Malnutrition as an underlying cause of childhood deaths associated with infectious diseases in developing countries

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Introduction Recent estimates suggest that malnutrition (measured as poor anthropometric status) is associated with about 50% of all deaths among children. Although the association between malnutrition and all-cause mortality is well documented, the malnutrition-related risk of death associated with specific diseases is less well described. We reviewed published literature to examine the evidence for a relation between malnutrition and child mortality from diarrhoea, acute respiratory illness, malaria and measles, conditions that account for over 50% of deaths in children worldwide.

Methods MEDLINE was searched for suitable review articles and original reports of community-based and hospital-based studies. Findings from cohort studies and case–control studies were reviewed and summarized.

Results The strongest and most consistent relation between malnutrition and an increased risk of death was observed for diarrhoea and acute respiratory infection. The evidence, although limited, also suggests a potentially increased risk for death from malaria. A less consistent association was observed between nutritional status and death from measles. Although some hospital-based studies and case–control studies reported an increased risk of mortality from measles, few community-based studies reported any association.

Discussion The risk of malnutrition-related mortality seems to vary for different diseases. These findings have important implications for the evaluation of nutritional intervention programmes and child survival programmes being implemented in settings with different disease profiles.

Keywords: developing countries; child nutrition disorders; communicable diseases, mortality; infantile diarrhea, mortality; measles, mortality; health planning; child health services.

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Introduction

Approximately 12 million children younger than 5 years of age die every year; most of these children live in developing countries. More than 50% of these deaths are attributed to diarrhoea, acute respiratory illness, malaria, or measles, conditions that are either preventable or treatable with low-cost interventions (*1*). Although malnutrition is prevalent in developing countries, it is rarely cited as being among the leading causes of death. This is due in part to the conventional way that cause of death data are reported and analysed. In many countries, mortality statistics are compiled from records in which a single proximate cause of death has been reported.

In the early 1990s Pelletier and colleagues used a different approach to estimate the contribution of malnutrition to all-cause mortality in children (*2*). Their analytical framework takes the underlying causes of death into account and it suggested that malnutrition (measured as poor anthropometric status) is an associated cause in about half of all deaths occurring among children in developing countries (*2, 3*). The results also highlighted the fact that even children with mild to moderate malnutrition, rather than only those with more severe forms, had an increased risk of dying. As a result, international attention has been refocused on the potential impact that preventing mild and moderate malnutrition, as well as severe malnutrition, can have on the survival of children.

Although the association between malnutrition and all-cause mortality is well documented, the association between malnutrition and mortality attributed to specific causes is less well described. Determining whether the malnutrition-related risk of death varies for different diseases also has implications for the implementation and evaluation of

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programmes designed to ensure the survival of children. If malnutrition does not increase the risk of mortality from all causes of death equally, intervention programmes that succeed in improving nutritional status may not have the same potential for reducing children's mortality in regions with different disease profiles.

The synergistic relation between malnutrition and infection is well known, and nutritional interventions have been recognized as an important approach for reducing mortality from acute respiratory illness and diarrhoea (*4*). The WHO Integrated Management of Childhood Illness initiative is based on the premise that combining efforts to promote the appropriate case-management of serious infectious diseases with nutritional interventions, immunization programmes, and other disease prevention and health promotion activities will be more effective in decreasing child mortality than implementing any one of the components alone (*5, 6*).

Infectious diseases remain the most important immediate cause of death among children and of disability worldwide. The burden of ill-health associated with these conditions is especially high in developing countries. Despite the progressive rise in chronic diseases as important causes of mortality, the epidemiological transition that is under way in the developing world does not reduce the need to continue investigating appropriate strategies for reducing child mortality from infectious diseases. In fact, these developments will make dealing with the unfinished agenda of mortality from infectious diseases even more of a challenge.

WHO is currently supporting a project to estimate quantitatively the contribution of malnutrition to cause-specific mortality in children. As part of this project, we reviewed the published literature to identify studies that addressed the relation between malnutrition and mortality from diarrhoea, acute respiratory infections, malaria, and measles. Although malnutrition may be an important associated cause of death in other conditions, the present review was restricted to these four major causes of death. The objective of this report is to provide a descriptive overview of the findings.

Methods

MEDLINE was searched for literature published either in English or with an English abstract in a foreign-language publication for the years 1966–99. Combinations of the following groups of keywords were used: mortality, death; malnutrition, protein-energy-malnutrition, anthropometry; diarrhea, dysentery; acute respiratory illness, acute respiratory infection, ARI, acute lower respiratory illness, acute lower respiratory infection, ALRI, pneumonia; malaria, plasmodium; and measles. A separate search was conducted to identify publications related to each one of the four main causes of death.

Further MEDLINE searches were conducted using the author's name and the "related articles" link for key publications. Abstracts identified using this process were read to select review articles and original research reports of community-based or hospital-based studies that assessed nutritional status and mortality in children and that mentioned diarrhoea, acute respiratory infection, malaria, or measles as causes of death. Full copies of these publications were obtained. Additional publications were identified from the reference lists of the articles retrieved and through discussions with colleagues.

Two types of studies were included in the tables of this review article. The first were original research reports of cohort and case–control studies that contained data on cause-specific mortality in children (attributed to diarrhoea, acute respiratory infection, malaria, measles, or a combination of these conditions) stratified by nutritional status assessed using anthropometric indicators or a history of clinical signs of malnutrition (that is, kwashiorkor, marasmus, oedema, or recent severe weight loss). The second were critical review articles that contained quantitative data and reports of original research results.

The following types of studies were not included: reports of case series; studies in which deaths were assigned to multiple, concurrent causes other than the four listed above (for example, acute lower respiratory infection associated with HIV infection); studies that assessed anthropometric status only as birth weight; studies that used the term malnutrition without any further descriptive information or reference to a source that would provide such information; and studies in which clear estimates of risk were either not presented or could not be calculated.

In defining malnutrition the majority of studies used indicators of anthropometric status (weight for age, weight for height, mid-upper arm circumference, etc.). Weight for age was the most frequently reported indicator. Some of the hospital-based studies reported a clinical assessment of kwashiorkor, marasmus, or oedema. The nutritional status indicators, cut-off points, and reference populations used in each study are presented with other relevant details in the results section.

The case definition for diarrhoea varied among the studies considered for review. The majority defined diarrhoea by clinical signs, using a combination of reported stool type, frequency of symptoms, and duration. A few defined diarrhoea according to the etiological agent based on laboratory analyses of stool samples. Studies that reported data on malnutrition and mortality attributed to diarrhoea (by any definition) were included.

