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Effects of Malnutrition on Child Survival in China As Estimated by PROFILES[1]

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JAY ROSS*, CHUN-MING CHEN#, WU HE#,1, GANG FU#, YU-YING WANG#, ZHEN-YING FU#, AND MING-XIA CHEN#

*The Academy for Educational Development, Washington DC, USA; #Chinese Center for Disease Control and Prevention, Beijing 100050, China

Objective To estimate the benefits of reductions in underweight and Vitamin A deficiency for child survival in China that might be expected as a result of lowering the prevalence of these conditions. **Methods** Profiles, a process of nutrition policy analysis was used to quantify the functional consequences of malnutrition in terms of child survival. **Results** *Underweight* The actual reduction in underweight between 1992 and 2001 (from 15.7% to the current 10.1 %) resulted in saving of 176 000 child lives. As estimated, without improvements, 612 000 children will die due to underweight between 2001 and 2010, 281 000 (46%) of them living in western provinces. Reducing underweight prevalence from 10.1% to 8% could overall save 62 000 lives. The reduction of underweight prevalence in the west alone might save 56 000 lives. Vitamin A in China as a whole, vitamin A deficiency accounts, as estimated, for 7.5% of deaths of children 6-59 months old, representing 206 000 deaths over the past ten years. Halving the prevalence over the period would save 49 000 child lives. The higher prevalence and higher mortality rates in western provinces mean that even with only 28% of the Chinese population, over half of child deaths there are related to vitamin A.

Key words: PROFILES; Malnutrition; Vitamin A; Underweight

INTRODUCTION

Nutritional conditions known to increase the risk of mortality in children include protein-energy malnutrition (PEM), as indicated by low weight-for-age[1], and vitamin A deficiency[2, 3]. Both forms of malnutrition continue to be public health problems in China, despite significant progress in reducing malnutrition and child mortality rates over the last decade. However, further reductions will require renewed efforts, especially in the less developed western part of the country.

The purpose of the current analysis is to quantify the contribution that underweight and vitamin A deficiency make to child mortality in China and the reduction that might be expected as a result of lowering the prevalence of these conditions. It is hoped that these estimates will help to inspire appropriate policy responses.

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[2]Correspondence should be addressed to Professor Wu HE, Tel: 0861-010-63022890, E-mail: fnh@public.bta.net.cn

Biographical note of the first author: Joy Ross, male, Policy Coordinator, The LINKAGES Project, Academy for Educational Development, USA.

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METHODS

The analysis reported here uses PROFILES, a process designed to estimate the functional consequences of malnutrition in terms of morbidity, mortality, economic productivity and others, and to use these consequences to provide evidence for policy making[4]. The PROFILES process includes the use of computer spreadsheet workbooks with a series of user entry sheets that accept nutrition prevalence, demographic data, model coefficients, and economic information. Another series of sheets performs the calculations based upon relationships described in the nutrition literature, estimating functional consequences of malnutrition over a period from the present to some future years. Alternative scenarios can be described, representing different degrees of improvement in nutritional status, providing estimates of both the consequences of malnutrition if there is no improvement and the benefits of improving nutrition in line with specified targets.

The period for the projections reported here was from 2001 to 2010. Additional analysis of the period from 1992 to 2001 provided estimates of the benefits of recent reductions in underweight and vitamin A deficiency on child survival. Despite rapid improvements in overall health, nutrition and economic conditions in China, large disparities remain between urban and rural areas or among provinces. The national government has identified 12 provinces, municipalities and autonomous regions as disadvantaged regions which are eligible for special development assistance programs: Inner Mongolia, Guangxi, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang and Chongqing, comprising altogether about 28% of the Chinese population. Additional separate estimates were made for the subset of province, municipality and autonomous region to illustrate the potential benefits of geographically targeted actions for improving local nutrition. This subset is collectively referred to in this report as "the west" or "the western provinces" or "12 provinces".

