A prospective study of malnutrition in relation to child mortality in the Sudan[1–3]

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ABSTRACT We examined prospectively the relation between malnutrition and mortality among Sudanese children. A cohort of 28 753 children between the ages of 6 mo and 6 y was examined every 6 mo for 18 mo. Two hundred thirty-two children died during 18 mo of follow-up (480 624 child-months). Low weight-for-height was associated with an increased risk of mortality ($P < 0.0001$). Even children with Z scores between -1 and -2 were 50% more likely to die in the following 6 mo than were children with Z scores > -1 (multivariate relative mortality: 1.5; 95% CI: 1.1, 2.2). There was also an inverse relation between height-for-age and mortality ($P < 0.0001$). Among breast-fed children, the relative mortality associated with a Z score for weight-for-height of < -3 compared with > -2 was 7.3 (95% CI: 3.3, 15.9); among children not breast-fed, it was 26.0 (95% CI: 12.8, 53.0; P for interaction = 0.001). A strong and significant synergy was also found between infection and wasting or stunting as predictors of child mortality (P for interaction = 0.001 and 0.02, respectively). In developing countries, children who are below the customary cutoff point of -2 Z for weight-for-height may be at higher risk of death. Breast-feeding and reduction of morbidity should be advocated in programs designed to reduce malnutrition and mortality among children. *Am J Clin Nutr* 1997;65: 1062–9.

KEY WORDS Malnutrition, mortality, morbidity, infection, breast-feeding, developing countries, Sudan, children

INTRODUCTION

Malnutrition in children is a major public health problem in many developing countries. About 43% (230 million) of children younger than 5 y in developing countries are reported to be stunted, whereas ≈9% (50 million) are wasted (1). Several studies have reported an inverse association between nutritional status, assessed by anthropometric measurements, and child mortality. Often, these investigations were limited by small sample sizes, short duration of follow-up, lack of adjustment of the results for potential confounding variables, and limited statistical power to identify factors that may modify the association between malnutrition and mortality. Conflicting results have been obtained. In some studies, only severe malnutrition was associated with increased mortality (2, 3) and in others an association between mild to moderate malnutrition and mortality was found (4, 5); in still others, nutritional status was not associated with mortality (6, 7).

We used the sample from the Sudan Vitamin A Study (8) to examine the association between mortality and nutritional status as defined by weight-for-height, height-for-age, and weight-for-age, adjusting for potential confounders. Because of the large sample size in this study (28 753 children) relative to other studies, it was possible to divide the spectrum of nutritional status into finer categories to study the association between various degrees of malnutrition and mortality. We also examined the relation between nutritional status and mortality within categories of age, sex, morbidity, breast-feeding, vitamin A intake, and seasonality.

SUBJECTS AND METHODS

In June 1988, 28 753 children were enrolled in a field trial to determine the effect of vitamin A supplementation on mortality and morbidity. Details are given elsewhere (8). The study population consisted of children between 6 and 72 mo of age who were free of signs of vitamin A deficiency, and who resided in five regions of Khartoum and Gezira in northern Sudan. After enrollment (round 1), each household was visited every 6 mo for a maximum of three visits (rounds 2–4). In alternating households, all eligible children were assigned to receive either a large dose of vitamin A (200 000 IU, or 60 mg) or a placebo at each round. Survival of each child was ascertained at each visit by questioning the mother or principal caretaker. Children who were diagnosed with xerophthalmia at any follow-up visit were given a large dose of vitamin A and were excluded from further follow-up. Children who were not present at the time of a visit were not followed up further, but their survival status was assessed at that round and at subse-

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quent rounds by questioning their families and neighbors. In case of death, information was collected on the following symptoms in the week preceding death: diarrhea, breathlessness, fever, rash, convulsions, or accidents.

Information on other potential risk factors for mortality was collected at baseline, including availability of running water in the house, maternal literacy, region of residence, and household wealth assessed subjectively by the interviewers on a 4-point scale. We found that each of the first three variables was highly correlated with household wealth and therefore used the four variables as indicators of socioeconomic status. At each visit, the mother was asked whether the child experienced any of the following symptoms in the preceding week: diarrhea (three or more episodes of loose or watery diarrhea per 24 h), cough (lasting $\geq$ 24 h), or fever. On the basis of this information, a child was considered well or was assigned to one of the following four mutually exclusive morbidity categories: diarrhea alone or with fever, cough alone, cough with fever with or without diarrhea, and fever alone. Interviewers also asked whether or not the child was being breast-fed.

At each round, weight was measured with a Salter scale to the nearest 100 g. Height (or recumbent length for children shorter than 85 cm) was measured to the nearest 1 mm with a locally made anthropometer. All measurements were carried out by two interviewers. The Centers for Disease Control and Prevention Anthropometric Software Package (CASP; Atlanta) was used to calculate Z scores at each round for weight-for-height, height-for-age, and weight-for-age. Dietary vitamin A intake was assessed at each round by asking the principal caretaker to recall whether or not a child had consumed each item on a list of vitamin A–containing foods in the previous 24 h. Approximate dietary intake of total vitamin A was obtained by multiplying the nutrient content of each food item by an assumed average portion (9).