The majority of deaths attributed to acute respiratory infection are caused by lower respiratory tract infections. Therefore, most of the studies considered for review reported clinical signs of acute lower respiratory infection and pneumonia. The case definitions for these conditions varied and included cough associated with breathing difficulty which manifested as wheezing, rapid breathing, indrawing of the chest, or cyanosis. In some of the hospital-based studies, case definitions included results from chest X-rays. Bacterial and viral cultures were taken in the studies that focused on the etiology of acute lower respiratory infection. Studies that reported data on malnutrition and mortality from acute respiratory infection, acute lower respiratory infection, or pneumonia by any definition were included.

The case definition for malaria also varied among the studies. Some defined malaria on the basis of a simple history of fever, while others reported malaria cases as those with clinical signs (that is, history of fever or fever and chills) and parasitaemia confirmed by microscopic examination of slides. Studies that reported data on malnutrition and mortality attributed to malaria (by any definition) were included.

The majority of studies defined measles using clinical signs (a history of rash). A few reported measles as cases with a history of rash and a confirmed presence of measles antibodies. Studies that reported data on malnutrition and mortality attributed to measles (by any definition) were included.

Although the original publications should be consulted to obtain the exact case definitions used for mortality from diarrhoea, acute respiratory illness, malaria, and measles, important differences that may have markedly influenced the risk estimates are highlighted in the results and discussion sections of this review.

The risk estimates (relative risk, odds ratios, and case fatality rates) listed in the tables are those that appeared in the original publications. Risk ratios identified as secondary calculations did not appear in the original publications but were calculated from data in the original reports.

Results

Studies that fulfilled the inclusion criteria are presented separately for diarrhoea (Table 1), acute respiratory infection (Table 2), and malaria (Table 3). Studies of measles conducted in various countries around the world published before 1990 have been summarized in a similar format in review articles by Aaby (*7, 8*). Studies conducted in India and published before 1994 have been reviewed by Singh and colleagues (*9*). The findings from those review articles and more recently published original research reports are summarized in the results section but are not presented separately. Studies that reported diarrhoea and acute lower respiratory infection as concurrent causes of death are included in Table 1.

The studies that were reviewed and included in the tables fall into two main design categories: cohort studies and case–control studies. In the community-based cohort studies nutritional status was assessed at baseline among presumably healthy children who were followed prospectively. Among those who died, the cause of death was determined by verbal autopsy and by reviewing hospital case notes, coroner's reports, or death certificates, or a combination of these. The relative risk of mortality was reported for the entire cohort. In the hospital-based studies, a cohort of children admitted to hospital was identified, and the records were reviewed to relate nutritional status at admission with subsequent mortality. These studies generally reported cause-specific case-fatality rates stratified by nutritional status.

In the case–control studies the nutritional status of children who died from a specific disease was compared with the status of control children and the odds ratios were reported. The type of controls varied. Some studies used healthy controls while others used children who had been admitted to hospital for the same disease.

Case-series reports were also found. In this type of study, the records of children who had died were examined to identify risk factors associated with mortality. Because nearly all of these studies reported only the prevalence of malnutrition among the children who had died and did not provide comparative data on the prevalence of malnutrition either among children who survived an episode of a disease or among children in the general population, the findings were not summarized.

The tables are divided into two parts to summarize the community-based studies and the facility-based studies. Within each section, cohort studies are listed first. The studies in each subsection are organized alphabetically by country and then chronologically by date of publication.

Diarrhoea

The data suggest that malnutrition is associated with an increased risk of death from diarrhoea and that the risk varies by type of diarrhoea (Table 1). All of the community-based studies reported an increased risk of mortality from diarrhoea among children who had low weight for their age (*10–15*). A dose–response relation was reported in the studies from India (*10, 11*), the Philippines (*15*), and Sudan (*13*), where the child's weight for age was stratified into multiple categories. The study in the Philippines also included age-stratified data and reported that the highest risks of mortality from diarrhoea associated with malnutrition occurred among children aged 6–11 months. In the study in Sudan, the risk of mortality was inversely related to children's height for age and weight for height.

A similar trend between malnutrition and an increased risk of mortality was observed in some, but not all, of the hospital-based studies (*16–31*). These studies examined a range of outcomes, including deaths from isolated diarrhoea, from non-bloody diarrhoea, and from dysentery. Eleven of the 16 studies were conducted in Bangladesh, India, or Pakistan. Most reported malnutrition using a dichotomous classification of the percentage of the median

Table 1. **Malnutrition and mortality from diarrhoea**

Country (reference)	Year	Outcome measure	Study design	Sample size (no. of deaths)	Age range	Indicator of nutritional status[a]	Findings[b]		
Community-based									
Bangladesh (*12*)	1980	Death from diarrhoea (all types but virtually all due to dysentery)	Cohort	2019 children (112 deaths; no. of deaths from diarrhoea not specified)	13–23 months at enrolment, followed for 2 years	**% median W/A**	**Diarrhoea mortality (per 1000 over 24 months)**		
						⩾ 65%	10.2		
						< 65%	37.7		
						(Harvard reference)	Ratio 3.7		
India (*10, 11*)	1986	Death from diarrhoea (all types)	Cohort	1467 children (23 deaths from diarrhoea)	< 5 years, followed for 20 months	**% median W/A**	**Case fatality rate**		*Risk ratio*
						> 80%	0.3%		*1.0*
						71–80%	0.4%		*1.0*
						61–70%	2.1%		*7.0*
						51–60%	7.5%		*24.0*
						(NCHS[a] reference)			
Philippines (*15*)	1997	Death from diarrhoea (all types)	Cohort	9942 children (62 deaths from diarrhoea)	< 2 years, followed until 24 months old, withdrawal, or end of study	**W/A *Z*-scores**	**0–5 months**	**6–11 months**	**12–23 months[c]**
						> 0	1.0	1.0	1.0
						−1 to ⩽ 0	1.5	1.9	1.6
						−2 to ⩽ −1	2.2	3.4	2.7
						−3 to ⩽ −2	3.3	6.4	4.4
						⩽ −3	4.9	11.8	7.3
						(NCHS reference)			
		Death from concurrent diarrhoea and acute lower respiratory infection	Cohort	9942 children (44 deaths from diarrhoea and acute lower respiratory infection)	< 2 years, followed until 24 months old, withdrawal, or end of study	**W/A *Z*-scores**	**0–5 months**	**6–11 months**	**12–23 months[c]**
						> 0	1.0	1.0	1.0
						−1 to ⩽ 0	1.5	2.4	2.5
						−2 to ⩽ −1	2.3	5.5	6.1
						−3 to ⩽ −2	3.4	13.0	5.2
						⩽ −3	5.2	30.6	37.5
						(NCHS reference)			
Sudan (*13*)	1997	Death among children with diarrhoea reported in previous week	Cohort	28 753 children (85 deaths from diarrhoea)	6–72 months, followed for 18 months	***Z*-scores**	**RR (W/A)**	**RR (H/A)**	**RR (W/H)**
						> −1	1.0	1.0	1.0
						−1 to −2	2.0 (0.7–6.2)	1.2 (0.8–3.7)	1.5 (1.1–2.1)
						−2 to −3	2.0 (0.6–6.1)	1.8 (0.8–3.9)	2.2 (1.4–3.5)
						−3 to −4	9.8 (3.4–28.4)	4.1 (1.8–9.2)	17.9 (10.9–29.4)
						< −4	41.4 (14.0–122.0)	8.3 (3.8–17.9)	31.0 (14.2 –67.6)
						(NCHS reference)			
Panama (*14*)	1985	Death from diarrhoea (all types)	Case–control	8 cases; 24 controls	< 5 years	**% median W/H**	**OR**		
						⩾ 90%	1.0		
						< 90%	23.0 (2.0–262.6)		
						(NCHS reference)			