The calculations rely on demographic projections based on current United Nations estimates of the population in 1995 by age and sex, and projected life expectancies and fertility rates[5]. The total population obtained for the year 2000 using these methods was 1.293 billion whereas the current State Statistical Bureau's population estimate is 1.266 billion[6]. All estimates were therefore proportionally adjusted by a factor of 1.266/1.293 or 0.979.

Similar procedures were used to derive demographic estimates for the 1992 model, using 1990 as the base year for projections. With the benefit of hindsight, the 1992 model was modified to reflect the observed trends in population, infant and child mortality, wages, and employment rates to bring its "projections" into line with the 2001 model.

Demographic data for the West were derived in the same manner as for China as a whole but the base year (1995) population pyramid was taken from the 1995 Chinese 1% sample survey, which provided population estimates by age and sex for each province[7]. The fertility estimates were assumed to be the same as for China as a whole and the life expectancy to be 5 years earlier as for China as a whole.

Although the risk of death increases with the number of victims of nutritional deficiencies, PROFILES spreadsheet models estimate the risk of death due to each condition independently. Theoretically, a child may be at risk of death due to the interaction of concurrent conditions so that the elimination of any one of them can save his life. Also theoretically, any condition alone can be fatal. Because we do not have information on the prevalence of concurrent conditions or on the way these risk factors interact, we have estimated the effects separately. The number of deaths predicted as a consequence of each condition should not be added together because this would overestimate the combined effect of malnutrition and the overall benefit of reductions in more than one condition. The models presented here calculate the number of deaths in children aged 6-59 months due to low weight-for-age and vitamin A deficiency. Mortality due to other nutritional conditions or outside the specific age ranges is not estimated. These estimates therefore do not capture the full effects of malnutrition on mortality.

Underweight

In children under five years of age, mortality increases exponentially (i.e., by a multiplicative factor) as PEM (as assessed by low weight-for-age) becomes more severe[1]. This conclusion is based on a meta-analysis of the findings of eight observational studies from five countries (Bangladesh, India, Malawi, Tanzania, and Papua New Guinea). A key finding is that this exponential relationship is consistent across countries with different malnutrition prevalences, morbidity patterns, and mortality rates.

Although these studies are observational and cannot strictly exclude alternative explanations, the consistency of a dose-response relationship, statistical control for potential confounders and biological plausibility argue strongly in favor of a causal explanation.

Based on these findings, the model assumes that risk of death among children is 2.5, 4.6, and 8.4 times greater among children who are mildly, moderately and severely underweight, respectively. Calculations only apply to children aged 6 months or older because the studies used in the meta-analysis that generated these coefficients generally exclude mortality *during the first 6 months of infancy.*

To calculate mortality due to underweight, the prevalence (Pr) for each level of severity is combined with the respective relative risk (RR) of mortality to obtain the proportion of all child deaths attributable to underweight of that severity level. This population attributable risk (PAR) is calculated according to the following formula[8]:

$$\mathrm{PAR} = \frac{\mathrm{Pr} * (\mathrm{RR} - 1)}{1 + (\mathrm{Pr} * (\mathrm{RR} - 1)}$$

The relative risk estimates were derived from studies that used the %-of-median system and therefore required prevalence expressed in the same way. Prevalence in terms of z-scores (Table 1) was therefore converted to prevalences in %-of-median terms using the conversion formulas derived by Pelletier *et al.*[9].

TABLE 1

Prevalence of Underweight Using the Z-score System.

PEM Level	Prevalence		
	1992 (National)	2001 (National)	2001 (West)
Moderate (<-2 to -3 SDs)	11.0	8.8	14.1
Severe (<-3 SDs)	4.7	1.3	2.7
Total (<-2 SDs)	15.7	10.1	16.8

Note. Sources: 1992: The Final Report for 1992 Child Survey, State Statistical Bureau; 2001: General Report of Chinese Food and Nutrition Surveillance System (CFNSS) in 2000[11].

