Nutrition and Morbidity: Acute Lower Respiratory Tract Infections, Diarrhoea and Malaria

DEBORAH LEHMMANN1, PETER HOWARD1 AND PETER HEYWOOD2

Papua New Guinea Institute of Medical Research, Goroka and Madang

SUMMARY

The three most important infectious diseases of young children in Papua New Guinea are acute lower respiratory tract infections, diarrhoea and malaria, each of which has been shown to have a negative effect on growth. Low nutritional status is associated with increased risk and severity of acute lower respiratory tract infections and with increased severity of diarrhoea. There is no evidence to indicate that malnutrition is associated with increased risk of malaria. Adequate control and prompt treatment of infectious diseases will improve nutritional status. At the same time, improvement in nutritional status will reduce morbidity and mortality due to infectious disease, particularly acute lower respiratory tract infections and diarrhoea.

INTRODUCTION

The proximate causes of growth retardation are generally agreed to include low birthweight, deficient nutrient intake and repeated episodes of infectious disease, the importance of each factor varying with the specific situation.

The most important infectious diseases of young children in Papua New Guinea (PNG) are acute lower respiratory tract infections, diarrhoea and malaria. The interaction between these infections and nutrition, particularly protein-energy malnutrition, is reviewed in this paper with particular emphasis on studies carried out in PNG.

NUTRITION AND ACUTE LOWER RESPIRATORY INFECTIONS

Acute lower respiratory tract infections (ALRI) are the commonest cause of admission and death among children in PNG. In the highlands, 47% of admissions under the age of 5 years are for pneumonia while in the lowlands pneumonia accounts for approximately one-quarter of admissions in the same age group (1). Data from Tari, Southern Highlands Province (SHP) show that on average there are 2.5 episodes of ALRI per child under one year of age and 1.6 episodes per child aged 12-23 months (2). Children under one year of age suffer more severe disease than older children: 20% of ALRI episodes in infants are classified as moderate-severe disease (the children have chest indrawing in addition to cough and breathlessness with or without fever), and one-tenth of those with chest indrawing have signs of more severe disease (difficulty in feeding and/or cyanosis and/or heart failure). In children aged 1-4 years, 10% of ALRI illnesses are classified as moderate-severe cases.

Data from Tari on children with known birthweight show that children weighing less than 2.5kg at birth have four times the risk of dying of ALRI in the first year of life compared to children who are born heavier (D. Lehmann and P. Heywood, unpublished data). Furthermore, among children who were weighed between 4 and 59 months of age and then followed in Tari (SHP) and Asaro, Eastern Highlands Province (EHP) it was found that those who were less than 70% weight-for-age (compared to the Harvard median) had eight times the risk of dying of ALRI of heavier children (D. Lehmann, unpublished data).

1 Papua New Guinea Institute of Medical Research, PO Box 60, Goroka, EHP, Papua New Guinea
2 Papua New Guinea Institute of Medical Research, PO Box 378, Madang, Papua New Guinea
Effect of ALRI on Nutrition

Mata has shown growth faltering (weight loss and height arrest) when children suffer from measles, whooping cough or ALRI, which may continue for weeks or months (3). Children who are malnourished before developing measles are likely to have more marked growth faltering and are more likely to suffer prolonged respiratory or gastrointestinal symptoms (4).

Under the stress of illness, children go into negative nitrogen balance. Tomkins et al. (5) report that during infection there is an increase in protein breakdown which is greater than the rise in synthesis of protein. If malnutrition is present at the onset of infection, these responses to infection are reduced.

The high incidence of ALRI in young children in PNG contributes to the deterioration in nutritional status over the first two years of life. Children who suffer from ALRI become anorexic and have difficulty feeding because of breathlessness, and therefore their food intake falls.

Effect of Nutrition on ALRI

Malnourished children have depressed immune responses which make them more vulnerable to infection. Delayed cutaneous hypersensitivity (DCH) to various antigens (an expression of cell-mediated immunity) is impaired in malnourished children; the response correlates directly with the nutritional status and improves with nutrition therapy. Serum antibody responses may be normal or decreased, while salivary IgA, which protects against invasion by microorganisms at mucosal surfaces, has been shown to be low in malnourished children. Bactericidal activity of polymorphonuclear leukocytes is reduced in malnourished children and can be corrected with improved nutrition. Malnutrition also results in a reduction of complement components, in particular C3 (6). In highland children in PNG, antibody titres to respiratory pathogens may be lower in young children suffering from ALRI. Moreover, highland children have higher levels of immunoglobulin and depressed cell-mediated immunity compared to expatriate children of the same age (C. Witt, personal communication), suggesting, firstly, that highland children experience more infections than expatriate children and, secondly, that their immune function may be depressed.