[a] W/A = weight for age; W/H = weight for height; H/A = height for age; AC = arm circumference; AC/age = arm circumference for age. NCHS = US National Center for Health Statistics.

[b] RR: relative risk; OR: odds ratio; NS: not signficant. Values in parentheses are 95% confidence intervals. Italicized values are secondary calculations based on the published data.

[c] Rate ratios based on coefficients for continuous variables in a Cox regression model.

[d] Underlying causes of death included acute watery diarrhoea (41%), persistent diarrhoea (19%), dysentery (9%), and acute respiratory infection (31%).

[e] Relative risk from multivariate logistic regression.

[f] Weight adjusted for dehydration status.

[g] OR from multivariate logistic regression.

[h] Jelliffe norms (*61*).

[i] OR from univariate logistic regression (protective effects).

[j] Nutrition Subcommittee of the Indian Academy of Pediatrics: 1971–72 (*62*).

[k] WHO reference (*63*).

Country (reference)	Year	Outcome measure	Study design	Sample size (no. of deaths)	Age range	Indicator of nutritional status[a]	Findings[b]	
Hospital-based								
Bangladesh (*23*)	1996	Death among children discharged from hospital after treatment for diarrhoea (all types)[d]	Cohort followed up at home at 6 and 12 weeks after discharge	427 cases (32)	1–23 months	**% median W/A** ⩾ 60% < 60% **% median H/A** ⩾ 85% < 85% (NCHS reference)	**RR[e]** 1.0 1.04 (0.57–1.89) 1.0 2.97 (1.43–6.16)	
Gambia (*25*)	1998	Death from gastroenteritis	Cohort	813 cases (106)	< 5 years	**W/A *Z*-score** > –2 < –2 to > –3 < –3 to > –4 < –4 (NCHS reference)	**Case fatality rate (%)** 17/305 (5.6) 25/220 (11.4) 28/170 (16.5) 36/118 (30.5)	*Risk ratio* *1.0* *2.0* *2.9* *5.4*
India (*30*)	1973	Death among children hospitalized with diarrhoea (all types)	Cohort	110 cases (17)	⩽3 years	**Status** Normal 1st degree malnutrition 3rd degree malnutrition (Gomes scale)	**Case fatality rate (%)** 1/26 (3.84) 3/28 (10.71) 7/30 (23.33) 6/26 (23.08)	***Risk ratio*** *1.0* *2.79* *6.08* *6.01*
India (*21*)	1994	Death among children hospitalized with diarrhoea (all types)	Cohort	1889 cases (327)	< 5 years	**% median W/A[f]** < 80% ⩾ 80% (Harvard reference)	**Case fatality rate (%)** 257/1321 (19.4) 66/568 (11.6) (*P*<0.00001) Difference in death rate among 7–36 month olds was not significant (19.1% vs 25.8%)	
India (*29*)	1991	Death among children hospitalized with diarrhoea (all types)	Cohort	357 cases (37)	< 5 years	**% median W/A** > 50% ⩽ 50%[c] **% median H/A** > 85% ⩽ 85% (NCHS reference)	**OR[g]** 1.0 3.3 (2.7–4.0) 1.0 1.9 (1.6–2.3)	
Pakistan (*19*)	1997	Death among malnourished children hospitalized with persistent diarrhoea	Cohort	302 cases (13)	4–36 months	**W/A *Z*-score** (unspecified reference)	**OR[g]** 7.6 (1.22–47.4)	
Bangladesh (*20*)	1986	Death among children hospitalized with complicated diarrhoea (all types)	Cohort	352 cases (34)	< 5 years	**Status** AC >12.5 cm **% median** AC/age[h] W/A > 60% W/H > 70% H/A > 85% (NCHS reference)	**OR[i]** 0.68 (0.56–0.81) 0.94 (0.91–0.97) 0.94 (0.93–0.98) 0.96 (0.94–0.99) 0.95 (0.90–0.99)	
Bangladesh (*28*)	1990	Death from concurrent diarrhoea and acute lower respiratory infection	Cohort of inpatients	401 inpatients (30)	< 5 years	**% median W/H** ⩾ 80% < 80% (NCHS reference)	**Case fatality rate** 6% 10% (NS)	*Risk ratio* *1.0* *1.7*
India (*17*)	1980	Death from acute diarrhoea	Cohort of inpatients with diarrhoea	200 cases (19)	< 60 months	**Status[j]** Normal Grades I–IV (Indian guidelines)	**Case fatality rates (%)** 1/22 (4.6) 18/160 (11.3) (*P*>0.1)	*Risk ratio* *1.0* *2.5*

