhoea but is reflected in serum potassium levels only after rehydration and correction of acidosis.
(2) Hypokalaemia may develop rapidly during rehydration.
(3) Clinical symptoms include muscular weakness, paralytic ileus, and cardiac arrhythmia.

Rehydration therapy can be carried out via the intravenous, intraperitoneal, oral, or intragastric routes.

The intravenous route. This is used when the patient is in shock or irresponsive. A number of rehydration solutions are available, the composition of two of them is given in Table 8. Sodium bicarbonate, potassium, and glucose are absorbed in spite of the diarrhoea and can be given orally in conjunction with the parenteral therapy if necessary. The amount of intravenous fluid to be given depends on:
(1) the initial deficit (5–12% of body weight);
(2) the continuing stool losses;
(3) the maintenance, taking into account the water requirements which average about 120 ml per kg per day.

Table 8. Composition of solutions for rehydration therapy

Administration route	Electrolytes				Glucose (mmol/litre)
	Na^+ (mEq/litre)	Cl^- (mEq/litre)	K^+ (mEq/litre)	HCO_3^- (mEq/litre)	
Oral	90	80	20	30	150
Intravenous	60–70 [a]	50–70	– [b]	30	150–300
	127 [c]	109	4 [b]	28 (lactate)	0
Intraperitoneal	60 [d]	51	18	27 (lactate)	150

[a] If child is in shock, a higher sodium content solution such as Ringer's lactate (127 mEq/litre of Na^+) is indicated.
[b] It may be necessary to wait until the child has passed urine before administering potassium by the intravenous route.
[c] This is Ringer's lactate solution.
[d] This is half strength Darrow's solution.

The rate of intravenous fluid administration can be calculated as follows:
(1) The shock must be corrected as soon as possible. This can be done by giving fluid rapidly at the rate of 20–30 ml/kg over the first hour.

(2) The remaining calculated deficit can be given over the next 8–12 hours.

(3) Thereafter, fluid for maintenance can be given throughout the 24-hour period.

The disadvantages of intravenous fluid therapy are that it may be difficult to initiate or to maintain in small children and, since it requires sterile pyrogen-free fluid, it is expensive.

The intraperitoneal route. This route is both simpler and requires less nursing care, but there is always a small risk of peritonitis. The great advantage is that a large amount of fluid (500–800 ml) can be given over a short period (10–15 minutes). The administration can be repeated during 8–12 hours as the need arises. It should not, however, be used as the sole route of therapy in cases of shock.

The oral or intragastric route. The oral fluid, whose composition is indicated in Table 8, can be made as follows:

Nutrient	*g/litre*
sodium chloride	3.5
sodium bicarbonate	2.5
potassium chloride	1.5
glucose	25.0

The great advantage is that it can be given by mouth and requires very little equipment (a catheter) if the intragastric route has to be used. The supplies are easily available and transported. Oral fluid should not be given to patients in shock but can be given as maintenance fluid after the patient has received the initial intravenous treatment. Its use therefore decreases the amount of expensive intravenous fluid required.

In most cases of diarrhoea, *when treatment is initiated at a sufficiently early stage, oral or intragastric therapy will be sufficient, and rehydration centres especially established for this purpose have proved to be of great value in this respect.* Such centres, which are relatively inexpensive to set up and run, are operating in many countries; they require few personnel (if auxiliaries are used they can be trained in the various techniques in a relatively short time). In view of the simplicity of the treatment, the possibility of treating the child at home should be considered if no rehydration centre exists.

In summary, oral rehydration therapy is a simple, safe, effective, and economical measure for treating the large majority of cases of dehydration observed in young children. The treatment can usually be administered by non-medical personnel and can therefore be carried out almost anywhere. The procedure requires only oral fluids in bottles and polyethylene catheters (size No. 2). Intravenous therapy may be necessary, but only in the most extreme cases; these children should always be referred by the rehydration centre to a hospital. Intraperitoneal therapy may be useful when it is necessary to administer a large volume of fluid in a short time to a child who is not in a state of shock.

