The Relationship Between Child Anthropometry and Mortality in Developing Countries: Implications for Policy, Programs and Future Research[1]

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SUMMARY

The prevention of child mortality is a commonly stated health goal in developing countries and the target of much international assistance in the health sector. Over the past decade the primary strategy for accelerating the reduction in child mortality has been the dissemination of simple, low-cost technologies, such as immunization, oral rehydration therapy and antibiotics, that target specific diseases (Huffmann and Steel 1994). This is done despite the knowledge that malnutrition and disease have a synergistic relationship (Scrimshaw et al. 1968) and that the optimal strategy may involve a combination of health and nutrition interventions. In the 1970s, for instance, it was estimated that malnutrition (notably protein-energy malnutrition—PEM) was the underlying or contributing cause of death for roughly half of all deaths to children aged 1–4 years in several Latin American countries (Puffer and Serrano 1973). Apart from this early study, however, there has been little effort to quantify the contribution of malnutrition to child nortality in other regions of the world in ways which are meaningful to policy. This paper reviews the results of 28 community-based, prospective studies, in 12 Asian and Sub-Saharan African countries, which examined the relationship between anthropometric indicators of malnutrition and child mortality. One purpose is to estimate the contribution of malnutrition to child mortality—distinguishing the effects of severe malnutrition from mild-to-moderate malnutrition— and to examine a number of related issues relevant to policy, programs and research in this area.

The accumulated results are consistent in showing that the risk of mortality is inversely related to anthropometric indicators of nutritional status and that there is elevated risk even in the mild-to-moderate range of malnutrition. This latter result contradicts the findings from an earlier, landmark study which suggested that mild-to-moderate malnutrition was not associated with an increased risk of mortality (Chen et al. 1980). The present results indicate that somewhere between 20% and 75% of child deaths are statistically attributable to anthropometric deficits, with most estimates falling in the range 25–50%. When taking account of the relative proportions of severe versus mild-to-moderate malnutrition in the population, the results show further than 16–80% of all nutrition-related deaths are associated with mild-to-moderate malnutrition rather than severe malnutrition. In most studies 46–80% of all nutrition-related deaths are in the mild-to-moderate category. This represents the proportion of nutrition-related deaths that would be missed by policies and programs focusing primarily or exclusively on the severely malnourished, a bias that does exist in many public health programs in practice if not by design.

Another important result is the confirmation that malnutrition has a potentiating (multiplicative) effect on mortality within populations, as predicted from the theory of synergism. This means that malnutrition has its biggest impacts in populations with already high mortality levels and that morbidity has its biggest impacts in the most malnourished populations. This finding has far-reaching implications for child survival policy and programs, suggesting that greater attention should be paid to nutritional improvement than at present.

A potential limitation of the above conclusion is the possibility that the relationship between mortality

and malnutrition may be confounded by behavioral and socioeconomic factors (e.g., caretaker knowledge and practices and access to health care). Several studies have addressed this question by controlling for confounders (through proxy socioeconomic variables), and these studies reveal that the anthropometry-mortality relationship is not due to such confounding. Usually this has been applied to severe cases of malnutrition, where the link to mortality is strongest, but one study indicated similar results among mild-to-moderate cases.

The results further suggest the possibility that, for a given anthropometric deficit, child mortality in South Asian children is lower than in children from other regions. This result is consistent with the findings from earlier cross-national comparisons (Haaga et al. 1985). It may relate to small maternal stature in these populations, which contributes to the exceptionally high rate of low birth weight (31%) and relatively benign carry-over effects on the size of preschool children. It is hypothesized that child anthropometric deficits arising in this fashion may not have the same functional consequences as deficits arising from poor maternal health and nutrition during pregnancy or from similar conditions in early childhood, an area requiring further research.

On the basis of a priori expectations as well as the results from the few studies examining these issues, the review concludes that the child anthropometry-mortality relationship is likely to be modified by a number of other factors, a result with important implications for policy and programs. Some of these factors include the age of the child, possibly sex of the child in some settings, length of follow-up after measurement, seasonality and breastfeeding. The policy importance is well illustrated by the breastfeeding results, which indicate that the elevated risk of death among severely malnourished children (>12 mo) is made even worse (four times worse) by the absence of breastfeeding. The programmatic importance of effect modifiers relates to such issues as deciding the optimal interval between measurements for screening purposes, choosing the most efficient anthropometric indicator and deciding the priority to be given to children of different ages when using a single screening indicator. Most studies have been limited in their ability to examine these issues due to small sample sizes, variation in analytical methodologies and failure to collect and/or use ancillary data in the analysis. However, future research should include consideration of these issues and may benefit from pooling the data from previous studies.