Country (reference)	Year	Outcome measure	Study design	Sample size (no. of deaths)	Age range	Indicator of nutritional status[a]	Findings[b]
Senegal (*16*)	1987	Death from isolated diarrhoea	Cohort of inpatients with diarrhoea	25 cases (8)	< 5 years	**% median W/H[k]** < 80% ⩾ 80% Oedema (WHO reference)	**Case fatality rates (%)** *Risk ratio* 1/9 (11.1) *1.0* 6/15 (40.0) *3.6* 1/1 (100.0)
Bangladesh (*26*)	1990	Death from dysentery	Case–control	23 cases; 23 controls hospitalized for dysentery	14–60 months	**% median W/A** ⩾ 60% < 60% (NCHS reference)	**OR** 1.0 8.9 (1.90–45.86)
Bangladesh (*18*)	1990	Death among patients hospitalized with shigellosis	Case–control	56 cases; 129 controls hospitalized with shigellosis	Children and adults (91% of cases were < 5 years old)	**% median W/A** ⩾ 50% < 50% (NCHS reference)	**OR** 1.0 2.1 (*P*=0.041)
Bangladesh (*31*)	1996	Death among children hospitalized with diarrhoea (all types)	Case–control	46 cases; 138 controls	< 5 years	**Status** W/A < 60% H/A < 85% W/H < 70% (NCHS reference)	**OR** 25.3 (3.9–164.3) 7.2 (1.1–48.4) 84.2 (9.1–775.9)
Brazil (*27*)	1992	Death from diarrhoea	Case–control	163 cases; 168 controls hospitalized for diarrhoea	< 1 year	**W/A *Z*-score[f]** ⩾ 0 –1 to –0.01 –2 to –1.01 –3 to –2.01 < –3.0 (NCHS reference)	**OR** 1.0 1.8 (0.5–7.5) 4.4 (1.2–15.9) 9.5 (2.6–34.1) 28.2 (7.6–104.2) linear test for trend (*P*<0.001)
Ethiopia (*24*)	1991	Death from non-bloody diarrhoea	Case–control	21 cases; 84 controls	< 5 years	**W/A** ⩾ 70% < 70% **H/A** ⩾ 90% < 90% **W/H** ⩾ 80% < 80% (NCHS reference)	**OR** 1.0 4.0 (NS) 1.0 8.3 (*P*<0.05) 1.0 3.8 (*P*<0.05)
Lesotho (*22*)	1988	Death from non-bloody diarrhoea	Case–control	*Study 1* 13 cases; 21 controls hospitalized for diarrhoea *Study 2* 8 cases; 15 controls hospitalised for diarrhoea	⩽ 24 months	**% median W/A** > 90% ⩽ 90% (NCHS reference)	**OR** Study 1 (10x3)/(18x3)=0.56 Study 2 (7x4)/(11x1)=2.54 No association between malnutrition and death from diarrhoea

weight for age or weight for height. Estimates of risk varied with one of the highest point estimates (an odds ratio of 8.9) reported in the case–control study of deaths from dysentery in Bangladesh (*26*).

Acute respiratory infection

The data suggest that malnutrition is strongly associated with an increased risk of mortality from acute lower respiratory infections and pneumonia (Table 2). A dose–response relation between decreasing weight for age and increasing risk of mortality was apparent in the three community-based studies (*15, 32, 33*). The study in the Philippines included age-stratified risks and reported the highest risks of death from acute lower respiratory infection associated with malnutrition among those aged 12–22 months followed by those aged 0–5 months (*15*). Children younger than 23 months were included in these three studies.

Table 2. **Malnutrition and mortality from acute respiratory infection**

Country (reference)	Year	Outcome measure	Study design	Sample size (no. of deaths)	Age range	Indicator of nutritional status[a]	Findings[b]		
Community-based									
Philippines (*15*)	1997	Death from acute lower respiratory infection	Cohort	9942 (39)	Birth cohorts followed until age 24 months, withdrawal, or end of study	**W/A *Z*-score** > 0 − 1 to ⩽ 0 − 2 to ⩽ −1 − 3 to ⩽ −2 ⩽ −3 (NCHS[a] reference)	**OR**[c] *0–5 months* 1.0 1.6 2.6 4.1 6.6	 *6–11 months* 1.0 1.5 2.3 3.4 5.1	 *12–22 months* 1.0 3.3 11.0 36.5 121.2
Brazil (*33*)	1989	Death from acute lower respiratory infection	Case–control	127 cases; 254 healthy controls	7–364 days	**W/A *Z*-score** > 0 0 to −0.9 −1.0 to −1.9 ⩽ −2.0 (NCHS reference)	**OR** 1.0 5.60 (2.11–14.85) 5.91 (2.06–16.91) 25.92 (6.12–109.90)		
Gambia (*32*)	1993	Death from acute lower respiratory infection	Case–control	124 cases; 124 healthy controls	0–23 months	**W/A *Z*-score** ⩽ −1.88 −1.87 to−1.27 −1.26 to−0.75 ⩾ −0.74 (NCHS reference)	**OR** 1.0 0.80 (0.27–2.36) 0.21 (0.04–1.15) 1.47 (0.42– 5.16)		
Facility-based									
Argentina (*42*)	1990	Death from acute lower respiratory infection	Cohort of inpatients with lower respiratory infection	805 inpatients (31)	< 5 years	**W/A** ⩾ 90% < 90% (unspecified reference)	**RR** 1.0 3.3 (1.61–7.00)		
Gambia (*43*)	1999	Death from acute lower respiratory infection	Cohort of inpatients with acute lower respiratory infection	190 inpatients (12)	< 5 years	**W/A *Z*-score** ⩾ −2 < −2 (NCHS reference)	**RR (adjusted for hypoxaemia)** 1.0 3.2 (1.03–10.29)		
Gambia (*25*)	1998	Death from pneumonia	Cohort of inpatients with pneumonia	2193 inpatients (153)	< 5 years	**W/A *Z*-score** > −2 < −2 to > −3 < −3 to > −4 < −4 (NCHS reference)	**Case fatality rate (%)** 56/1281 (4.4)[d] 35/507 (6.9) 42/276 (15.2) 20/129 (15.5)	*Risk ratio* *1.0* *1.6* *3.4* *3.5*	
India (*35*)	1997	Death from acute lower respiratory infection	Cohort of inpatients with acute lower respiratory infection	201 inpatients (21)	2 weeks–5 years	**W/A *Z*-score** ⩾ −3 < −3 (NCHS reference)	**OR (multivariate analysis)** 1.0 3.9 (1.01–9.7)		
Papua New Guinea (*36*)	1989	Death from severe pneumonia	Cohort of patients admitted with severe pneumonia	711 inpatients (107)	Children > 28 days (upper age not specified)	**% median W/A** ⩾ 80% < 80% (Harvard reference)	**Case fatality rate (%)** 54/[54+453] (11) 53/[53+151] (26) (calculated from data in Table 1 of the original publication)	*Risk ratio* *1.0* *2.4*	
Philippines (*38*)	1985	Death from acute lower respiratory infection	Cohort of inpatients with acute lower respiratory infection	810 inpatients (34)	< 5 years	**Malnutrition**[e] Normal Mild Severe	**Case fatality rate (%)** 0.6 2.3 7.7	*Risk ratio* *1.0* *3.8* *12.8*	
Philippines (*39*)	1988	Death from acute lower respiratory infection	Cohort of inpatients with acute lower respiratory infection	729 inpatients (34)	< 5 years	**% median W/A**[f] ⩾ 90% 75–89% 60–74% < 60% (Philippine reference)	**RR (adjusted)** 1.0 4.4 (2.0–9.52) 11.3 (5.7–22.4) 27.0 (13.1–55.7)		

