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Nutrition, Infection and Child Growth in Papua New Guinea

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A B S T R A C T

Growth patterns of populations in Papua New Guinea (PNG) have traditionally shown considerable variation, with the greatest difference lying between coastal and highland populations. While genetic differences in explaining these patterns cannot be excluded, the generally poor growth relative to western growth references is largely due to the complex interactive effects of undernutrition and infection. The effects of diet, nutrition and infection on the nutritional status of a child vary with age, the general disease ecology and the type and extent of exposure to it, patterns of infant and young child feeding, and types of food consumed. There are two possible ways in which the relationship between undernutrition and infection can begin; one in which poor nutritional status leads to impaired immunocompetence and reduced resistance to infection, and the other in which exposure to infectious disease can lead to a range of factors that reduce food intake, absorption of nutrients, or increase nutrient requirements. In PNG prior to, and at early stages of modernisation, primary malnutrition is likely to have been the usual initiating factor in the onset of growth faltering due to undernutrition-infection interactions. However, the possibility that infection may have been the initiating event in some societies cannot be excluded. This would have happened by way of early dietary supplementation of infants with foods of minor nutritional significance, which could have acted as a vehicle for the introduction of infectious disease to the child. With modernisation and adoption of primary health care principles, earlier supplementation of infant diet than was previously the case became common in PNG. This has lead to general improvements in growth and nutritional status. However, in populations where undernutrition is still common, infection has become more important than primary malnutrition as the initiator of growth faltering due to undernutrition-infection interactions.

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Introduction

Growth faltering relative to western growth references has been extensively documented for populations in Papua New Guinea (PNG)[1–6]. While undernutrition has been cited as the common cause for such growth patterns, the influence of infection is also considerable, since disease patterns reflect high prevalences of malaria[7], parasitic infestation[8], as well as extensive diarrhoeal[9] and respiratory[10] infection. Interactions between undernutrition and infection are known to lead to the typical patterns of growth faltering from about the age of weaning, common in developing countries[11,12]. This is a function of both generalised and nutrient-specific undernutrition on infection[13–15] and immunocompetence[16–18], as well as of infection on nutritional status[19,20]. Although the relationships between undernutrition and physical growth and development in populations in PNG has been reviewed[21,22], the importance of infection in the causation of growth faltering has been little considered. In the present article, growth patterns of children in PNG are described, with particular emphasis on the interrelationships between undernutrition and infection in the growth faltering process.

Nutrition, Infection, and Growth and Development

The influence of infection on infant and child growth in developing countries has been extensively documented[23–25]. While infants are breastfeeding, they are largely protected from the disease environment both nutritionally and immunologically[26]. In addition, infants who are kept close to their mother for reasons of convenience of care and breastfeeding are less likely to come into contact with objects or foods contaminated with pathogens, and are thus shielded from the disease environment behaviourally. Most women are unable to produce sufficient breastmilk to sustain a western pattern of infant growth beyond six months postpartum, and dietary supplementation will often start around or before that time[27]. Delayed supplementation may lead to growth faltering and undernutrition, leaving the infant more suspectible to infectious diseases, while earlier dietary supplementation may provide adequate nutrient intake, but concomitantly introduce the child to agents of diarrhoeal disease[25].

Growth faltering associated with the interaction between undernutrition and infection may continue for months or years, depending on the severity of the disease environment, and the abundance and quality of the nutritional environment. In most populations, the process of growth faltering is complete by the age of two years, after which the shorter, stunted child may follow a parallel trajectory to the western growth references[28]. Although this period of departure from the growth references derived from measures of western populations can be regarded as an accommodation to the disease and nutritional environment, such accommodation is usually associated with high mortality rates[24], and cannot be regarded as desirable.

One aspect of growth and development which mediates the overall growth response to undernutrition and infection is the development of the immune system. At birth, the neonate is largely protected from pathogens in the birth canal by the immunologlobulin G antibody from the mother[29]. When breastfed, the infant receives maternal immunoglobulin A which is protective, with a broad spectrum of antipathogenic activity[30]. Although there is little evidence to suggest that diarrhoea has any effect on the growth of exclusively breastfed infants in developing countries[25], it is not clear

whether the lack of effect is because breast feeding reduces the duration of infection, its intensity, or both.