Early detection and management of mild cases of malnutrition

Surveillance of children, prevention of infectious diseases, early diagnosis and treatment of all infections, and early detection of any lag in growth are essential activities in the prevention of PEM. Immunization against childhood infectious diseases is usually carried out at maternal and child health centres and under-5-year clinics, where children, particularly those at risk, may also be kept under surveillance.

The best way of assessing the child's state of nutrition is probably to use a growth chart on which weight is periodically plotted. While a single weight measurement may not give a satisfactory indication of the way a child is growing, repeated measurements will show whether his growth is satisfactory or not. A flattening of the weight curve is the first sign of a deteriorating nutritional status and of PEM. Various models of chart are now in use and one has recently been developed by WHO for international use. Most charts include spaces in which to record the "high-risk factors" that have a bearing on a child's state of nutrition. Information of this kind that is often recorded includes low birth weight, twins or multiple births, high birth order, measles, whooping-cough, and severe or repeated episodes of diarrhoea, and deaths of siblings, particularly before 12 months.

The importance of immunization against infectious diseases of childhood has already been mentioned. Prevention of infectious diarrhoea in childhood through immunization is not feasible but prevention of the secondary effects, especially dehydration, can be achieved at minimum cost with a considerable reduction in the accompanying signs of malnutrition.

REFERENCES

1. Williams, C.D. *Arch. Dis. Childh.*, **8**: 423 (1933)
2. Jelliffe, D.B. *J. Pediat.*, **54**: 227 (1959)
3. WHO Technical Report Series, No. 477, 1971 (Eighth report of the Joint FAO/WHO Expert Committee on Nutrition)
4. Waterlow, J.C. *Fatty liver disease in the British West Indies.* London, Her Majesty's Stationery Office, 1948 (Medical Research Council Special Report Series, No. 263)
5. Waterlow, J.C. et al. *Advanc. Protein Chem.*, **15**: 131 (1960)
6. McLaren, D.S. et al. *Lancet*, **1**: 533 (1967)
7. McLaren, D.S. & Read, W.W.C. *Lancet*, **2**: 146 (1972)
8. Nelson, W.E., ed. *Textbook of pediatrics*, 8th ed. Philadelphia, Saunders, 1964, pp. 48–53
9. Bengoa, J.M. The state of world nutrition. *In :* Recheigl, M., ed. *Man, food and nutrition.* Cleveland, Chemical Rubber Company, 1973