Country (reference)	Year	Outcome measure	Study design	Sample size (no. of deaths)	Age range	Indicator of nutritional status[a]	Findings[b]
Philippines (*41*)	1990	Death from acute lower respiratory infection	Cohort of inpatients with acute lower respiratory infection	537 inpatients (89)	< 5 years	**W/A *Z*-score[g]** ⩾ –2 < –2	**RR (adjusted)** 1.0 2.1 (1.4–3.0)
Philippines (*40*)	1990	Death from severe acute lower respiratory infection	Cohort of inpatients with acute lower respiratory infection (same cohort analysed in study *41*)	528 inpatients (88)	< 5 years	**W/A *Z*-score** ⩾ –2 < –2 < –3 < –4 **H/A *Z*-score** ⩾ –2 < –2 < –3 < –4 (NCHS reference)	**OR** 1.0 2.00 (1.04–3.85) 2.52 (1.32 –4.81) 3.22 (1.51–6.87) 1.0 0.79 (0.42–1.50) 1.21 (0.55–2.66) 1.50 (0.77–2.93)
Zambia (*37*)	1998	Death from pneumonia	Cohort of inpatients with severe pneumonia	158 cases (23)	4 weeks–< 5 years	**W/A *Z*-score** No cut-off specified (NCHS reference)	Logistic regression ß-coefficient for weight = –0.6519 (*P*=0.0073) (OR =0.52: Authors report malnutrition as a risk factor for mortality)
Brazil (*27*)	1992	Death from pneumonia	Case–control	127 cases; 126 controls hospitalised with pneumonia	< 1 year	**W/A *Z*-score[h]** ⩾ 0 –1 to –0.01 –2 to –1.01 –3 to –2.01 < –3.0 (NCHS reference)	**OR** 1.0 2.0 (0.8–5.1) 2.6 (0.9–7.2) 3.8 (1.4–10.3) 11.7 (4.2–32.6) (linear test for trend *P*<0.001)
India (*34*)	1992	Death from pneumonia	Case–control	70 cases; 140 controls hospitalised with pneumonia	1 month–11 years	**Malnutrition[i]** Normal, grades I–II Grades III–IV (Indian reference)	**OR (adjusted)** 1.0 5.8 (2.2–15.6)

[a] W/A = weight for age; NCHS = US National Center for Health Statistics.

[b] RR: relative risk; OR: odds ratio. Values in parentheses are 95% confidence intervals. Italicised values are secondary calculations based on the published data.

[c] Rate ratio based on the coefficient for the continuous weight for age *Z*-score variable in the Cox regression models.

[d] Originally published (erroneous) values for the >–2 *Z*-score group were 56/1284 (16.9%).

[e] Criteria not listed. Publication by the same author (*39*) classified nutritional status using reference data for Filipinos and percentage of median weight for age as: normal ⩾ 90%, first degree malnutrition 75–89%, second degree malnutrition 60–74%, and third degree malnutrition < 60%.

[f] Ref. *64*.

[g] Reference not listed. Publication by the same author (*40*) used NCHS reference.

[h] Adjusted for hydration status at admission.

[i] Nutrition Sub-Committee of the Indian Academy of Pediatrics: 1971–72 (*62*).

The same consistent trend between malnutrition and an increased risk of mortality was observed in the hospital-based cohort and the case–control studies (*25, 27, 34–43*). Significantly increased risks of mortality were observed in all of the studies, and point estimates suggest that poor anthropometric status is associated with a twofold to threefold increased risk of death from acute lower respiratory infection. The studies were conducted in Asia, Africa, and South America. Six of the 12 used dichotomous cut-off points to define malnutrition, most commonly < –2 *Z*-scores or <80% of a reference median. Five studies stratified nutritional status into multiple categories and reported a dose–response relation between nutritional status and risk estimates for mortality. Most of these studies included children under 5 years old.

Malaria

Comparatively few studies assessed nutritional status and death from malaria. The data from hospital-based studies conducted in Africa suggest that anthropometric status at admission is associated with subsequent death from malaria (*25, 44–48*). The largest study involved a cohort of over 8000 cases of malaria and over 700 deaths in the Gambia. Compared with children who had weight for age *Z*-scores >–2, case fatality rates were twofold higher among children with scores of <–3 to > –4 and threefold higher among those with scores < –4 (*25*). Likewise, data from the

Table 3. **Malnutrition and mortality from malaria**

Country (reference)	Year	Outcome measure	Study design	Sample size (no. of deaths)	Age range	Indicator of nutritional status[a]	Findings[b]		
Community-based[a]									
Hospital-based									
Chad (*48*)	1997	Death from malaria	Cohort of those admitted with malaria	227 malaria cases (23)	1–59 months	**W/H *Z*-score** ⩾ −2 <− 2 to ⩾−3 < −3 (NCHS[a] reference)	**Case fatality rate (%)** 12/139 (8.6) 6/63 (9.5) 5/25 (20) (NS)	*Risk ratio* *1.0* *1.1* *2.3*	
Gambia (*25*)	1998	Death from uncomplicated malaria	Cohort of those admitted with malaria	5620 inpatients (432)	< 5 years	**W/A *Z*-score** >−2 <−2 to >−3 <−3 to >−4 <−4 (NCHS reference)	**Case fatality rate (%)** 6.8 7.2 11.0 20.2	*Risk ratio* *1.0* *1.1* *1.6* *3.0*	
		Death from cerebral malaria	Cohort of those admitted with malaria	1292 cases (234)	< 5 years	**W/A *Z*-score** >−2 <−2 to >−3 <−3 to >−4 <−4 (NCHS reference)	**Case fatality rate (%)** 16.9 17.8 23.8 37.5	*Risk ratio* *1.0* *1.1* *1.4* *2.2*	
		Death among children with severe malaria who had transfusions for anaemia	Cohort of those admitted with malaria	1473 cases (63)	< 5 yrs	**W/A *Z*-score** >−2 <−2 to >−3 <−3 to >−4 <−4 (NCHS reference)	**Case fatality rate (%)** 3.1 4.5 7.9 9.8	*Risk ratio* *1.0* *1.5* *2.5* *3.1*	
Madagascar (*46, 47*)	1993	Death from all types of malaria	Cohort of those admitted with malaria	1567 inpatients[d]	0–14 years	**Nutritional status[e]** Normal Slight malnourished Moderate Severe	**Mortality (%)** *1983–92* 8.3 8.0 29.5 30.0	 *1993* — — 5 30	 *1994* — — 12.5 50
Nigeria (*45*)	1997	Death from cerebral malaria	Cohort of those admitted with cerebral malaria	57 cases (8)	1–5 years	**Status** Normal Malnourished (Wellcome classification)	**Case fatality rate (%)** 5/49 (10%) 3/8 (38%) (P=0.07)		
Senegal (*44*)	1998	Death from malaria	Case–control	52 cases; 52 controls hospitalized with malaria	⩽ 15 years	**W/A *Z*-score** < −2 (NCHS reference)	**OR (multivariate analysis)** 3.0 (1.0–9.4)		

[a] None located.