Dietary supplementation of infants increases their exposure to pathogenic agents, while cessation of breastfeeding both increases pathogenic exposure and removes the maternal antibody contribution to the infants' immune system. Given the relative immaturity of the immune system in infancy, it is not surprising that diarrhoeal infections are most common among children of the developing world at this stage of life. However, it is not clear whether immune system immaturity as assessed by circulating levels of antibodies relative to adult levels also reflects a reduced ability to mount an immune response, or whether the immune response is attenuated by undernutrition. Nor is it clear whether undernutrition at the time of weaning leads to maturational delays in immune system development, in addition to linear growth retardation. Although undernutrition has been associated with immunosuppression, there are circumstances where repeated infections, in association with increased maturity of the immune system and the acquisition of adaptive immunity with increasing age across early childhood, may result in elevated immunological surveillance.

Elevated white cell counts among children in the absence of apparent clinical infection has been described as immunological stress by Solomons[31], who suggested that this phenomenon could influence growth independently of nutritional status. This author drew a parallel between the elevated immune response of some children undergoing growth faltering in developing countries, with the elevated levels of immunological markers found in battery-reared poultry in the absence of routine administration of antibiotics. The inclusion of antibiotics in poultry feed has a growth-promoting effect irrespective of environmental quality, by reducing the immune response to infectious agents in their generally poor environment. Extending this principle to the study of human growth faltering, Solomons[31] proposed the 'dirty chick hypothesis', which might operate among human populations in areas of high and stable disease prevalence.

Growth Patterns in Papua New Guinea

PNG is a country of considerable geographical[32,33], and genetic[34–36] diversity, and patterns of human growth and development show differences across regions which are likely to be due to both environmental and genetic factors[22,37,38]. Broadly, PNG can be divided into four regions: Highlands, Coastal, Island, and Highland Fringe. This division reflects ecological, genetic and economic differences which are difficult to disaggregate. It is difficult to establish and quantify the genetic effects on growth in PNG, especially in situations where environmental effects are great[22]; of the environmental factors which influence human growth in PNG, undernutrition and infection are the most important. There is considerable variation in mean birthweight, with children of the Highlands region generally having higher mean birthweights than children from Coastal, slands, and Highland Fringe regions[21], although universally, mean birthweights are lower than in industrialised nations[2,39–46]. The difference in birthweight between regions persists through infancy, with Highlands children being heavier than either Coastal or Highland Fringe populations. There is some evidence of catch-up growth in weight in early infancy in both Highlands and Coastal regions[39,42,45,46]. This pattern of catch-up growth is similar to that of infants in other developing countries[47], and

suggests that intra-uterine growth retardation is common in PNG[48].

At 18 and 30 months of age respectively, Highland Fringe children are lighter than children in the other three regions[49]. However, the greater weight of Highlands children at these ages is not accompanied by greater length relative to Coastal and Island populations[38]. This suggests that differences in physique may be attributable to genetic factors, although this is difficult to test[22].

Beyond 30 months of age, growth faltering has been shown to persist across most of childhood and adolescence, being associated with delays in developmental maturity in some PNG populations[3,5,39,50,51]. This growth pattern results in late onset of adulthood and shorter adult stature relative to western populations[3,5,38]. Although this has been described as an adaptation to poor nutritional environment by Malcolm[3], the price of this adaptation includes high mortality[4,5,42,43,52] and morbidity[43,53] in childhood. In addition, there is evidence of delayed motor development among children below the age of two years who are of shorter than average stature[54–56].

Mechanisms of Growth Faltering

Growth faltering in PNG must be observed against a background of high infectious disease prevalence which includes malaria[7], intestinal parasitism[57] and acute respiratory tract infections[10]. The newborn child was traditionally breastfed for extended periods of up to 5 years[58,59], and the introduction of supplementary food often took place much later than in industrialised nations. The introduction of supplementary food, while nutritionally important, can also be a vehicle for gastrointestinal tract infection[60]. Traditionally, such supplementation took place after growth faltering had started, and sometimes as late as 12 months post-natally[59]. Under these conditions, growth faltering in infancy was likely to have been due to primary nutritional deficiency. Support for this interpretation comes from data concerning dietary supplementation, which is often guided by dental eruption[42,61]. The initial emergence of deciduous dentition in PNG is delayed relative to western standards by primary undernutrition[6,54], and usually takes place after growth faltering has taken place. In some PNG societies, the introduction of some solid foods may take place within the first few weeks or months of life[42,44]. While such practices have been described as being quantitatively nutritionally insignificant despite being culturally important[42], this might present a pathway for the early introduction of diarrhoeal disease among such infants, and the onset of growth faltering due to nutrition-infection interactions initiated by disease processes. More generally, as earlier supplementation of infant diet in contemporary PNG is encouraged by primary health workers, growth faltering in infancy may be driven by infectious disease processes rather than primary undernutrition, if poor hygiene prevails.