Vitamin A Deficiency

A meta-analysis by Beaton *et al.*[2] concludes that children aged 6-59 months who live in high VAD areas and who receive vitamin A supplements are 23% less likely to die than children not receiving the supplements. Assuming a direct relationship between prevalence of VAD and mortality risk, with no mortality reduction observed where vitamin A deficiency is not present, and a 23% reduction where the prevalence of VAD is equal to 40% (the estimated mean in the Beaton *et al.*[2] meta-analysis), the individual risk ratio for a mildly deficient child is 1.75, relative to a non-vitamin A deficient child. This risk ratio is used here to estimate the contribution of VAD deficiency to overall child mortality.

The prevalence of vitamin A deficiency (serum retinol < 20 mcg/dL) in China, derived from a survey of the Capital Institute of Pediatrics in Beijing undertaken between December 1999 and March 2000, is 10.8%. The prevalence for the western provinces, calculated from information in the report of that survey is 16.8%. A reduction of vitamin A deficiency by half is projected for 2010. No historical data on the prevalence of vitamin A deficiency were available to allow meaningful analyses to be conducted separately for 1992.

RESULTS

Underweight

The %-of-median prevalence, the relative risk of mortality for under-5, and the percentage contribution to mortality by degree of PEM for China are shown in Table 2. Thus, 22% of all child mortality is attributable to PEM (as measured by underweight) and its interaction with infectious diseases. The remaining 78% is due solely to other causes.

TABLE 2

Relative Risk (RR) and Population Attributable Risk (PAR) of Child Mortality Related to Malnutrition.

PEM Level (% of Median W/A)	RR	Prevalence			PAR			% of PEM-related Deaths		
		1992	2001	West	1992	2001	West	1992	2001	West
Mild (70-79)	2.5	0.194	0.157	0.213	0.203	0.183	0.223	67.2	82.3	73.3
Moderate (60-69)	4.6	0.039	0.014	0.032	0.099	0.039	0.081	32.8	17.7	26.7
Severe (<60)	8.4	0	0	0	0	0	0	0	0	0
Total		0.233	0.171	0.245	0.302	0.222	0.304	100	100	100

Note: Sources: 1992: Final Report of 1992 Child Survey (State Statistical Bureau); 2001: General Report of CFNSS in 2000 (14 sites in the West)[11].

Table 3 shows the number of child deaths that can be attributed to PEM as measured by underweight, assuming no reduction in prevalence and assuming that nutrition targets are reached. The 1992 model shows that the actual reduction in underweight between 1992 and 2001 (from 15.7% to the current 10.1 %) has resulted in 176 000 child lives saved. The overall reduction in under-5 mortality from 57.4 to 39.7 per thousand live births during the same period means that 1.803 million child lives were saved in China as a whole. Thus, the improvement in nutritional status is estimated to have contributed about 10% (0.176/1.803) towards the reduction in under-5 mortality during this period. This only includes the lives saved due to reductions in underweight and only between 6 and 59 months.

The 2001 model shows that underweight remains a significant cause of under-5 mortality in China. As estimated, without improvements, 612 000 children will die due to underweight between 2001 and 2010, and 281 000 (46%) of them live in the western provinces. Reducing underweight from 10.1% to 8% could save 62 000 lives in overall. If the prevalence of underweight in the west might be reduced from 16.8% to the current national level of 10.1, this alone would save 56 000 lives.