[b] W/H = weight for height; W/A = weight for age.

[c] NS = not significant. Italicised values are secondary calculations based on the published data.

[d] Number of deaths not specified.

[e] No further description given.

Republic of Chad (*48*), Madagascar (*46, 47*), Nigeria (*45*), and Senegal (*44*) indicate that malnourished children admitted to hospital for severe malaria fared less well than adequately nourished cases. No community-based studies were identified.

Measles

Aaby concluded, after an extensive review of historical studies from industrialized countries and contemporary studies in developing countries, that factors such as overcrowding, the intensity of exposure, and patterns of disease transmission are more important than nutritional status as risk factors for measles mortality (*7, 8*). Although many of the hospital-based studies have shown an association between nutritional status at admission and death from measles, no association was found in nearly all of the community-based studies. Singh and colleagues reached a similar conclusion from the Indian studies: the data were insufficient to establish an association between a child's nutritional status before the illness and mortality from measles (*9*).

No additional recent reports of community-based studies were identified. Several more recent hospital-based cohorts and case-series reports were identified from Indonesia (*49*) and Mexico (*50, 51*). The findings from these studies are similar to previous reports: poor nutritional status is related to an increased risk of mortality from measles among children who have been hospitalized. These more recent studies provide no further information about the relation between nutritional status before illness as a risk factor for mortality from measles.

Discussion

This review shows that the relation between malnutrition and mortality varies by cause of death. This is not unexpected given the wide range of causative agents and host defence mechanisms involved in episodes of diarrhoea, acute respiratory illness, malaria, and measles. This review also highlights the lack of good quality, prospective, population-based data that address the relation between different facets of nutritional status and cause-specific mortality.

Study design

The studies that were systematically reviewed had two main designs: observational cohort studies and case–control studies. The strongest evidence for examining the relation between a child's nutritional status before an illness and mortality outcome comes from the observational community-based cohort studies. The next strongest evidence comes from community-based case–control studies with data on nutritional status before illness. In general, cohort studies are more informative because the temporal sequence of events is better documented. However, even in cohort studies the direction of the effect can be confused when children have intermittent illnesses or chronic subclinical infections that result in nutritional deterioration.

The next most informative studies are the hospital-based case–control and cohort studies; however, the interpretation of these studies is problematic for two reasons. In these studies, the nutritional status of the child before the illness is unknown and the nutritional status at the time of admission to hospital must be used. Using indicators that do not change rapidly with illness, such as height for age, can partially overcome this problem. A second problem with these studies is the potential for selection bias occurring in individuals who go to and are admitted to hospital for treatment. Most of the hospital-based studies did not report how the nutritional status of children who were admitted compared with children in the general community. The weakest evidence for evaluating the relation between nutritional status before an illness and cause-specific mortality comes from case-series reports.

Cause-specific mortality and malnutrition

A well-established causal relation exists between malnutrition and diarrhoea. Numerous studies have shown that children with poor anthropometric status experience diarrhoea that is more severe and lasts longer; this indicates that they might also experience a higher risk of mortality associated with diarrhoea. The data suggest that this is the case. A strong and consistent association was observed between nutritional status and mortality from diarrhoea, with higher risks for dysentery. Similar findings were reported in a case-series investigation from Matlab, Bangladesh, where malnutrition was defined by using a relative's report of recent or severe malnutrition in the child. In those analyses malnutrition was associated with 5% of deaths from acute watery diarrhoea, 16% of deaths from acute non-watery diarrhoea, 23% of deaths from diarrhoea occurring after measles, and 45% of deaths from persistent diarrhoea (*52*). Persistent diarrhoea and dysentery account for the majority of deaths related to diarrhoea in the developing world, and malnutrition is undoubtedly an important contributing factor in some of those deaths.

A strong and consistent relation was observed between nutritional status and death from acute lower respiratory infection. Although acute respiratory infections are caused by a wide variety of bacterial and viral agents, the studies consistently reported a twofold to threefold greater risk of mortality associated with low anthropometric status. Several of the hospital-based studies used severe respiratory disease as a criterion for inclusion. Had less stringent criteria been applied a weaker association might have been observed between low anthropometric status and mortality. In addition, many of the children had concurrent illnesses, such as measles or diarrhoea, which might have strengthened the observed association between nutritional status and mortality. Acute respiratory infections are one of the most important causes of mortality among children and the results of these studies suggest that malnutrition is an important associated factor in these deaths.

The limited data available from hospital-based studies of mortality from malaria suggest that poor nutritional status at admission is related to an increased risk of death. A variety of nutrient deficiencies, including protein-energy malnutrition, have also been linked to an increased risk of malaria morbidity (*53*). However, no community-based studies were identified that related nutritional status to mortality among children with slide-confirmed malarial parasitaemia. In one community-based study of nutritional status and all-cause mortality conducted in a region of the Democratic Republic of the Congo (formerly Zaire) where malaria is endemic, an association was observed between severe malnutrition and all-cause mortality but not mild or moderate malnutrition (*54*). Malaria was cited as the most common cause of death among the study participants. Unfortunately, data from this study are of limited use in addressing the relation between nutritional status and mortality from malaria because no blood slides were taken to confirm the diagnosis and data were not presented on the diagnostic specificity of fever for a malaria attack. The clinical signs of severe malaria are similar to pneumonia, septicaemia, and other infectious diseases (*55*) and diagnosing malaria using non-specific indicators, such as fever alone, can be misleading and may mask potential associations with malnutrition. Longitudinal community-based studies that follow children with slide-confirmed malaria will be required to investigate the relation between nutritional status before illness and mortality from malaria.