Nutrition-infection interactions and their impact on growth and development have a clear temporal dimension, with time of onset of weaning being a landmark in the onset of these interrelationships in contemporary PNG. Immune system immaturity of the infant facilitates these relationships, as well as the impaired cell-mediated immunity[62] and responsiveness[63] which has been reported for infants and children in PNG. Impaired immune system status is likely to be due to primary undernutrition, and is likely to lead to increased susceptibility to diseases associated with growth faltering, including malaria[53], parasitic infection[64], and acute respiratory infections[10]. Across early childhood, constant exposu-

re to infectious agents may result in adaptive immunity, but with immunological stress[31,60] possibly leading to cytokine-mediated growth faltering and undernutrition as a consequence of immunological surveillance in the infectious disease rich environments of this country. This may take place at a later age than the undernutrition-infection interactions of infancy[65].

Finally, the growth patterns of children in PNG represent survivors of the undernutrition-infection interrelationship, in which high mortality rates in infancy may remove significant numbers of individuals in some populations. The extent to which the growth patterns represent survivorship varies greatly. For example, in the Eastern Highlands Province, mortality in the 0–5 years age group is 9% of all live-births, while in Gulf and Morobe Province, mortality rates are 12% and 10% respectively[52]. For the Anga, a population with considerable growth faltering[6], 0–5 years mortality is 20%, while for the Asai in 1962–6, it was 27%[4]. In contrast, 0–5 years mortality rates in the contemporary highlands of PNG are 3% for the Tari population, and 2% for the Asaro population[10]. PNG is a country undergoing rapid modernisation (66). With this has come a secular trend towards increased body size in some parts of the country[67,68]. While far from universal, this trend is associated with reduced infant and young child mortality, and the population growth patterns represent less in the way of survivorship curves than in the past.

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PREHRANA, ZARAZNE BOLESTI I RAST DJECE U PAPUI NOVOJ GVINEJI

S A Ž E T A K

Poznato je da rast djece u populacijama Papue Nove Gvineje (PNG) pokazuje znatne varijacije, a najveće su razlike uočene između obalnih i gorskih populacija. Iako u različitim obrascima rasta djece nije moguće isključiti ulogu genetičkih činioca, smatra se da je zaostajanje u rastu djece s PNG u odnosu na zapadne referentne vrijednosti velikim dijelom posljedica složenog međudjelovanja pothranjenosti i zaraznih bolesti. Utjecaj hrane, prehrane i zaraznih bolesti na prehrambeno stanje djeteta uvelike je ovisan o dobi, općoj ekologiji bolesti te načinu i obimu izloženosti, načinima hranjenja dojenčadi i male djece kao i vrsti hrane koju uzimaju. Dva su moguća načina na koja su povezane pothranjenost i infekcija: jedan kod kojega pothranjenost vodi ka padu imuniteta i smanjenju otpornosti prema infekciji i drugi kod kojega izloženost zaraznim bolestima vodi ka nizu činioca koji smanjuju unos hrane i apsorpciju hranjivih tvari ili povećavaju potrebu za hranjivim tvarima. Čini se da je prije modernizacije u PNG i u njenim začecima, rana pothranjenost početni uzrok zaostajanja u rastu zbog njenog međudjelovanja sa zaraznim bolestima. Ne može se isključiti niti mogućnost da je u nekim populacijama početni korak infekcija do koje može dovesti dohranjivanje dojenčadi. S modernizacijom i usvajanjem načela primarne zdravstvene zaštite, u PNG je postalo uobičajeno nadohranjivanje u ranijoj dojenačkoj dobi što je dovelo do općeg poboljšanja rasta i prehrambenog stanja. Međutim u populacijama u kojima je pothranjenost još uvijek prisutna, infekcija je u međudjelovanju s pothranjenošću mnogo značajniji začetnik zaostajanja u rastu, nego što je sama rana pothranjenost.