Of the total number of children enrolled at baseline, follow-up rates were 92%, 87%, and 84% at 6, 12, and 18 mo, respectively. There was no significant difference in baseline weight-for-height or height-for-age between children lost to follow-up and those remaining in the study. Children were grouped into the following five categories for each anthropometric index: > -1 Z, ≤ -1 to > -2 Z, ≤ -2 to > -3 Z, ≤ -3 to > -4 Z, and ≤ -4 Z. The relation between nutritional status at the beginning of each round and mortality during the following 6 mo was examined. Children who were lost to follow-up or were excluded from further follow-up because they developed xerophthalmia were censored for the remaining period of follow-up. Thus, each child assessed at the beginning of a round contributed 6 child-months of observation. We considered each child a new observation, if they survived to the beginning of the next round, and updated the exposure variables accordingly. Pooled multivariate logistic regression was used to estimate mortality rate ratios (relative mortality, RM) and 95% CIs (10). Mortality rates for a given exposure were calculated by dividing the number of deaths by the cumulated child-months of follow-up. The RM was computed as the rate among children in a given category of nutritional status relative to the lowest category.

The associations between nutritional status and total mortality or symptom-specific mortality were examined. During the follow-up period, 232 children died; of these, 99 (42.7%) had diarrhea in the period preceding death, 65 (28.0%) had fever, 23 (9.9%) had breathlessness, 24 (10.3%) died as a result of accidents, and 21 (9.0%) had other symptoms. A few children had missing data for weight, height, or age at a particular round; the number of deaths and child-periods used in the analyses are indicated in the tables below. Results were adjusted for covariates that could explain an association between nutritional status and mortality, including age at the time of anthropometric measurement, sex, vitamin A intake (from capsule and diet), morbidity in the week preceding nutritional-status assessment, and socioeconomic-status variables. We also examined whether the association between nutritional status and risk of mortality was modified by age, sex, breast-feeding, morbidity, capsule (vitamin A compared with placebo), dietary vitamin A, and seasonality. For the latter analyses, separate logistic-regression analyses for categories of each potential modifier were used. We also tested for the presence of interaction by including product terms of nutritional status (continuous Z score) and the variable of interest in a model containing the other risk factors; the likelihood ratio test was used to evaluate the statistical significance of the interaction. A test for trend in the relation between nutritional status and mortality was computed by modeling the nutritional-status Z score as a continuous variable. Restricted cubic splines (11) were used to create smooth plots of log RM rates and nutritional status, as shown in the figures. For each curve, four knots were placed at the 5th, 35th, 65th, and 95th percentiles. The curves were adjusted for all variables included in the multivariate model. The reference level for all plots was a Z score of 0. Data were analyzed by using the Statistical Analysis System (SAS) version 6.04 (SAS Institute Inc, Cary, NC).

The study was approved by the Committee on the Use of Human Subjects in Research of the Harvard School of Public Health, the Director General of Primary Health Care of the Ministry of Health in the Sudan, and both Directors of Health for Khartoum and Central Regions.

RESULTS

Two hundred thirty-two deaths occurred during 480 624 child-months of observation. A significant positive trend was noted between mortality and the degree of wasting, as defined by weight-for-height (P for trend < 0.0001; **Table 1**, **Figure 1**). Children in each of the four lower categories of weight-for-height were at a higher risk of death compared with children in the baseline category, even after adjustment for socioeconomic status, morbidity, and seasonality (Table 1). Children with Z scores between -1 and -2 were 50% more likely to die in the following 6 mo compared with children with a Z score > -1 (multivariate RM: 1.5; 95% CI: 1.1, 2.2). When children in extreme categories (≤ -4 Z compared with > -1 Z) were compared, the RM was 19.7 (95% CI: 9.2, 42.1). When the results were adjusted for height-for-age Z score, the RM comparing children in extreme categories was 31.0 (95% CI: 14.2, 67.6). The results were not different for children in the upper four categories of weight-for-height, suggesting that height-for-age was more important as a confounder, and hence a risk factor for death, at very low levels of weight-for-height compared with children with higher weight-for-height Z scores.