James (7) has reported that malnourished children have similar numbers of attacks of respiratory disease as well-nourished children but that malnourished children are sick for longer and are three times more likely to develop bronchitis and nineteen times more likely to develop pneumonia. Mata (4) noted that children who grow well are likely to suffer fewer days of respiratory symptoms than those who do not grow well. By contrast, in an intervention study in India, episodes of lower respiratory infection were of shorter duration where medical services were provided, while nutrition supplementation in addition to medical services did not have a summation effect (8). However, the investigators comment that it was financially beneficial to have the two programs together and that this would provide all the benefits of a medical care program and a nutrition care program.

Data from Goroka Base Hospital, EHP show that children under two years of age who are malnourished are four times more likely to be admitted with pneumonia and, if admitted, are four times more likely to die of the disease (9). Figure 1 shows the mean percent weight for age (compared to the Harvard median) by age, in healthy children from the Asaro Valley near Goroka, in children admitted to hospital with moderate or severe disease who survive and in children who died of severe disease. The relationship between malnutrition and risk of developing ALRI and severity of ALRI is maintained irrespective of the duration of illness before admission.

Data concerning the role of iron in infection are conflicting. Weinberg (10) has reported that microorganisms require iron for growth and that during microbial infections hosts attempt to withhold iron from invading organisms. He also reports that in conditions which result in hyperferraemia or hypotransferrinaemia there is an increased risk of infection. Papua New Guinean highland children under 2 years of age are iron deficient by western standards as determined by free erythrocyte protoporphyrin (FEP) (C. Witt,
personal communication). However, in a prospective study of children from the Asaro Valley, children who were iron deficient, as measured by levels of FEP and mean corpuscular haemoglobin concentration (MCHC), were at no greater risk of developing ALRI than children who were not iron deficient (C. Witt, personal communication).

**Interventions**

The following measures aimed at controlling ALRI morbidity will assist in preventing malnutrition:

1. Prompt appropriate antibiotic therapy for a minimum of five days will reduce the number of days of illness and the associated anorexia and difficulty in feeding. Parents must be taught that children with cough and breathlessness require a course of penicillin at an aid post and that inpatient care is required for those children who in addition have difficulty feeding.

2. Aid post orderlies must treat children suffering from cough and breathlessness.
with the correct dose of penicillin. They must be able to recognize chest indrawing and difficulty in feeding and refer these children for inpatient care.

3. Immunization against measles and whooping cough as near the recommended age as possible will prevent children from developing these diseases and their chronic sequelae.

4. Pneumococcal vaccine has been shown to reduce mortality due to ALRI as the sole cause of death by 50% in young children in the highlands (11). Preliminary analysis of morbidity data from Tari shows that there is a reduction in the number of episodes of moderate and severe ALRI in the first year after being immunized with pneumococcal vaccine (T. Marshall, personal communication). There is no difference in efficacy of pneumococcal vaccine in preventing ALRI deaths among malnourished and well-nourished children (D. Lehmann, unpublished data). If pneumococcal vaccine were delivered through routine health services in the highlands in the future we would almost certainly see a reduction in morbidity and mortality from ALRI in children.

Measures taken to prevent malnutrition discussed elsewhere in this issue will reduce the risk of developing ALRI and also the risk of dying of the disease.

**NUTRITION AND DIARRHOEA**

The evidence for the strong association between diarrhoea and malnutrition in many parts of the developing world is compelling. The peak age-specific prevalence rates for both diarrhoeal diseases and malnutrition coincide in infants and children under five years of age. Both are significant problems where predisposing conditions coexist, namely inadequate and polluted water supplies, poor environmental sanitation, low levels of personal and domestic hygiene, poverty, overcrowding and low education levels. In addition, historical evidence from developed countries suggests that the correction of these adverse conditions preceded, or at least coincided with, a fall in the incidence of diarrhoea and a general improvement of the nutritional status of children.

During the last thirty years the interactions between infections, particularly diarrhoeal diseases, and nutrition have been extensively studied and keenly debated. The pioneering work of Scrimshaw and coworkers in Central America led to the hypothesis that a bidirectional causal relationship exists between diarrhoea and nutritional status. Malnutrition predisposes a child to diarrhoea and, conversely, diarrhoea causes growth retardation and precipitates severe malnutrition (12).

This synergistic relationship (diarrhoea causing acute weight loss, arrest in linear growth and malnutrition) has been demonstrated in detailed prospective studies in Guatemala (4, 13), The Gambia (14,15), Uganda (15) and Bangladesh (16). The evidence for the converse, that malnutrition predisposes to diarrhoea, is not so conclusive and is controversial. Tomkins in Nigeria (17) and Trowbridge in El Salvador (18) found that impaired nutritional status was associated with an increased prevalence of diarrhoea. One study in Guatemala (19) showed an increased incidence of diarrhoea in lighter children (lower weight for age) 1-4 years old. Two studies did not establish a relationship between three parameters of nutritional status (low weight, stunting and wasting) and incidence (7, 20), whereas Tomkins (17) showed wasting, but not low weight or stunting, to be a predictor of incidence. The only study to disentangle the component factors of prevalence (incidence and duration of episodes) is that of Black et al. (21). They found that Bangladeshi children less than 2 years old with low weight for height had episodes of longer duration but similar incidence rates when compared to better-nourished children.