Finally, it is suggested that observational (i.e., non-intervention) studies of the type reviewed here may be inherently limited in their ability to answer a central policy question, namely the extent to which *reductions* in child mortality through health sector interventions may be compromised by persistently high rates of malnutrition. A stronger approach would be through careful evaluation of on-going, large-scale intervention programs, especially those that have successfully controlled severe malnutrition and are shifting attention to mild-to-moderate forms.

INTRODUCTION

The prevention of child mortality is perhaps the most commonly stated goal of national health policy in developing countries and is a major focus of international and bilateral aid in the health sector. This is reflected in the health plans of individual countries and by the increased attention in recent years to the promotion and/or dissemination of simple, low-cost technologies for child survival (Grant 1983, USAID/CDC 1992). Huffmann and Steel (1994) have reviewed the impact of these technologies on child survival and questioned whether nutrition has been given appropriate attention in the overall strategies. They note that some of the life-saving technologies have the potential to simultaneously improve nutrition and were originally designed to do so, but in the implementation process this objective was typically overlooked in favor of the more easily implemented components of the strategies. They note that this not only represents a missed opportunity to improve nutrition, but may also limit the effectiveness of the technologies on saving lives because of the importance of malnutrition as a contributor to infant and child mortality.

The issues raised by Huffmann and Steel are important for deciding the appropriate mix of strategies to promote child survival at a national and international level. While the argument might be made that governments and external agencies should strive to improve nutrition *simultaneous* with efforts to improve child survival, the reality of resource constraints means that decisions must always be made concerning the relative weight to be given to nutritional improvement versus technological interventions. UNICEF notes that expenditures on direct nutrition activities represented only 13% of the amount spent on other health activities in 1990 (Parker and Jesperson 1994). In order to evaluate the appropriateness of this resource allocation at an international level or within a given country the first step is to assess the quantitative contribution of malnutrition to mortality.

The report of the Inter-American Investigation of Mortality in Childhood (Puffer and Serrano 1973) was the first systematic attempt to estimate the contribution of malnutrition to child mortality in one region of the world. It suggested that 35% of all deaths to children <5 years of age involved malnutrition (severe or mild-to-moderate) as an underlying or contributing cause in 13 Latin American countries. The corresponding estimate for children aged 12–23 month was 60% and that for 2–4 year-olds was 54%.

Shortly after the Inter-American Investigation, the nutrition-mortality linkage received important confirmation in a small number of studies in India (Kielmann and McCord 1978) and Bangladesh (Chen et al. 1980; Sommer and Lowenstein 1975). These studies were conducted prospectively over a long period of time (months to years) and were population based, in contrast to earlier studies that were either retrospective, employed short follow-up periods and/or were based on hospital admissions (Garrow and Pike 1967; Gomez et al. 1956; McLaren et al. 1969; Puffer and Serrano 1973). These studies also found that relatively simple anthropometric indicators of nutritional status are related to the risk of future mortality. At a policy level this has confirmed the potential importance of malnutrition for designing child survival strategies and ╭ a programmatic level it provides one of the rationales for using growth monitoring in health programs to assist in identifying high-risk children.

Although the studies cited above have provided important documentation that anthropometric indicators of malnutrition are related to mortality risk, a number of important questions remain. The purpose of this paper is to draw on the existing literature to address these issues to the extent possible. Specifically, this paper reviews the results of prospective, population-based studies to examine the following questions:

- Are there any differences in the relationship between anthropometry and mortality across populations?
- What fraction of child mortality is attributable to malnutrition as measured by anthropometric deficits?
- What is the contribution of mild-to-moderate malnutrition versus severe malnutrition to this fraction?
- Does the relationship between anthropometric indicators and mortality differ according to the age or sex of the child?
- To what extent are these relationships confounded or modified by other factors such as household socioeconomic status, concurrent morbidity and feeding practices?
- How are these relationships affected by the length of follow-up of the child after measurement?
- Which anthropometric indicators are most closely related to mortality and how do static (one-time) measures compare with repeated measures on the same child (velocities)?

The paper concludes by identifying the implications for policy, programs and future research.