10. PUFFER, R.C. & SERRANO, C.V. *Patterns of mortality in childhood.* Washington, DC, Pan American Health Organization, 1973 (PAHO Scientific Publication No. 262)
11. DEMAEYER, E.M. ET AL. *Ann. Soc. belge Méd. trop.*, **34**: 875 (1954)
12. BÉHAR, M. & SCRIMSHAW, N.S. Epidemiology of Protein Malnutrition. *In:* Galdston, I., ed., *Human nutrition, historic and scientific.* New York, International Universities Press, 1960, p. 257
13. GARROW, J.S. *Arch. lat. amer. Nutr.*, **16**: 145 (1966)
14. WATERLOW, J.C. & ALLEYNE, G.A.O. *Advanc. Protein Chem.*, **25**: 117 (1971)
15. WHITEHEAD, R.G. & ALLEYNE, G.A.O. *Brit. med. Bull.*, **28**: 72 (1972)
16. MCCANCE, R.A. Malnutrition in the children of underdeveloped countries. *In:* Gardner, D. & Hull, D., ed. *Recent advances in Pediatrics*, 4th ed. London, Churchill, 1971, p. 479
17. WHITEHEAD, R.G. ET AL. *Lancet*, **2**: 287 (1971)
18. WITTMANN, W. ET AL. *S. Afr. med. J.*, **41**: 664 (1967)
19. INGENBLEEK, Y. ET AL. *Lancet*, **2**: 106 (1972)
20. WHITEHEAD, R.G. *Lancet*, **2**: 567 (1965)
21. WHITEHEAD, R.G. *Lancet*, **1**: 203 (1966)
22. DUBOIS, J. ET AL. *Rev. franc. Étud. clin. biol.*, **13**: 153 (1968)
23. GARROW, J.S. ET AL. *Electrolyte metabolism in severe infantile malnutrition.* Oxford, Pergamon, 1968
24. VIS, H.L. ET AL. *Rev. franç. Étud., clin. biol.*, **10**: 729 (1965)
25. WATERLOW, J.C. The rate of recovery of malnourished infants in relation to the protein and calorie levels of the diet. *J. trop. Pediat.*, **7**: 16–22 (1961)
26. ASHWORTH, A. ET AL. *Lancet*, **2**: 600 (1968)
27. DEAN, R.F.A. *Plant proteins in child feeding.* London, Her Majesty's Stationery Office, 1953 (Medical Research Council Special Report Series, No. 279)
28. DEMAEYER, E.M. *Ann. Soc. belge Méd. trop.*, **34**: 139 (1954)
29. BÉHAR, M. ET AL. *Ann. N.Y. Acad. Sci.*, **69**: 954 (1968)
30. GARROW, J.S. & PIKE, M.C. *Lancet*, **1**: 1 (1967)
31. JELLIFFE, D.B. *Child nutrition in developing countries.* Washington, DC, US Department of Health, Education, and Welfare, 1968
32. CAMERON, M. & HOFVANDER, Y. *Manual on feeding infants and young children.* New York, FAO/WHO/UNICEF Protein Advisory Group, 1971
33. JELLIFFE, E.F.P. *J. trop. Pediat.*, **17**: 3, 136 (1971)
34. *Lancet*, **2**: 302–303 (1970)

ADDITIONAL BIBLIOGRAPHY

AUTRET, M. & BÉHAR, M. *Sindrome policarencial infantil (kwashiorkor) and its prevention in Central America.* Rome, Food and Agriculture Organization, 1954

AUTRET, M. & BÉHAR, M. Le syndrome de polycarence de l'enfance en Amérique centrale (kwashiorkor). *Bull. Wld Hlth Org.*, **11**: 891 (1954)

BÉHAR, M. ET AL. *Wld Rev. Nutr. Diet.*, **1**: 73 (1959)

BÉHAR, M. ET AL. Treatment of severe protein deficiency in children. *Amer. J. clin. Nutr.*, **5**: 506-515 (1957).

BLIX, G., ed. *Mild-moderate forms of protein-calorie malnutrition.* Uppsala, Almqvist & Wiksells, 1963 (Symposia of the Swedish Nutrition Foundation, No. 1)

BROCK, J.F. & AUTRET, M. *Kwashiorkor in Africa.* Geneva, World Health Organization, 1952 (Monograph Series, No. 8)

GÓMEZ, F. ET AL. *Ann. N.Y. Acad. Sci.*, **69**: 969 (1957)

JELLIFFE, D.B. *Infant nutrition in the subtropics and tropics,* 2nd ed. Geneva, World Health Organization, 1968 (Monograph Series, No. 29)

KING, M. *Medical care in developing countries.* London, Oxford University Press, 1966

Malnutrition in African mothers, infants, and young children. *In: Second Inter-African Conference on Nutrition organized by the Commission for Technical Cooperation in Africa South of the Sahara (CCTA) at Fajara, the Gambia, November 1952.* London, Her Majesty's Stationery Office, 1954

PATWARDHAN, V.N. & DARBY, W.J. *The state of nutrition in the Arab Middle East.* Nashville, Vanderbilt University Press, 1972.

Pre-school child malnutrition — primary deterrent to human progress. *In : International Conference on Prevention of Malnutrition in the Pre-School Child.* Washington, DC, National Academy of Sciences/National Research Council, 1964 (Publication No.1282)