The evidence for a relation between nutritional status and mortality from measles is less consistent. Although many of the hospital-based studies found an association between status at admission and risk of mortality, numerous community-based studies have been conducted and nearly all reported no association between nutritional status and mortality. Measles has a characteristic rash, and a validation study in Africa showed that the verbal autopsy method detected measles deaths with greater than 75% sensitivity (*56*). Therefore, misclassification of measles mortality is unlikely to explain the lack of association observed in the community-based studies in Africa.

Limitations

There are several other limitations and potential sources of bias in the studies. These include the variation between the time of anthropometric assessment and assessment of mortality, the imprecise ascertainment of cause-specific mortality, the assessment of comorbidity, variation in the age range of the children studied, problems associated with the interpretation of anthropometric indicators, and the relation between low birth weight and subsequent anthropometric status.

The time frame between the assessment of nutritional status and mortality varied in these studies. Community-based studies of nutritional status and all-cause mortality have shown that the association between anthropometric status and risk of mortality differs: stronger associations are observed with shorter time intervals. The time frame was less variable for the hospital-based studies in which admission status was related to outcome (generally death or recovery and discharge) over a comparatively short period of time.

Obtaining reliable information on causes of death is difficult. This is especially true in community-based studies conducted in developing countries where the verbal autopsy method is used to ascertain the cause of death. However, there are few alternatives for obtaining data in settings where deaths occur outside hospitals and information about the cause of death is not recorded elsewhere. The situation is somewhat less problematic in hospital-based studies because treatment records exist. But even where good records exist, assigning one single cause of death is often difficult because many children have concurrent illnesses before death, such as diarrhoea and acute lower respiratory infection. A misclassification in the data on the cause of death will affect the observed relation between nutritional status and cause-specific mortality. In one study that reported separate risk estimates, a stronger association between nutritional status and mortality was observed for concurrent diarrhoea and acute lower respiratory infection than for mortality from either condition alone (*15*).

The age range of the children in the studies that were reviewed varied. Most studies included children younger than 5 years of age and reported overall risk estimates rather than estimates stratified by age. In the one study that reported age-stratified risks, the relation between nutritional status and cause-specific mortality from diarrhoea and acute respiratory illness varied for children aged 0–5 months, 6–11 months, and 12–23 months (*15*). This is not surprising when the immunological and other biological differences between infants and older children are considered.

Malnutrition is a complex phenomenon. Low anthropometric status may result from a combination of nutritional factors, such as deficiencies in protein or calories or a variety of minerals and micronutrients (*57*), or from other infectious disease processes. Most of the studies reported the child's weight for age, a measurement that does not distinguish acute malnutrition from chronic or past malnutrition. Even though an association is apparent, the underlying factors that account for the relation between low anthropometry and mortality remain unclear. This gap in our knowledge has important implications for the development of effective prevention programmes.

Studies that only examined the relation between low birth weight and cause-specific mortality were not included in this review. In one sense, the division between those and the studies that assessed anthropometric status in young infants is somewhat artificial because birth weight clearly influences anthropometric status in infancy (*58–60*). In another sense, however, the underlying factors responsible for the association between low birth weight and cause-specific mortality may differ from the factors that contribute to the association between later nutritional status and mortality. This requires further investigation. The determination of whether low birth weight itself is an independent risk factor for cause-specific mortality has important implications for the development of intervention strategies.

Conclusions

It is clear that despite the limitations of each study, malnutrition plays an important contributing role in some of the most common causes of mortality in children. The findings also suggest that the risk of mortality associated with malnutrition may not be equivalent for all conditions or across all age groups. Clarifying these relations has implications for planning and evaluating programmes. If the relation between malnutrition and cause-specific mortality differs between diseases then the potential impact on child survival of programmes that successfully reduce the prevalence of malnutrition may differ in areas with different primary causes of death.

This review also shows that despite three decades of work considerable research still needs to be done. Comparatively few studies have been conducted using designs that can adequately capture the associations between pre-existing nutritional status and the subsequent risk of mortality from different diseases. Population-based, longitudinal studies that carefully monitor nutritional status and cause-specific mortality are needed to quantify better the risk of death associated with malnutrition. Moreover, the relation between the different components of malnutrition — wasting, stunting, and micronutrient deficiencies — need further study so that their contribution to child mortality is better understood. Such information could help in designing intervention programmes that promote the survival of children. ■

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Résumé

La malnutrition en tant que cause sous-jacente des décès par maladies infectieuses chez l'enfant dans les pays en développement

Chaque année, on compte environ 12 millions de décès d'enfants de moins de 5 ans, pour la plupart dans des pays en développement. Plus de 50 % de ces décès sont dus à la diarrhée, aux infections respiratoires aiguës, au paludisme ou à la rougeole, maladies évitables ou curables moyennant des interventions peu coûteuses. La malnutrition, fréquente dans les pays en développement, est rarement citée parmi les causes majeures de décès car il s'agit essentiellement d'un facteur sous-jacent et non d'une cause directe de la mort. D'après des analyses récentes portant sur l'impact des causes sous-jacentes de décès chez l'enfant, la malnutrition (mesurée par les paramètres anthropométriques) serait associée au décès dans près de la moitié des cas dans les pays en développement.

Bien que l'association entre la malnutrition et la mortalité par toutes causes soit bien établie, la part du risque associé à la malnutrition dans les décès dus à certaines maladies est moins bien documentée. L'OMS soutient actuellement un projet visant à chiffrer la contribution de la malnutrition à la mortalité due à certaines maladies chez l'enfant. Dans le cadre de ce projet, nous avons examiné la littérature médicale afin d'identifier les études portant sur la relation entre la malnutrition et la mortalité par diarrhée, infections respiratoires aiguës, paludisme et rougeole. Ce rapport donne un aperçu de nos résultats.

Pour identifier les études pertinentes, nous avons interrogé la base de données MEDLINE au moyen de mots clés, de noms d'auteurs et de la fonction « Related articles » pour rechercher les mises au point et les rapports originaux portant sur des études réalisées en milieu hospitalier et dans la communauté. D'autres publications ont été identifiées à partir des bibliographies des articles sélectionnés et lors de discussions avec des collègues. Les résultats des études prospectives (de cohorte) et des études cas-témoins ont également été examinés.