CONCEPTUAL AND METHODOLOGICAL CONSIDERATIONS

The available studies differ in a number of respects which have an important bearing on their interpretation and comparability. The studies and some of these important features are described in **Table 1** and elaborated upon below. Before describing the studies it is important to note the distinction between nutritional status and anthropometric indicators of nutritional status. Although the terms are sometimes used interchangeably the distinction is important in the present review. Nutritional status refers to the internal state of the individual as it relates to the availability and utilization of energy and nutrients at the cellular level. Protein-energy nutritional status, therefore, refers to the state of the individual in relation to these two "nutrients." Because this state cannot be directly observed, one relies on measurable indicators of this state. Anthropometrics provide relatively simple and convenient indicators of protein-energy status, but they are not synonymous with it. For instance, a child may have a moderately low weight-for-age because of recent diarrheal dehydration (though being well fed), because he is stunted from nutritional insults some years ago (though currently well nourished) or because of improper feeding practices in recent months (though presently free of disease). Alternatively, the child may have some combination of these conditions. Each of these scenarios has different implications for the child's *current* nutritional status (viz. nutrient availability and utilization at cellular level) and for the probability of mortality in the coming 1 month, 6 months or 12 months. These scenarios also mean that, in various circumstances, the use of anthropometric indicators may lead to underestimates or overestimates of the effects of nutritional status on mortality. Thus, the present review is concerned with *anthropometry*-mortality relationships in the first instance and only through cautious inference does it discuss *nutrition*-mortality relationships. A more direct approach to estimating *nutrition*-mortality relationships, and the one most meaningful when estimating the nutritionally preventable fraction, is through intervention trials. Although fewer in number, these studies have been reviewed elsewhere (Rose and Martorell 1992).

As shown in Table 1 there are 28 reports available in the journal literature (in two cases supplemented with dissertations). These studies were identified through computer-based searches (Medline and Agricola) from January, 1983 through December, 1992 and through secondary citations given in all of these papers. This list is thought to be complete with respect to prospective, population-based studies comparing one or more anthropometric indicators to risk of subsequent mortality. It excludes hospital or clinic-based studies.

As shown in the table, some studies are included in the list more than once, when reanalysis of the same data provided additional information bearing on the objectives of this paper. Thus, the 28 reports actually

TABLE 1

Description of population-based studies included in this review

Study No.[1]	Population	Age range	Effective length of follow-up[2]	Effective no. of deaths[3]	No. of children[4]	Gross[5] mortality rate	Citation
		mo	mo				
1a	Matlab, Bangladesh	12–23	24	112/48	2019	27.7	Chen et al. 1980
1b	Matlab, Bangladesh	12–23	24	112/48	2019	27.7	Bairagi 1981
1c	Matlab, Bangladesh	12–23	24	112/48	2019	27.7	Chowdhury 1988
1d	Matlab, Bangladesh	12–23	24	98/39*	1998	27.7	Cogill 1982
2a	Matlab, Bangladesh	12–59	18	154/35	3757	27.3	Sommer and Lowenstein 1975
2b	Matlab, Bangladesh	12–59	18	154/35	3757	27.3	Trowbridge and Sommer 1981
2c	Matlab, Bangladesh	12–59	6	49*	922	N/A[6]	Briend and Zimicki 1986
3a	Matlab, Bangladesh	6–36	1	52/29	4927*	21.1	Briend et al. 1987
3b	Matlab, Bangladesh	12–36	1	49/28*	4612*	21.1	Briend et al. 1988
4	Matlab, Bangladesh	12–59	12	23/4	961	14.3	Bairagi et al. 1985
5	Teknaf, Bangladesh	12–59	6	60/16	2625*	5.1	Alam et al. 1989
6a	C-M Hwy, Bangladesh[7]	12–36	1	69/47*	1087*	31.7	Briend and Bari 1989a
6b	C-M Hwy, Bangladesh	0–36	1	66/47*	1011*	32.6	Briend and Bari 1989b
7	Punjab, India	12–36	12	148/26	2808	52.7	Kielmann and McCord 1978
8	W. Java, Indonesia	0–59	18	151/20	3461	43.6	Katz et al. 1989[8]
9	Papua New Guinea	6–30	18	47/4	1147	27.3	Heywood 1982
10	Kasongo, Zaire	6–59	3	105	7092	4.2	Kasongo Project Team 1983
11	Kasongo, Zaire	6–59	3	52	4273*	3.5	Kasongo Project Team 1986
12	Iringa, Tanzania	6–30	12	88/7	2452	35.9	Yambi 1988
13	Guinea-Bissau	6–59	12	109/17	2228*	48.9	Smedman et al. 1987
14	Senegal	6–59	6	301	3153*	47.8	Briend et al. 1989
15	S. Malawi	0–59	12	84/18	1178*	28.5	Lindskog et al. 1988
16	N. Malawi	6–59	12	84/8	2883	29.1	Pelletier et al. 1994
17	SW Uganda	0–59	12	104/12	4320	24.1	Vella et al 1994
18	NW Uganda	0–59	12	21/8	1178	17.8	Vella et al. 1992
19	Yemen	0–84	12	47/6	2071	22.7	Bagenholm and Nasher 1989
20	Matlab	6–36	24	412/139	16276	12.7	Fauveau et al. 1990
21	Zaire	0–72	30	246/30	5167	19.0	Van Den Broeck et al. 1993

[1] Studies in a series (e.g., 1a–1d) represent analysis of the same data set.