TABLE 3

Effects of PEM on Mortality of Children (6-59 Months)

Variable	1992	2001 (National)	2001 (West)
Prevalence of Underweight in Base Year (<-2 SDs) (%)	15.7	10.1	16.8
Target Prevalence in 10 Years (%)	10.1	8.0	10.1
PAR[a] in Base Year	0.302	0.222	0.304
PAR in Target Year	0.200	0.178	0.182
Deaths Due to Underweight Over Period if no Improvement (Millions)	1.145	0.612	0.281
Lives Saved From Reducing Underweight During Period (Millions)	0.176	0.062	0.056

Note.[a]: PAR=population attributable risk

Vitamin A

Model assumptions and estimated effects of vitamin A deficiency on child mortality in China and the western provinces are shown in Table 4. In China as a whole, vitamin A deficiency accounts for 7.5% of estimated deaths of children 6-59 months old, amounting to 206 000 deaths over the past ten years. Halving the prevalence over the period would save 49 000 child lives. The higher prevalence in the western provinces, and the higher mortality rates there mean that with only 28% of the Chinese population, it accounts for over half of vitamin A related child deaths in this country.

TABLE 4

Assumptions and Results for the Effects of Vitamin A Deficiency on Survival

Variable	National	West
Prevalence of VAD (6-59 m) (2001)	10.8[a]	16.8[a]
Ten-year Target Prevalence (2010)	5.4	8.4
PAR in Base Year	0.075	0.112
PAR in Target Year	0.039	0.059
Deaths Due to VAD Over 10 Years if no Improvement (Millions)	0.206	0.104
Lives Saved From Halving VAD Over Period (Millions)	0.049	0.024

Note.[a]: Survey on VAD Among Children in China: Capital Institute of Pediatrics Survey (Dec. 1999 to Mar. 2000)[12]. West prevalence calculated from this survey.

DISCUSSION

Improvements in nutrition in China since 1992 have resulted in remarkable parallel gains in health, survival and performance. The reduction in the prevalence of underweight from 15.7% in 1992 to the current level of 10.1% has prevented estimated 176 000 child deaths, representing 10% of the total reduction in under-5 mortality from all causes over this period. Similar analyses presented elsewhere suggests that a reduction in the prevalence of child stunting (from 32.7% to 14.4% during the same period) has resulted in future economic productivity gains with a net present value (in 2001) of estimated ¥101 billion. These results serve to demonstrate that it is possible to reduce malnutrition within a short period of time and that this has enormous functional benefits.

However, malnutrition and nutritional inequities persist in China, with worse off rural areas and western provinces. Efforts to improve the nutritional situation therefore should now focus on these more disadvantaged populations. For example, the analysis presented here suggests that for China as a whole, reducing the prevalence of underweight from 10.1% to 8.0 % over the next ten years could save 62 000 lives. If this were accomplished by reducing the prevalence in the West from 16.8% to the *current national level* of 10.1%, 56 000 of the lives (90%) would have been saved there. Similarly, although the western provinces account for only 28% of the population, half of vitamin A related deaths occur there.

Surprisingly, most of the negative consequences of malnutrition are due to its relatively mild forms. The negligible prevalence of severe underweight in China and the relatively low prevalence of moderate underweight means that most (82%) of PEM-related deaths are attributable to mild PEM. One important implication is that any effort to address PEM-related mortality should therefore focus on the more common and less visible problem of mild growth faltering. And since mild growth faltering is less easily detected, a preventive approach is likely to be needed.

Similarly, the studies relating vitamin A deficiency to mortality found that most of the deaths which had been avoided with vitamin A supplementation were not among children with clinical signs of deficiency but among those with sub-clinical forms detectable only with blood analysis.

Again, this implies that only population-wide interventions to reduce the prevalence of sub-clinical deficiency are likely to have any significant impact on the problem described here.

In addition to the expected short-term reductions in child mortality, improvements in child nutrition are likely to have long-term benefits in terms of economic productivity and lower susceptibility to non-communicable diseases[10]. These long-term consequences have enormous economic consequences and serve to underscore the urgency of the need to reduce the prevalence of early malnutrition.

The proposed preventive solutions include: public heath education to improve infant feeding practices in the whole population; fortification of vegetable oil with vitamin A; vitamin A supplementation for children under 2 and for mothers after delivery; and improved maternal nutrition, both before and after conception. The available evidence suggests that these strategies are essential for the protection of child health and the realization of China's development aspirations.

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