Height-for-age, a measure of stunting, was also associated with a higher risk of mortality (P for trend < 0.0001; Table 1,

TABLE 1
All-cause relative mortality and 95% CIs in relation to nutritional status[1]

Nutritional index	Z scores				
	> −1	−1 to −2	−2 to −3	−3 to −4	< −4
Weight-for-height					
No. of child-months	222 060	174 402	40 470	3324	876
No. of deaths	59	79	34	28	9
RM (95% CI) adjusted for					
(a) age + sex	1.0	1.7	3.0	24.7	25.8
(b) a + SES + vitamin A intake	1.0	1.6	2.5	27.2	20.7
(c) b + morbidity + seasonality	1.0	1.5 (1.1, 2.2)[2]	2.3 (1.5, 3.6)	18.0 (11.0, 29.5)	19.7 (9.2, 42.1)
(d) c + height-for-age Z score	1.0	1.5 (1.1, 2.1)	2.2 (1.4, 3.5)	17.9 (10.9, 29.4)	31.0 (14.2, 67.6)
Height-for-age					
No. of child-months	118 380	131 288	106 098	55 002	29 970
No. of deaths	35	46	38	38	47
RM (95% CI) adjusted for					
(a) age + sex	1.0	1.2	1.3	2.4	4.7
(b) a + SES + vitamin A intake	1.0	1.2	1.1	2.1	4.0
(c) b + morbidity + seasonality	1.0	1.2 (0.7, 1.8)	1.1 (0.7, 1.7)	2.1 (1.3, 3.4)	3.9 (2.5, 6.3)
(d) c + weight-for-height Z score	1.0	1.2 (0.8, 1.9)	1.1 (0.7, 1.7)	2.0 (1.3, 3.2)	3.4 (2.2, 5.5)
Weight-for-age					
No. of child-months	85 266	161 676	141 810	44 538	7956
No. of deaths	17	40	52	52	43
RM (95% CI) adjusted for					
(a) age + sex	1.0	1.4	2.0	5.2	20.4
(b) a + SES + vitamin A intake	1.0	1.3	1.7	4.5	16.9
(c) b + morbidity + seasonality	1.0	1.3 (0.7, 2.2)	1.7 (0.9, 2.9)	4.2 (2.4, 7.4)	15.2 (8.4, 27.6)

[1] RM, relative mortality; SES, socioeconomic-status variables [wealth (ordinal, four levels), availability of running water in the house (yes or no), maternal literacy (yes or no), region of residence (four dummy variables)]. Vitamin A intake included dietary vitamin A intake (continuous) and capsule (vitamin A and placebo). Morbidity variables (six dummy variables) and season (five dummy variables) are described in the text.
[2] CIs in parentheses.

Figure 2). However, the relation was significant only when children in the two lowest categories (≤ −3 *Z*) were compared with the highest one. The multivariate RM comparing children in extreme categories was 3.9 (95% CI: 2.5, 6.3). Children with *Z* scores between −2 and −3 were not at an increased risk of mortality (RM: 1.1; 95% CI: 0.7, 1.7). Weight-for-age, a measure of both stunting and wasting, was also inversely associated with mortality (*P* for trend < 0.0001; Table 1, **Figure 3**).

The association between each of the three anthropometric indexes and mortality was stronger when deaths due to acci-

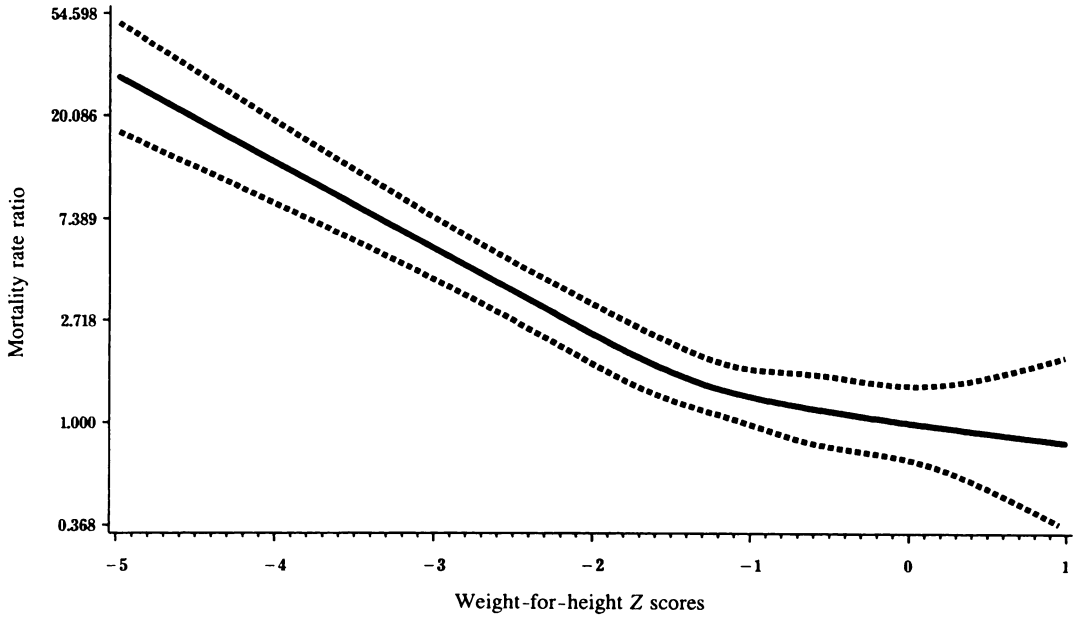

FIGURE 1. The reference level for each mortality rate ratio is a *Z* score of 0. The dotted lines represent the 95% CIs around the mortality rate ratios.