[2] Refers to maximum possible length of follow-up used in the main analysis. Some studies using child-months as the denominator in the analysis often did so because the actual length of follow-up varied among children, with children only measured once at the beginning of the period: studies 5, 13 and 15; others measured children regularly and examined mortality in the following month or period: studies 3a, 3b, 6a, 6b, 11 and 14.

[3] Refers to number actually used in the main analysis and the number in the "severe" category of the anthropometric indicator (when available). *Studies that reported exclusion of accidental deaths.

[4] * Asterisk refers to studies in which child-months (or child-semesters) are used as the unit of analysis, which in all cases is higher than the number of children shown here.

[5] Defined as effective no. deaths/effective no. children, expressed per 1,000 per year; note that the effective follow-up period often differed from the period over which these deaths occurred, in which case the rate is standardized relative to the latter. The rate is intended here as a crude measure of completeness of death reporting.

[6] These represent incomplete samples from previously archived data (study 2a) and thus a mortality rate cannot be calculated.

[7] Chandpur-Comilla Highway, study area 70 km from Dhaka. Studies 6a and 6b refer to the same basic data set, but the two papers disagree on the age range, and one excludes 3 drowning deaths and 73 other (unspecified) children.

[8] This source provides results on weight-for-height and height-for-age; results on weight-for-age were obtained through personal communication with this research group for the purpose of this paper.

refer to 21 separate studies, representing 12 distinct third-world populations. There is a clear bias in the literature in favor of Bangladesh, for which 14 reports exist based on 7 different studies. There are 10 reports from Africa, representing studies in 6 countries, and no reports from Latin America.

The studies differ in the range of children's ages, with some having fairly restricted ranges and others covering the entire underfives period. Variation in age may have an important effect on study results because of the well-known changes in anthropometric indicators, feeding practices, disease exposure and health care that take place during the period from birth through 5 years (Leslie and Gupta 1989; Martorell and Habicht 1986). It is relevant to note, for instance, that the study that has been most widely cited and debated in the literature (Chen et al. 1980) and has undoubtedly had a significant impact on

policies and programs is also the one with the most restricted age range (12–23 months). The few studies available for explicitly examining this issue are reviewed in a later section.

Length of follow-up also varies widely across the studies, ranging from 1 to 30 months. This may also have a significant influence on the predictive ability of various indicators, because those reflecting wasting (e.g., weight-for-height, various arm circumference indicators and, at younger ages, weight-for-age) are indicative of an acute condition. This may predispose to death in a short follow-up interval but such indicators typically resume normal values within weeks or mo and should have little or no carry-over effects on mortality in the longer term. Other indicators (e.g., height-for-age) reflect a lifetime of chronically poor health and nutrient intake, with little relevance to the child's current nutritional status and would not be expected to contribute *directly* to mortality in older children. They may nonetheless have good predictive value if they identify children and households with chronically poor environmental and behavioral characteristics, which are themselves responsible for greater mortality. Thus, variation across studies should be expected in the ranking of indicators from best-to-worse as a result of the length of follow-up employed and ages of study children.

Another important factor in many of these studies is the relatively small numbers of deaths available for analysis. The relatively low prevalence of severe (<60% weight-for-age) malnutrition (2–10% in most studies) results in small numbers of deaths in the severe category (with 6 of the distinct studies having <10 deaths in this category). This suggests that the estimates of mortality rates within categories of nutritional status have a fairly wide confidence interval and that conclusions regarding the existence, or lack thereof, of threshold effects, population differences, etc. should be made and interpreted with caution.

As indicated in Table 1, a calculation of approximate mortality rates based on the data provided in each report identifies several studies with unusually low mortality estimates and a high probability of incomplete death registration. In most cases this results in misclassification of the unreported deaths as survivors (because the default in most studies was probably to assume they survived) and significant loss of power to distinguish the deceased and the survivors on the basis of anthropometry.

Another feature of the mortality data that varies among studies is the way in which accidental deaths are treated in the analysis. Several studies (noted in Table 1) excluded these from analysis, whereas others included them. As reflected by the discussion over this point in connection with Chen's study (Chen et al. 1981; Mosley 1981), this can have a significant impact on estimates of sensitivity, specific-

ity and (to a lesser extent) attributable risk. The reports excluding accidental deaths as indicated in Table 1 represent only those in which explicit mention was made.

Table 1 shows that the studies differ in how they express and analyze mortality. Most reports provide sufficient information to permit the calculation of mortality rates (deaths per 1,000 children per year) according to various levels of anthropometric indicators. Others quantified mortality as the number of deaths per 1,000 child-month of observation, which was necessitated by the design of the study (variation in length of follow-up among children in the study). The latter method results in rates that are numerically lower than standard mortality rates and cannot be readily converted or compared to such rates. However, the estimates of anthropometry-mortality relationships and differences in prediction across indicators should be very similar for these two methods. The present report emphasizes studies with a fixed follow-up period, but the results for the other studies are broadly similar and have been described elsewhere (Pelletier 1991).