In practice, where severe malnutrition and diarrhoea coexist at high levels of endemicity few could argue that there is not a close relationship between them, whatever its precise nature. Because of their multiple and often shared determinants preventive and therapeutic interventions will be directed at reducing the burden of both problems. In areas where severe malnutrition (low weight for age) and diarrhoea are present at low to moderate endemic levels,
such as PNG, it is probably difficult to define the precise nature of the interaction because of the logistic problems in studying the large sample sizes required to demonstrate the small differences between risk groups.

There are two studies which have addressed the question of the diarrhoea-malnutrition interaction in PNG. Biddulph and Pangkatana (22) showed that malnourished children (less than 75% weight for age) with severe gastroenteritis required longer periods of rehydration than well-nourished children, suggesting increased severity in the former group. In children between the ages of one and four years in Enga Province, Binns (23) found significantly higher incidence rates of diarrhoea in lighter children (less than 80% weight for age) than in their heavier peers. In addition, following episodes of diarrhoea 83% of children failed to gain weight or lost weight during the month after a diarrhoea episode. The measure of incidence in this study was based on a one-month recall by mothers, which is recognized as unreliable by most experienced field workers, and the methodological description does not allow assessment of the validity of the study for other areas of the country.

In the light of present knowledge it is not possible to draw firm conclusions about the nature of the interaction between diarrhoea and malnutrition in PNG children. However, if, as the available data suggest, the incidence of diarrhoea is low compared to many developing countries (estimated at about one episode per child per year in children less than five years old), it is perhaps worth considering why this should be so. A number of factors related to transmission and severity may combine to produce the low force of infection.

1. It appears that most cultural groups have a natural appreciation of the polluting effects of human faecal material. This is reflected in an awareness not to defaecate near water supplies and the no-touch or indirect methods used for anal cleansing. However, it is not known whether an infant’s faeces or diarrhoea stools are regarded as being more or less polluting. In spite of low levels of personal hygiene, this suggests that the level of contamination of the environment by enteropathogens is low.

2. PNG is a relatively underpopulated country and with the exception of urban and a few rural areas population densities are low and many communities relatively isolated. This probably acts to reduce the amount of inter-household and inter-community transmission. However, this situation is changing as road communications lead to increased local population concentrations.

3. Prolonged breastfeeding is almost universal in PNG societies. This practice has been protected by the Baby Feed Supplies (Control) Act of 1977, which has probably stemmed an increase in the use of bottle feeding, especially in urban areas, although unfortunately there is no hard evidence to demonstrate this.

4. In many parts of the country the nutritional status in the first five years of life is reasonably good.

5. In most rural societies, except after a large mumu (feast), when unconsumed food may be kept for some days, it appears that food is not stored overnight or for long periods during the day. Thus transmission via contaminated food may be uncommon, though this needs verification.

6. In the highlands at least, traditionally little water is drunk. Compared to some lowland areas water is plentiful and reasonably accessible although utilization for all purposes is reportedly low. From what evidence is available, it is not grossly polluted.

Whatever may be the community incidence of diarrhoea and malnutrition in PNG, they are still major public health problems as measured by the burden on curative health services. Preventive and curative interventions to reduce this burden have been given high priority in the government’s current five-year health plan (1986-90) (24). The cornerstone of the diarrhoeal disease control (CDD) program is based on correct case management – the assessment of dehydration status, appropriate oral rehydration therapy (ORT) and improved nutritional management. Current efforts focus on improved management at village level including home-based recognition, the use of home-made fluids, the maintenance of energy intake during episodes and increased feeding
during the recovery phase to ensure catch-up growth.

Preventive CDD interventions which have been given a high priority are:
1. measles immunization to reduce the morbidity and mortality from measles-associated diarrhoea;
2. the provision and increased use of safe and adequate water supplies in rural areas;
3. improved facilities for the safe disposal of faeces (pit latrines);
4. improved personal hygiene; and
5. improved weaning practices (more energy introduced at a younger age) and food hygiene.

It is recognized that the vital component to successful implementation of these interventions is the mobilization of resources at the village level. Emphasis is to be directed at the integrated primary health care approach by motivation and education of individuals and communities through schools, village-level health services (aid posts, MCH clinics and health inspectors) and the use of the mass media.