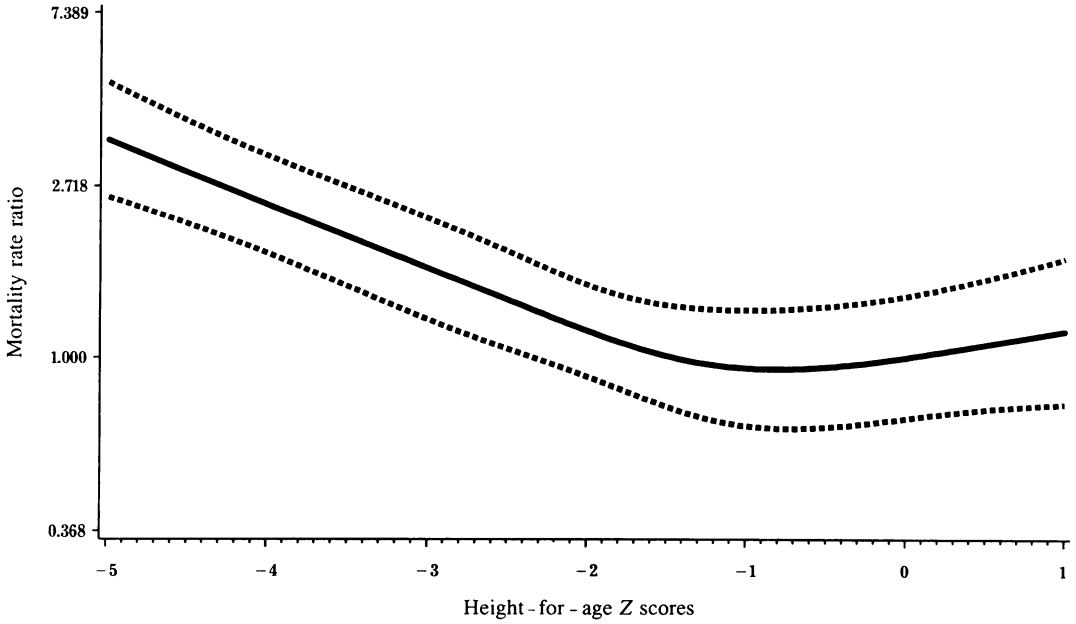

FIGURE 2. The reference level for each mortality rate ratio is a *Z* score of 0. The dotted lines represent the 95% CIs around the mortality rate ratios.

dents were excluded (**Table 2**). Nutritional status defined by any of the three indexes was inversely associated with diarrhea-, fever-, and breathlessness-related mortality (Table 2). Compared with children who had a weight-for-height *Z* score > -1, those who had *Z* scores between -1 and -2 were 2.8 times more likely to experience a fever-related death (95% CI: 1.4, 5.5). When children in extreme categories of weight-for height were compared, the relative risk of diarrhea-related death was 24.3 (95% CI: 9.1, 64.8), whereas that for breathlessness-related deaths was 19.4 (95% CI: 2.3, 163.3). Height-for-age was not associated with increased mortality due to accidents; when children with a height-for-age *Z* score < -3 were compared with those with a *Z* score > -1, the RM was 1.1 (95% CI: 0.1, 10.3). On the other hand, weight-for-height was associated with higher risk of deaths due to accidents; the corresponding RM was 9.6 (95% CI: 1.1, 83.7) (Table 2).

The relation between weight-for-height and mortality was more pronounced among children who were 2–4 y of age than among those either younger or older; however, a formal test of interaction showed that it was not significant (**Table 3**). There was no significant difference in the association between wasting or stunting and mortality across categories of vitamin A status (defined as experimental capsule or dietary intake) or sex (Table 3 and **Table 4**). The role of breast-feeding was examined in analyses limited to children who were aged ≤ 2 y at the time of anthropometric measurement and breast-feeding as-