Finally, it is important to recognize that the prospective studies included in this analysis cannot, by themselves, provide evidence of causality between malnutrition and child mortality. Strictly speaking, they can only provide evidence of association. It is possible, and indeed likely, that child malnutrition and mortality may cluster in the same households as a result of socioeconomic and behavioral factors that cause malnutrition *and* mortality. When such confounding is operating, the observed, bivariate association between malnutrition and mortality would tend to *overestimate* the strength of the actual relationship between the two. A substantial portion of this review is devoted to examining these potential confounding effects. The results of these analyses should be considered in light of evidence from other sources (community interventions clinical studies, and knowledge of biological mechanisms) to draw causal inferences. Thus, it is important to note that terms like "nutrition-related deaths," "population attributable risk," "the effects of malnutrition" and others used in this report are subject to these qualifications concerning causality versus association.

RESULTS

Anthropometry-mortality relationships and population attributable risk

Figures 1–4 illustrate the relationship between mortality and four indicators of nutritional status:
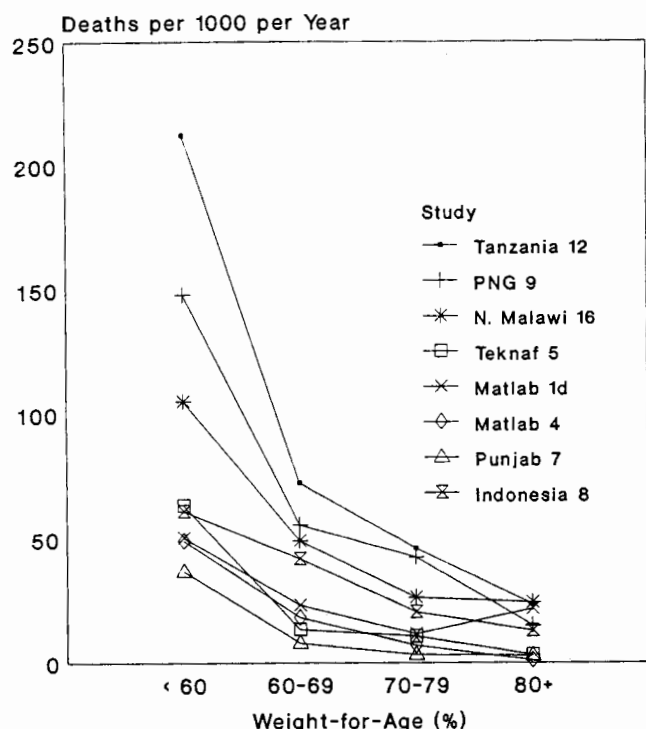
Deaths per 1000 per Year

FIGURE 1 Relationship between child mortality and weight-for-age as a percentage of international median. Adapted from Yambi (1988), Heywood (1982), Pelletier et al. (1994a), Alam et al. (1989), Cogill (1982), Bairagi et al. (1985), Kielmann and McCord (1978) and Katz et al. (1989). Study descriptions are provided in Table 1. PNG = Papua New Guinea.

weight-for-age (WA)², simple arm circumference (AC), weight-for-height (WH) and height-for-age (HA). These rates were either taken directly from the literature or calculated from data provided in the original reports and, in a few cases, estimated from figures in these reports.[3]

Figure 1 shows a consistent increase in child mortality with decreasing WA in all eight studies for which standard rates could be calculated. Mortality shows a basically linear increase as WA declines from 80% of median to 60% of median and a marked increase as WA declines below 60% of median. Similar results are seen in the studies expressing mortality relative to child-mo (Pelletier 1991).

The one notable exception is from Matlab, Bangladesh (study 1d), in which there is no consistent relationship between mortality and WA at levels >60–69%.[4] This study, which was one of the first to appear in the literature on this subject, suggested the existence of a threshold of WA (65% of median in the original report) above which there was no elevation in mortality risk. It is apparent from Figure 1 that this result has not been confirmed by subsequent results in the same study area (Bairagi et al. 1985), elsewhere in Bangladesh (Alam et al. 1989) nor in other populations

such as India (Kielmann and McCord 1978), Indonesia (Katz et al., personal communication), Papua New Guinea (Heywood 1982), Guinea-Bissau (Smedman et al. 1987), Tanzania (Yambi 1988) and Malawi (Pelletier et al. 1994a). Although the gradient in mortality risk is greatest below 60% WA, these other studies demonstrate a consistent gradient even at levels above this point.