D'après les données, la malnutrition serait associée à un risque accru de décès par diarrhée, et ce risque varierait selon le type de diarrhée. Toutes les études réalisées dans la communauté ont rapporté une augmentation du risque de décès par diarrhée chez les enfants ayant un rapport poids/âge faible ; une relation de type dose-réponse a été rapportée lors d'études réalisées en Inde, aux Philippines et au Soudan. Les données laissent également à penser que la malnutrition est fortement associée à un risque accru de décès par infection aiguë des voies respiratoires basses. Une relation inverse entre le rapport poids/âge et le risque de décès était apparente dans les trois études réalisées dans la communauté. Un nombre comparativement plus faible d'études ont porté sur la relation entre l'état nutritionnel et les décès par paludisme. Les données d'études en milieu hospitalier réalisées en Afrique indiquent une association entre les paramètres anthropométriques à l'admission et le décès par paludisme. Une relation moins systématique entre l'état nutritionnel avant la maladie et la mortalité a été observée dans le cas de la rougeole. D'après un examen approfondi des données historiques dans les pays industrialisés et des données contemporaines dans les pays en développement, Aaby a conclu que des facteurs tels que le surpeuplement, l'intensité de l'exposition et les modalités de transmission de la maladie sont des facteurs de risque plus importants que l'état nutritionnel pour la mortalité rougeoleuse.

La relation la plus forte et la plus régulière entre la malnutrition et l'augmentation du risque de décès a été observée pour la diarrhée et les infections respiratoires aiguës. Bien que limitées, les données évoquent également une augmentation potentielle du risque de décès par paludisme. Une association moins régulière a été observée dans le cas de la rougeole.

Il est clair que, malgré les limites de l'interprétation des diverses études examinées, la malnutrition contribue à certaines des causes majeures de mortalité chez l'enfant, et que le risque est différent selon les maladies. Cependant, l'absence de données de bonne qualité issues d'études prospectives réalisées dans la communauté limite les conclusions que l'on peut tirer quant à la relation entre la malnutrition et la mortalité liée à chacune des maladies considérées. Si la malnutrition n'augmente pas de la même façon le risque de mortalité pour les diverses maladies, les programmes d'intervention qui parviennent à améliorer l'état nutritionnel peuvent ne pas avoir le même potentiel de réduction de la mortalité chez l'enfant dans des régions dont le profil de morbidité est différent. L'élucidation de ces relations aura des répercussions importantes sur l'élaboration et l'évaluation des programmes d'intervention.

Resumen

La malnutrición como causa subyacente de las defunciones infantiles por enfermedades infecciosas en los países en desarrollo

Aproximadamente unos 12 millones de niños menores de cinco años mueren cada año; la mayoría de ellos viven en países en desarrollo. Más del 50% de esas defunciones se deben a diarrea, enfermedades respiratorias agudas, paludismo o sarampión, afecciones todas ellas prevenibles o tratables con intervenciones de bajo costo. La malnutrición, muy frecuente en los países en desarrollo, rara vez se cita entre las principales causas de muerte porque es sobre todo un factor subyacente, más que una causa directa de muerte. Sin embargo, algunos estudios recientes en los que se ha analizado la repercusión de causas subyacentes de muerte parecen indicar que la malnutrición (medida con criterios antropométricos) es una causa asociada en aproximadamente la mitad de todas las defunciones infantiles en los países en desarrollo.

Aunque la relación entre la malnutrición y la mortalidad por todo tipo de causas está bien documentada, está peor descrito el riesgo adicional que supone la malnutrición en lo que respecta a la defunción por enfermedades específicas. La OMS patrocina actualmente un proyecto que tiene por objeto estimar cuantitativamente la contribución de la malnutrición a la mortalidad por causas específicas en la infancia. Como parte de este proyecto, examinamos la literatura publicada para identificar los estudios referentes a la relación entre la malnutrición y la mortalidad por diarrea, infecciones respiratorias agudas, paludismo y sarampión. En este informe se presenta una visión general de nuestros resultados.

Para localizar los estudios realizados, se hizo una búsqueda en MEDLINE de artículos de revisión e informes originales de estudios comunitarios y hospitalarios utilizando las palabras clave pertinentes, nombres de autores y el enlace «artículos relacionados». Otras publicaciones se identificaron a partir de las listas de referencias de los artículos seleccionados y del intercambio de opiniones con colegas. Se incluyeron en la revisión los resultados de estudios prospectivos de cohortes y de estudios de casos y testigos.

Los datos indican que la malnutrición se asocia a un mayor riesgo de muerte por diarrea y que el riesgo varía según el tipo de diarrea. Todos los estudios comunitarios informaban de un mayor riesgo de muerte por diarrea entre los niños con un peso bajo para su edad; en estudios realizados en la India, Filipinas y el Sudán se informaba de una relación dosis-respuesta. Los datos sugieren asimismo que la malnutrición está estrechamente relacionada con un mayor riesgo de mortalidad por infecciones agudas de las vías respiratorias inferiores. En los tres estudios comunitarios se observaba claramente una relación dosis-respuesta entre la disminución del peso para la edad y el aumento del riesgo de mortalidad. Fueron comparativamente pocos los estudios en que se evaluaron el estado nutricional y las defunciones por paludismo. Los datos aportados por estudios realizados en hospitales de África parecen indicar que los valores antropométricos en el momento del ingreso están relacionados con la mortalidad posterior por paludismo. Se observó una relación menos sistemática entre el estado nutricional antes de la enfermedad y la mortalidad por sarampión. Sobre la base de un extenso análisis de estudios históricos realizados en los países industrializados y estudios contemporáneos llevados a cabo en países en desarrollo, Aaby concluyó que factores como el hacinamiento, la intensidad de la exposición y las pautas de transmisión de las enfermedades son más importantes que el estado nutricional como factores de riesgo de la mortalidad por sarampión.

La relación más sólida y sistemática entre la malnutrición y un mayor riesgo de defunción fue la observada para la diarrea y las infecciones respiratorias agudas. Los datos, aunque limitados, sugieren también un riesgo potencialmente mayor de defunción por paludismo. Se observó también una relación, si bien menos obvia, entre el estado nutricional y la mortalidad por sarampión.

Pese a las limitaciones de que adolecen todos los estudios analizados, está claro que la malnutrición contribuye a algunas de las causas más importantes de mortalidad en la infancia, y que ese riesgo adicional probablemente no es del mismo orden para todas las enfermedades. Sin embargo, la falta de datos de buena calidad procedentes de estudios prospectivos y comunitarios limita las conclusiones que pueden extraerse respecto a la relación entre la malnutrición y la mortalidad por causas específicas. Si la malnutrición no aumenta por igual la mortalidad debida a las distintas causas de defunción, los programas de intervención que logran mejorar eficazmente el estado nutricional no tendrán el mismo efecto de reducción de la mortalidad infantil en regiones con diferentes perfiles de morbilidad. Por tanto, es importante esclarecer la relación entre esas variables con miras al desarrollo y evaluación de programas de intervención.

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