Recent publications edited by Gracey (25) and Chen and Scrimshaw (26) provide excellent reviews of the relationship between diarrhoea and malnutrition.

**NUTRITION AND MALARIA**

**Effect of Malaria on Growth**

Malaria may affect growth both ante- and post-natally.

Birthweight is an important determinant of postnatal growth (27) and the effect of malaria during pregnancy on birthweight has been investigated in a number of studies. The most convincing of these is that of McGregor et al. in The Gambia (28). The effect of placental malaria infection on birthweight was investigated in more than 6000 births. Pregnant women were more likely to have parasites in the placental than in the peripheral blood, malarial placentae were more likely in primiparous than multiparous women, and dense placental infections were also more frequent in primiparae. Mean singleton birthweight was depressed by 170g in the presence of malaria but the difference was only significant for primiparae.

The effect of malaria on postnatal growth has been investigated in two different types of studies. In the first type, examples of which are the studies in The Gambia of Marsden (29) and Rowland et al. (14), the effect of individual episodes of illness on weight gain during the period in which the illness occurred was estimated. Both studies indicated that an episode of malaria had a negative effect on weight gain in the period immediately following the episode.

Whilst an episode of malaria may have a short-term effect on growth, through depressed food intake and negative energy and nitrogen balance, the net effect of malaria on growth will depend on the extent to which the capacity for catch-up growth is subsequently realized.

The second type of study has addressed this question by estimating the net effect of malaria on growth over a much longer period of time.

The most rigorous study is that of McGregor et al. (30). Two groups of 20 newborns were enrolled in a 3-year prospective study. One group was given weekly chloroquine and the other a placebo. Unprotected children initially gained weight more slowly but subsequently gained ground and by 36 months were just as heavy as the protected group. However, the mean height of the protected children at three years of age was more than 3cm greater than that of the unprotected group.

Thus, the evidence from the one well-designed study of the longer-term effects of malaria on growth is for a negative effect on height but not weight. However, short-term studies of the effect of individual episodes indicate the reverse — a negative effect of malaria on weight but not on height. Part of this conflict can be explained by the greater short-term variability in weight than in height.

Nevertheless, although malaria may be an important factor affecting growth the fact that
both the shortest and the tallest children in PNG are found in districts in which malaria is highly endemic (Maprik and Morehead districts, respectively) indicates that other factors are also very important.

All of the studies quoted above have been in areas where malaria is highly endemic. In areas where malaria is episodic rather than endemic, such as the highlands of PNG, and immunity to malaria is less, an individual episode may be more severe and have greater effects. Thus, in Enga Province, Sharp and Harvey (31) found splenomegaly, used as an index of recent experience of malaria, to be associated with stunting in young children.

**Effects of Nutrition on Malaria**

The few studies which have addressed this question - see Heywood and Harvey (32) - have serious design and analysis flaws and it is not possible at the moment to draw firm conclusions.

**Iron**

Malarial parasitaemia usually results in some degree of anaemia in which red cell morphology is consistent with iron deficiency. Successful intervention studies have resulted in increased haemoglobin levels. At the same time there is a rise in serum iron and serum ferritin. Thus, understanding of the haematological picture in malaria is complicated since, although red cell morphology is consistent with iron deficiency, other measures indicate adequate iron status (32).

The effect of iron status on malaria is controversial. Recent studies in PNG indicate that the effect in children may depend on their immune status. In infants Oppenheimer et al. (33) showed that those subjects injected with iron supplement at 2 months of age showed significantly greater malarial parasitaemia and palpable spleens at 6 and 12 months of age than children who received a placebo. In contrast, Harvey (34) working with school-children showed no effect of an oral iron supplement, and improved iron status, on malaria.

**DISCUSSION**

Each of the important infectious diseases of children has been shown to have a negative effect on growth, at least in the short term. However, if catch-up growth after each episode is complete it is possible for there to be a negative short-term effect and no effect in the long term. One of the most important factors determining the net long-term effect is the extent to which catch-up growth occurs.

Under favourable conditions the rate of growth following a period of illness can be very high. However, most evidence indicates that although only modest increases in food intake are needed to support catch-up growth during the convalescent period, they seldom occur (35). The cultural context in which a disease occurs is likely to be an important variable influencing catch-up growth (32). The cultural context will influence not only the actual foods produced and considered food, but also who receives food and when, as well as the availability of food during an illness episode.

The synergism between nutrition and infection means that there are considerable health gains to be made by a combined attack on both malnutrition and infection. However, because the control measures for infection will often be very different from those used for malnutrition the synergism between the control programs will often not be apparent. It is important that health staff appreciate the relationship between malnutrition and infection so that control programs, including prompt and effective treatment of episodes of infectious disease, may be coordinated and the maximum improvement in the health of young children obtained.

**REFERENCES**