Given the far higher prevalence of mild-to-moderate malnutrition (60–80% WA) as compared to severe, this result has important policy implications as emphasized by the estimates of population attributable risk (PAR) provided in **Table 2.**[5] The PAR associated with total malnutrition (defined as WA < 80% of median) ranges from a low of 19% in N. Malawi to a high of 73% in one Bangladesh study,[6] with most other studies falling in the range 21–48%. Table 2 also reveals that mild-to-moderate malnutrition (60–80% WA) represents 46% to 93% of the total PAR across studies (except the Chen study). This represents a range of estimates of the percent of nutrition-related mortality that would be missed by

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[2] Abbreviations used: AC, arm circumference; ACA, arm circumference-for-age; AC/HT, arm circumference/height; ACHT, arm circumference-for-height; AC/A, arm circumference/age; ARI, AIDS-related illness; d_a, normalized distance statistics; HA = height-for-age; MMM, mild-to-moderate malnutrition; MSS, maximum sum of sensitivity and specificity; ORS, oral rehydration solution; PAR, population attributable risk; PEM, protein-energy malnutrition; RR, relative risk; RRm, relative risk due to malnutrition; ROC, receiver operating characteristic; SES, socioeconomic status; WA, weight-for-age; WH, weight-for-height; W/H, weight/height; W/ H², weight/height².

[3] These figures and many of the results that follow employ the "percent of median" classification system for anthropometry, rather than the Z-score system, because this review is based on the data as reported in the published papers.

[4] Note that the rates shown here by four categories of WA are based on data provided by Cogill (1982), which exclude accidental deaths. It differs from the original report (Chen et al., 1980), which used the Gomez classification and included all deaths. The form of the relationship is the same in the two versions, but the analysis of data in Cogill enhances cross-study comparability and is used in this and subsequent results.

[5] Note that with the exception of Cogill (1982) none of the WA reports shown in Tables 2 and 3 mention excluding accidental deaths. The re-analysis of Chen's data from that provided in Cogill (1982) was by necessity based on nonaccidental deaths; however, at a cutoff point of WA < 70% this only raises the PAR from 38% (with accidents) to 44% (without accidents).

[6] The Guinea-Bissau study suffered from the confounding effect of a measles epidemic during the follow-up period, which affected the urban portion of the sample where nutritional status is better than in the rural samples (90% versus 84% WA). Thus, the risk attributable to WA is likely to be an underestimate. The Bangladesh study with PAR = 73.5% had a follow-up period of only 6 mo, compared with 12–24 mos for all other studies. Similarly, the study with the next highest PAR (63.0%, based only on severe protein-energy malnutrition (PEM) also from Bangladesh), had a follow-up period of only 1 mo. Because most deaths to malnourished children occur in the first few mo after measurement, a longer follow-up period would probably have resulted in a narrower range of PAR estimates.

TABLE 2

*Estimates of population attributable risk for severe and mild-to-moderate protein-energy malnutrition (PEM)
in relation to child mortality*[1,2]

Population and study	Severe PEM			Mild-to-Moderate			Normal		Total PAR	PAR percent MMM
	MR	Prev.	PAR	MR	Prev.	PAR	MR	Prev.		
Weight-for-age[3]										
India (7)	36.7	4.2	26.1	4.8	61.2	22.5	2.8	34.6	48.6	46.2
Bangladesh (5)	63.2	5.1	25.2	11.6	70.2	48.5	3.2	24.7	73.7	65.8
Bangladesh (1d)	50.4	19.4	19.9	23.1	69.0	3.9[a]	21.5	11.6	23.8	16.5
Papua New Guinea (9)	148.1	1.6	7.8	44.2	35.5	38.1	14.8	62.9	45.9	83.0
Tanzania (12)	212.1	1.3	6.9	51.8	35.4	28.3	23.2	63.3	35.2	80.5
N. Malawi (16)	105.3	2.6	7.3	32.5	38.4	11.7	23.6	59.0	19.0	61.7
Indonesia (8)	61.0	1.4	3.0	38.4	35.2	40.4	12.7	63.5	43.4	93.0
Arm circumference[4]										
Bangladesh (5)	73.4	6.1	24.9	13.8	76.4	32.0	7.0	17.5	56.9	56.2
Bangladesh (1d)	104.7	5.3	19.1	26.3	43.9	19.4	15.3	50.8	38.5	50.5
Bangladesh (2c)	113.3	4.0	33.1	16.2	29.5	24.0	5.6	66.5	57.0	42.1
N. Malawi (16)	181.8	1.2	6.7	40.4	18.9	11.6	23.1	79.6	18.3	63.2
S.W. Uganda (17)	187.5	2.5	16.7	45.5	13.7	15.2	17.3	81.3	31.9	47.6
Weight-for-height[5]										
Bangladesh (1d)	29.8	24.4	7.6	23.2	48.4	2.0	22.2	27.1	9.5	20.7
Bangladesh (5)	30.0	7.4	11.7	10.6	40.4	0.0	10.8	52.2	11.0	0.0
Indonesia (8)	71.1	2.0	5.8	31.4	20.0	17.1	14.9	78.0	22.9	74.6
PNG (9)	148.1	1.6	7.5	44.5	19.6	17.1	20.6	78.8	24.6	69.7
Tanzania (12)	97.8	3.8	7.6	61.9	21.4	21.5	25.6	74.8	29.1	73.9
N. Malawi (16)	61	4.2	5.9	31.0	17.9	5.0	23.6	77.9	10.9	45.8
S.W. Uganda (17)	84.5	3.8	9.6	40.0	15.3	12.0	20.0	81.0	21.6	55.5
N.W. Uganda (18)	125.0	3.0	8.5	54.3	17.3	13.5	27.1	79.7	22.0	61.6
Yemen (19)	36.4	7.7	12.7	15.2	33.7	7.5	11.9	58.6	20.1	37.1
Height-for-age[6]										
Bangladesh (1a)	56.6	23.2	33.5	19.4	67.8	7.1	16.5	9.0	40.6	17.5
Bangladesh (5)	30.7	15.2	29.4	10.4	42.8	11.3	7.2	42.0	40.7	27.7
Indonesia (8)	38.6	10.0	4.8	49.7	54.1	41.5	20.5	35.9	46.2	89.7
Papua New Guinea (9)	72.7	4.8	7.2	41.3	73.9	49.1	16.4	21.3	56.3	87.2
Tanzania (12)	56.8	3.6	2.8	37.2	72.3	17.1	28.7	24.1	20.0	85.9
N. Malawi (16)	52.9	13.0	16.4	24.8	64.0	14.2	18.8	23.1	30.6	46.4