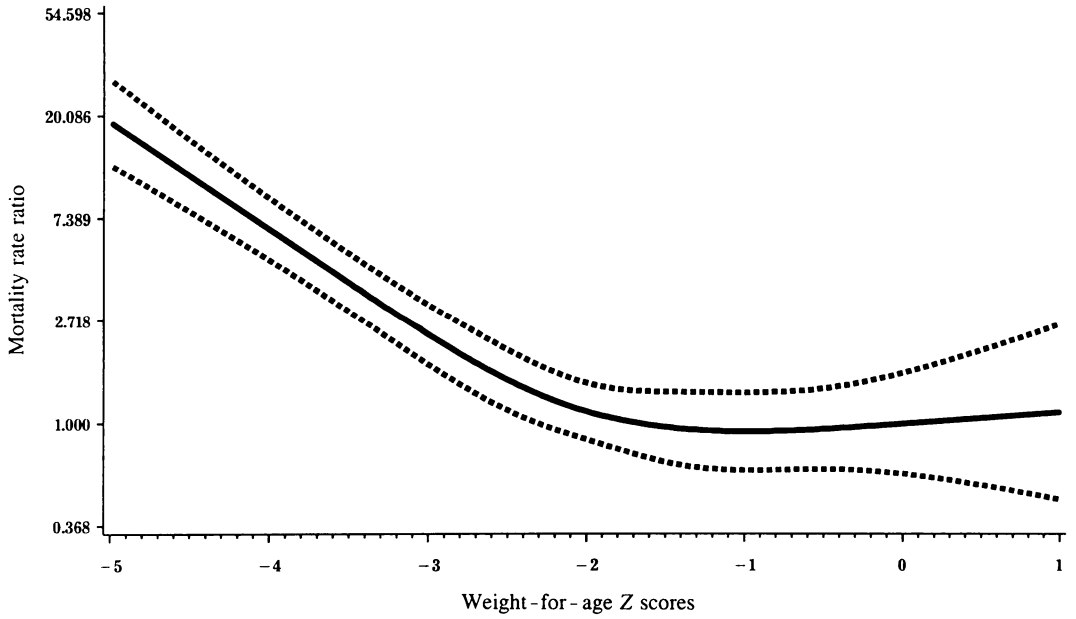

FIGURE 3. The reference level for each mortality rate ratio is a *Z* score of 0. The dotted lines represent the 95% CIs around the mortality rate ratios.

TABLE 2
Cause-specific relative mortality and 95% CIs in relation to nutritional status[1]

Symptom or cause of death	Z scores				
	> −1	−1 to −2	−2 to −3	−3 to −4	< −4
Weight-for-height					
All, excluding accidents (n = 191)	1.0	1.7 (1.2, 2.4)	2.5 (1.6, 4.0)	21.3 (13.0, 34.9)	22.0 (10.3, 47.2)
Diarrhea (n = 85)	1.0	1.4 (0.7, 2.5)	3.5 (1.8, 6.6)	26.5 (13.4, 52.3)	24.3 (9.1, 64.8)
Fever (n = 54)	1.0	2.8 (1.4, 5.5)	1.9 (0.7, 5.4)	26.4 (10.1, 69.2)	28.6 (6.1, 134.0)
Breathlessness (n = 23)	1.0	1.2 (0.5, 3.3)	3.0 (1.0, 9.3)	5.8 (0.7, 47.3)	19.4 (2.3, 163.3)
Accidents (n = 13)[2]	1.0	0.8 (0.2, 2.8)	1.7 (0.3, 8.5)	9.6 (1.1, 83.7)	
Height-for-age					
All, excluding accidents (n = 191)	1.0	1.2 (0.8, 2.0)	1.2 (0.8, 2.0)	2.3 (1.4, 3.8)	4.6 (2.8, 7.4)
Diarrhea (n = 85)	1.0	1.7 (0.8, 3.7)	1.8 (0.8, 3.9)	4.1 (1.8, 9.2)	8.3 (3.8, 17.9)
Fever (n = 54)	1.0	0.8 (0.4, 1.7)	0.7 (0.3, 1.6)	1.2 (0.5, 2.8)	2.5 (1.1, 5.8)
Breathlessness (n = 23)	1.0	5.5 (0.8, 46.1)	4.5 (0.5, 40.8)	10.8 (1.2, 93.3)	23.4 (2.8, 195.0)
Accidents (n = 13)	1.0	0.8 (0.2, 3.3)	0.3 (0.03, 2.2)	1.5 (0.3, 6.7)	1.1 (0.1, 10.3)
Weight-for-age					
All, excluding accidents (n = 191)	1.0	1.4 (0.8, 2.6)	1.7 (1.0, 3.1)	5.1 (2.8, 9.1)	19.2 (10.4, 35.5)
Diarrhea (n = 85)	1.0	2.0 (0.7, 6.2)	2.0 (0.6, 6.1)	9.8 (3.4, 28.4)	41.4 (14.0, 122.0)
Fever (n = 54)	1.0	0.8 (0.3, 1.9)	1.1 (0.5, 2.7)	2.2 (0.9, 5.6)	8.8 (3.2, 23.8)
Breathlessness (n = 23)	1.0	1.7 (0.2, 16.7)	4.4 (0.5, 36.2)	13.6 (1.7, 110.4)	31.9 (3.4, 294.7)
Accidents (n = 13)[2]	1.0	0.7 (0.1, 4.2)	1.8 (0.4, 8.6)	0.8 (0.1, 9.4)	

[1] Relative mortality and CIs "all, excluding accidents", diarrhea, and fever are from multivariate logistic models including age, sex, wealth, running water in house, maternal literacy, region of residence, dietary vitamin A intake, and capsule. Logistic models for breathlessness included age, sex, wealth, and dietary vitamin A intake. n is the number of deaths.

[2] There were no deaths in the lowest category; therefore, the lowest two categories were combined as one.

sessment. The association between weight-for-height and mortality was strongly modified by breast-feeding. Among breast-fed children, weight-for-height Z scores < -3 were associated with a 7.3-fold increase in mortality when compared with subjects with Z scores > -2 (95% CI: 3.3, 15.9). The corresponding RM among children who were not breast-fed was 26.0 (95% CI: 12.8, 53.0); a formal test of interaction showed it to be significant (P = 0.001).