[1] Adapted from Kielmann and McCord (1978), Alam et al. (1989), Cogill (1982), Heywood (1982), Yambi (1988), Pelletier et al. (1994a), Katz et al. (1989), Briend and Zimicki (1986), Vella et al. (1994), Vella et al. (1992), Bagenholm and Nasher (1989) and Chen et al. (1980). Study descriptions are provided in Table 1.

[2] MR = mortality rate per 1,000 children per year associated with each grade of PEM; PAR = population attributable risk of mortality associated with each grade of PEM; Prev. = percent of children in each grade of PEM; MMM = mild-to-moderate malnutrition; PAR = $[P_i(RR_i - 1)]/\{[P_i(RR_i - 1)] + 1\}$, where P_i is the prevalence of malnutrition in a given grade and RR_i is the relative risk of mortality in the grade compared to those in the "normal" grade.

[3] Severe, <60% weight-for-age; mild-to-moderate, 60–79% weight-for-age; normal, >80% weight-for-age.

[a] The PAR is set at 0 because the MR for this grade is lower than the reference grade of PEM; total PAR is assumed to equal PAR for severe PEM.

[4] Severe, <110 mm; mild-to-moderate, 110–129 mm; normal, ≥130 mm (studies 1d, 2c). Severe, <121 mm; mild-to-moderate, 121–131 mm; normal, >130 mm (study 5, 16, 17).

[5] Severe, <80% or <−2 Z; mild to moderate, 80–89% or −1 Z; normal, ≥90% or ≥−1 Z.

[6] Severe, <85% height-for-age; mild-to-moderate, 85–94% height-for-age; normal, ≥95% height-for-age (except study 5 where mild-to-moderate is 85–89%; and, normal ≥ 90%.

nutrition programs if exclusive or primary attention were to be given to severe cases.[7]

Two notable exceptions exist in the literature concerning mortality and anthropometric indicators, both from Zaire. One is a study from Kasongo, Zaire (Kasongo Project Team 1983), which found no relationship between the two. This study generated some discussion concerning the possible population-specific

nature of this relationship (Bairagi 1981, Chen et al. 1981). However, with the benefit of additional studies

[7] Note that PAR is used here simply to assess the extent to which malnutrition-related deaths are to be found in different grades of malnutrition. It is not a valid statistic for comparing across indicators because its magnitude is greatly influenced by the prevalence and, thus, the location of the cutoff point. More valid methods to choose among several indictors are described in a later section.

from Africa since that time,[8] it appears that methodological problems in the study may be a more likely explanation. For instance, the original study emphasized that the data, manpower and techniques used in the study are typical of what might be expected in a normal health clinic in Zaire. In addition, Table 1 shows that the 105 deaths analyzed in the study probably represent at most 20% of total deaths occurring in the sample during this period, because the gross mortality rate calculated from the report is only 4.2/1,000/year. Thus, this study by itself does not support the suggestion that the fundamental relationship between anthropometry and mortality differs in Sub-Saharan African populations.[9]

The second exception comes from Bwamanda, Zaire (Van Den Broeck et al. 1993). This study found no association between anthropometric indicators of nutritional status and mortality when extreme malnutrition cases are excluded (defined as kwashiorkor or extreme marasmus based on clinical diagnosis). This study does not appear to suffer from the methodological problems found in the Kasongo study. However, the authors note that the study area has been the target of an intensive integrated development project for the past 20 years, such that the population experiences less diarrheal burden, has high immunization rates and has access to effective curative health care. Under such circumstances, relatively rare in the developing world, it appears that the association between mild-to-moderate malnutrition and mortality may be attenuated. The authors further suggest that endemic malaria and severe anemia may have comparable case fatality rates across different grades of nutritional status. Because these are the dominant causes of mortality in this population, this would further attenuate the association between mild-to-moderate malnutrition and mortality.

Although the same fundamental relationship between anthropometry and mortality is seen in all populations studied, the results in Figure 1 give the appearance of possible population differences in the effects of malnutrition on mortality. Thus, Tanzania Papua New Guinea and N. Malawi have higher mortality rates than the four South Asian populations and Indonesia at any given WA, but especially for WA < 60%. This does not appear to be consistently accounted for by differential length of follow-up or age ranges, which are both intermediate between those of various South Asian studies (Table 1). The observation that (over the entire range of weight-for-age) mortality in the three African studies appears to be elevated relative to the South Asian rates is consistent with the clear trend observed along these lines in cross-national comparisons of data from 22 countries (Haaga et al. 1985). The differential response (slope) of mortality on malnutrition suggested here is taken up in a later section.
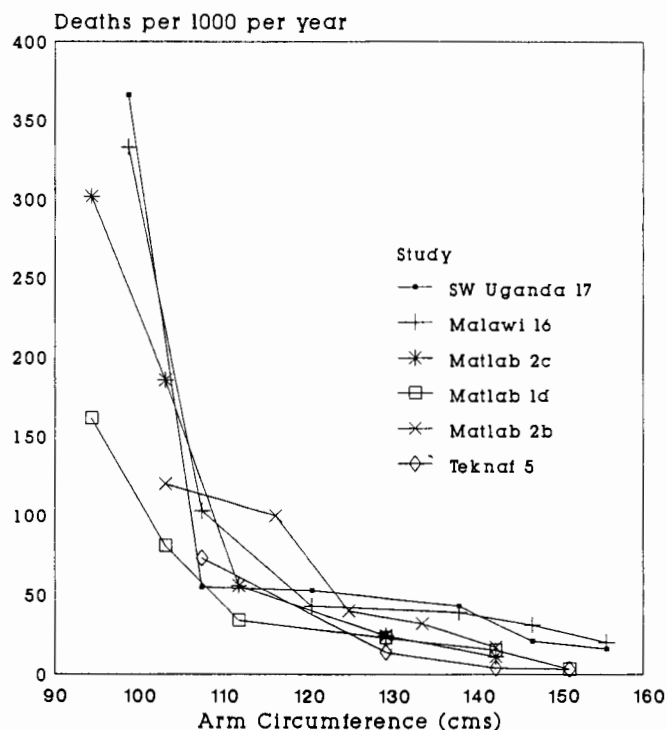

FIGURE 2 Relationship between child mortality and mid-to-upper arm circumference. Adapted from Vella et al. (1994), Pelletier et al. (1993), Briend and Zimicki (1986), Cogill (1982), Trowbridge and Sommer (1981) and Alam et al. (1989). Study descriptions are provided in Table 1.

Figure 2 shows the relationship between simple arm circumference and subsequent mortality. As with WA, mortality shows an exponential increase with declining AC, with a small but detectable elevation in risk at intermediate levels of AC (110–129 mm) and a marked elevation at the extreme levels (<110 mm). There appears to be far less interstudy variation than seen with WA. Because the length of follow-up varies from 6 to 24 months across studies, two studies excluded accidental deaths and two did not, and the measurements were taken under different conditions by different field teams, the similarity of results across these studies can be taken as an indirect indication of the robustness of the overall relationship. It is notable that the two African studies are similar to those from Bangladesh, unlike the divergence seen in WA (above).

The estimates of PAR for arm circumference (Table 2) vary from 18% to 57%. This is within the range of estimates based on weight-for-age. The fraction at-

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[8] In addition to the studies represented in Figure 1 and Table 2, there are studies from Senegal, Guinea-Bissau and S. Malawi confirming the basic relationship, but all based on child-mos as the unit of observations.

[9] Due to the virtual absence of any statistically significant relationship in the Kasongo study, its methodological problems and, most importantly, the noncomparable method of presentation in the original reports (internal standards and no cell-specific sample sizes), this study is not considered further in this section.