There was also a strong interaction between nutritional status, as defined by weight-for-height, and morbidity in the prediction of child mortality. In a comparison of children with a Z score < -3 with those with a Z score > -2, the RM was 9.1 (95% CI: 4.2, 19.5) among children who had no symptoms, 27.0 (95% CI: 7.6, 96.0) among children who had fever alone, and 48.3 (95% CI: 19.8, 117.4) among those who had cough with fever. A test for interaction was significant (P = 0.001; Table 3). The season during which anthropometric measurements were assessed also modified the relation between wasting and mortality (Table 3). There was a significant interaction between morbidity and stunting in the prediction of mortality (P = 0.02; Table 4).

DISCUSSION

We report strong inverse associations between height-for-age, weight-for-height, and weight-for-age and mortality, even after adjustment for possible confounding by age, sex, vitamin A intake, morbidity, seasonality, and socioeconomic status. The association between undernutrition and mortality may reflect the effect of morbidity on both anthropometry and risk of mortality before nutritional assessment. To address this concern, we adjusted for morbidity occurring in the week before nutritional assessment. As expected, the results were attenuated after adjustment for morbidity, but the inverse associations persisted. However, it is still possible that residual confounding by morbidity or socioeconomic status explains at least in part the association between malnourishment and mortality.

The inverse association between nutritional status and mortality agrees with the findings of several studies from Asia and Africa (12), but differs from the results of a classic study from Bangladesh (2) and observations in Kasongo, Zaire (6), and Guinea Bissau (7), where malnourishment was not associated with mortality. The results from the Bangladesh study were not confirmed in follow-up studies conducted in the same area (13), whereas the Kasongo study was limited by methodologic problems that may have resulted in underascertainment of deaths (12). A measles epidemic that occurred during the follow-up period of the Bissau study may have biased the results because measles may be fatal among children with varied nutritional status. A recent study from Zaire found an association between malnutrition and mortality. This association, however, was observed only among children with severe malnutrition, particularly marasmus or kwashiorkor (3).

Low weight-for-height was associated with an increased risk of dying. Even children who were not classified as malnourished because they had a Z score greater than the customary cutoff point (−2) experienced greater mortality. This finding illustrates the importance of recognizing that the customary cutoff point (a Z score −2), although useful for planning purposes, is not intended to be diagnostic of increased risk of disease or death (14). The cutoff implies that 97.5% of the reference population of healthy children had values within this range. Values that lie within this range do not ensure that the individual is healthy (15). In a recent study from Zaire (3), children who had Z scores between −1 and −2 experienced an

TABLE 3
Relative mortality (RM) in relation to weight-for-height as modified by age, sex, breast-feeding, vitamin A supplementation, morbidity, and seasonality[1]

Characteristic	No. of deaths (rate/1000 child-months) among all children	Characteristic-RM relation[2]	RM within subgroups of characteristic[3]			Test for interaction: χ, df, P value[4]
			> -2 Z	-2 to -3 Z	< -3 Z	
Age (y)						
≥ 5	27 (0.14)	1.0	1.0	1.3 (0.4, 4.3)	6.7 (0.9, 50.5)	
4	24 (0.29)	1.7 (1.0, 3.0)	1.0	0.6 (0.1, 4.2)	18.3 (4.1, 82.5)	
3	53 (0.62)	2.5 (1.5, 4.2)	1.0	2.1 (0.9, 4.7)	32.3 (15.1, 68.9)	
2	85 (1.35)	4.4 (2.7, 7.2)	1.0	2.5 (1.4, 4.2)	15.8 (9.2, 27.3)	
< 1	15 (1.56)	6.2 (3.0, 12.8)	1.0	1.1 (0.2, 5.2)	5.1 (1.0, 26.4)	6.67, 4, 0.15
Sex						
Boys	94 (0.42)	1.0	1.0	1.7 (0.9, 3.0)	16.7 (9.7, 28.8)	
Girls	115 (0.53)	1.3 (0.9, 1.8)	1.0	2.2 (1.3, 3.7)	16.6 (9.4, 29.4)	0.28, 1, 0.60
Capsule						
Placebo	102 (0.46)	1.0	1.0	2.3 (1.4, 3.9)	14.7 (8.2, 26.4)	
Vitamin A	107 (0.48)	1.1 (0.8, 1.5)	1.0	1.6 (0.9, 2.9)	18.4 (10.8, 31.2)	0.02, 1, 0.89
Breast-feeding[5]						
No	49 (1.26)	1.0	1.0	3.2 (1.6, 6.5)	26.0 (12.8, 53.0)	
Yes	51 (1.52)	1.4 (0.8, 2.6)	1.0	1.7 (0.8, 3.6)	7.3 (3.3, 15.9)	10.69, 1, 0.001
Morbidity						
None	86 (0.30)	1.0	1.0	0.9 (0.4, 2.0)	9.1 (4.2, 19.5)	
Diarrhea	48 (1.11)	1.6 (1.0, 2.6)	1.0	1.6 (0.8, 3.4)	8.9 (4.2, 19.1)	
Fever	18 (0.58)	1.2 (0.6, 2.3)	1.0	2.9 (0.9, 9.5)	27.0 (7.6, 96.0)	
Cough	17 (0.28)	1.0 (0.5, 1.7)	1.0	no deaths	13.3 (1.6, 110.1)	
Cough + fever	38 (1.65)	1.3 (0.7, 2.5)	1.0	5.4 (2.4, 12.5)	48.3 (19.8, 117.4)	17.70, 4, 0.001
Seasonality						
January–February	42 (0.54)	1.0	1.0	2.1 (0.7, 6.0)	51.3 (20.9, 126.2)	
March–April	17 (0.37)	0.9 (0.4, 1.8)	1.0	6.1 (2.1, 17.7)	12.0 (1.4, 99.5)	
May–June	52 (0.64)	1.0 (0.5, 1.9)	1.0	1.1 (0.5, 2.6)	7.9 (3.5, 17.9)	
July–August	51 (0.74)	1.2 (0.7, 2.0)	1.0	1.4 (0.6, 3.2)	10.7 (4.9, 23.4)	
September–October	25 (0.32)	0.6 (0.3, 1.2)	1.0	3.3 (1.2, 9.0)	23.6 (8.2, 67.4)	
November–December	22 (0.25)	0.5 (0.3, 1.1)	1.0	1.8 (0.5, 6.5)	27.1 (8.0, 91.3)	14.25, 5, 0.01

[1] 95% CIs in parentheses.
[2] Relation among children with a Z score > -2. Multivariate models included age, sex, wealth, availability of running water in the house, maternal literacy, region of residence, capsule (vitamin A and placebo), dietary vitamin A intake, morbidity, seasonality, and height-for-age Z score.
[3] Multivariate models included age, sex, wealth, availability of running water in the house, maternal literacy, region of residence, capsule (vitamin A and placebo), and dietary vitamin A intake.
[4] Chi-square is the difference between the -2 log likelihood in a model with and without the interaction terms.
[5] Breast-feeding analyses were limited to children in the first 2 y of life.

increased risk of mortality from all causes; however, when deaths from nutritional causes were excluded, increased mortality risk was apparent only among children with weight-for-height Z scores ≤ -2. The lack of incremental risk among mild to moderately wasted subjects in Zaire was explained by the lower incidence of diarrhea and higher access to curative health care in that population, in contrast with the Sudan sample (12). Therefore, in areas where undernutrition, mortality, and morbidity rates are high, children who are not classified as malnourished because they have Z scores above the conventional cutoff are likely to be at risk. Health services and interventions should emphasize prevention of malnourishment and not target only those who have reached the cutoff point used to classify children as wasted.

We found that the risk of death was clearly increased only for children who had height-for-age Z scores < -3. This agrees with the findings of the study in Zaire (3), where mild to moderate stunting was not associated with increased nutrition-specific or nonnutritional mortality whereas severe stunting was associated with significant risk of death. These findings should not be interpreted to mean that mild to moderate stunting is without hazards. The state of being stunted or "small" may be associated with a decreased capacity for physical work later in life, increased risk of morbidity, and adverse effects on mental development; at the same time, stunting is a descriptive index of the adverse environment during early growth and development and clearly needs to be addressed (16).

Given the large number of deaths in this study compared with other studies, we were able to examine whether the relation between nutritional status and mortality was modified by other variables. Identifying such modifiers may have policy implications: if certain groups are found to be at higher risk, appropriate services may be targeted to them (12). There was an apparently stronger relation between weight-for-height and mortality among 2–4-y-old children than among younger or older children; however, age did not modify the relation between height-for-age and mortality. Neither sex nor vitamin A intake (from diet or capsule) modified the wasting-mortality or stunting-mortality relations. Breast-feeding per se was not as-

TABLE 4
Relative mortality (RM) in relation to height-for-age as modified by age, sex, breast-feeding, vitamin A supplementation, morbidity, and seasonality[1]

Characteristic	No. of deaths (rate/1000 child-months) among all children	Characteristic-RM relation[2]	RM within subgroups of characteristic[3]			Test for interaction: χ, df, P value[4]
			> -2 Z	-2 to -3 Z	< -3 Z	
Age (y)						
≥ 5	27 (0.14)	1.0	1.0	0.8 (0.3, 2.2)	1.9 (0.8, 4.5)	
4	24 (0.29)	1.3 (0.5, 3.3)	1.0	1.8 (0.6, 5.5)	3.6 (1.3, 9.5)	
3	53 (0.62)	3.7 (1.8, 7.3)	1.0	0.7 (0.3, 1.7)	2.2 (1.2, 4.1)	
2	85 (1.35)	6.4 (3.3, 12.4)	1.0	1.0 (0.5, 1.8)	2.9 (1.8, 4.8)	
< 1	15 (1.56)	7.6 (3.3, 18.7)	1.0	1.4 (0.4, 5.1)	2.5 (0.5, 12.7)	2.20, 4, 0.70
Sex						
Boys	92 (0.41)	1.0	1.0	0.9 (0.5, 1.7)	2.8 (1.7, 4.5)	
Girls	112 (0.51)	1.3 (0.8, 2.0)	1.0	1.1 (0.6, 1.8)	2.5 (1.6, 3.8)	0, 1, 1.00
Capsule						
Placebo	100 (0.46)	1.0	1.0	1.5 (0.9, 2.5)	3.2 (2.0, 5.1)	
Vitamin A	104 (0.47)	1.4 (0.9, 2.6)	1.0	0.7 (0.4, 1.2)	2.2 (1.4, 3.4)	3.07, 1, 0.08
Breast-feeding[5]						
No	49 (1.26)	1.0	1.0	1.1 (0.5, 2.5)	3.7 (1.9, 7.2)	
Yes	51 (1.52)	1.2 (0.6, 2.4)	1.0	1.0 (0.4, 2.1)	2.3 (1.1, 4.5)	2.51, 1, 0.11
Morbidity						
None	83 (0.29)	1.0	1.0	0.9 (0.5, 1.6)	1.7 (1.0, 2.9)	
Diarrhea	47 (1.11)	1.2 (0.6, 2.3)	1.0	1.6 (0.7, 3.8)	4.2 (2.0, 8.7)	
Fever	18 (0.58)	1.6 (0.8, 3.5)	1.0	0.5 (0.1, 2.4)	2.6 (0.9, 7.3)	
Cough	16 (0.27)	0.7 (0.3, 1.6)	1.0	0.3 (0.04, 2.9)	4.2 (1.5, 12.3)	
Cough + fever	38 (1.65)	1.9 (1.5, 5.4)	1.0	1.2 (0.5, 3.0)	2.4 (1.1, 5.4)	11.17, 4, 0.02
Seasonality						
January–February	42 (0.54)	1.0	1.0	1.0 (0.4, 2.3)	2.8 (1.4, 5.7)	
March–April	17 (0.37)	0.9 (0.3, 2.1)	1.0	1.3 (0.4, 4.4)	2.0 (0.6, 6.4)	
May–June	52 (0.64)	0.8 (0.4, 1.8)	1.0	1.5 (0.7, 3.0)	2.7 (1.4, 5.1)	
July–August	46 (0.67)	1.2 (0.6, 2.4)	1.0	0.8 (0.4, 2.0)	2.4 (1.2, 4.6)	
September–October	25 (0.32)	0.6 (0.2, 1.7)	1.0	0.7 (0.2, 2.9)	3.0 (1.1, 7.8)	
November–December	22 (0.25)	0.5 (0.2, 1.2)	1.0	0.5 (0.1, 2.5)	4.1 (1.6, 10.6)	3.48, 5, 0.63

[1] 95% CIs in parentheses.
[2] Relations among children with a Z score > -2. Multivariate models included age, sex, wealth, availability of running water in the house, maternal literacy, region of residence, capsule (vitamin A and placebo), dietary vitamin A intake (continuous), dietary vitamin A intake, morbidity, seasonality, and weight-for-height Z score.
[3] Multivariate models included age, sex, wealth, availability of running water in the house, maternal literacy, region of residence, capsule (vitamin A and placebo), and dietary vitamin A intake.
[4] Chi-square is the difference between the -2 log likelihood in a model with and without the interaction terms.
[5] Breast-feeding analyses were limited to children in the first 2 y of life.

sociated with reduced mortality among normally nourished children, possibly because only a small fraction of the children were in their first year of life when the beneficial effect of breast-feeding has been reported (17). Breast-feeding was a strong modifier of the association between weight-for-height and mortality. Wasted children were at a much higher risk of dying if they were also not being breast-fed. A similar finding was reported in a study from Bangladesh, where a low midupper arm circumference (which is a measure of wasting) and weaning had a synergistic relation with mortality (18). Malnourished children who continue to breast-feed would be receiving antibodies and other immunologic substances from their mother and this may provide some protection against death from infection (19).

Both morbidity and poor nutritional status are common in developing countries, and both are individually associated with an increased risk of death. We noted strong synergism between morbidity and indicators of wasting or stunting, in relation to increased mortality. These findings were consistent with results of studies in which indexes of cellular immunity were reported to be depressed in mild-to-moderate as well as in severe malnutrition (20). Although synergy between the two risk factors has been thought to exist for some time (21), to our knowledge it has not been reported in the context of a prospective study. The findings reported here agree with reports of a positive association between the slope of mortality and malnutrition in various studies and the mortality rate of well-nourished children in these studies, suggesting that malnutrition has a greater effect on mortality in populations that already have higher morbidity and mortality levels (22).

In conclusion, health and nutritional services in developing countries should not be targeted only to severely malnourished children. Breast-feeding must be promoted, even among undernourished children, and attempts should be made to reduce morbidity in child survival programs.

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