Vitamin A deficiency and child survival in sub-Saharan Africa: A reappraisal of challenges and opportunities

Victor M. Aguayo and Shawn K. Baker

Abstract

Background. *Children with vitamin A deficiency have higher risk of morbidity and mortality than vitamin A–sufficient children. Estimates on the potential child survival benefits of vitamin A deficiency control are needed for policy and program advocacy.*

Objective. *To determine the current prevalence of children at risk for vitamin A deficiency in sub-Saharan Africa in order to estimate the potential child-survival benefits of effective and sustained policies and programs for the control of vitamin A deficiency in this region.*

Methods. *Estimates of the prevalence of vitamin A deficiency generated in 1998, data from 11 nationally representative vitamin A deficiency surveys conducted in sub-Saharan Africa between 1997 and 2003, and the measured effects of vitamin A deficiency on child mortality were combined to estimate the prevalence of children at risk for vitamin A deficiency in sub-Saharan Africa and the potential child-survival benefits of effective and sustained policies and programs for the control of vitamin A deficiency in this region.*

Results. *Our analysis shows that in the absence of effective and sustained policies and programs for the control of vitamin A deficiency, an estimated 42.4% of children 0 to 59 months of age in sub-Saharan Africa (43.2 million children) are at risk for vitamin A deficiency. Such effective and sustained policy and program action for the control of vitamin A deficiency can bring about a potential 25% reduction in mortality in children 0 to 59 months with respect to 1995 mortality levels (i.e., before the onset of large-scale vitamin A supplementation programs in sub-Saharan Africa).*

Conclusions. *Effective and sustained control of vitamin A deficiency has the potential to be among the most cost-effective and high-impact child-survival interventions in sub-Saharan Africa. A stronger political commitment and a more appropriate level of investment in the effective control of vitamin A deficiency could make a large contribution toward the attainment of the Millennium Development Goal for the reduction of child mortality rates by two-thirds between 1990 and 2015. Among the many challenges that Africa will need to face in the coming years, vitamin A deficiency is one that can be overcome. The need is urgent, and the solutions are known, effective, and affordable.*

Key words: Child mortality, child survival, sub-Saharan Africa, vitamin A deficiency

Introduction

For several decades, vitamin A deficiency has been recognized as the leading cause of preventable pediatric blindness in developing countries [1]. A better understanding of the public health importance of vitamin A deficiency began in the early 1980s, when community-based studies showed that the rates of morbidity and mortality from diarrhea and respiratory infections were higher in children with mild xerophthalmia than in children without any vitamin A deficiency–related eye signs [2, 3]. Between 1986 and 1993, eight population-based intervention trials, enrolling more than 165,000 children worldwide, assessed the contribution of vitamin A deficiency to child mortality [4–11]. In 1993, four independent meta-analyses based on these trials showed that, in areas where vitamin A deficiency is prevalent, child mortality is reduced by 23% to 34% after vitamin A intervention [12–15]. This significant reduction in childhood mortality is attributable largely to the reduction in mortality from measles [10, 16], severe diarrhea and dysentery [17], and possibly falciparum malaria [18].

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To bring the attention of policy makers to vitamin A deficiency in countries where country-level vitamin A deficiency survey data were not available, the Micronutrient Initiative, UNICEF, and Tulane University generated country-level estimates of the prevalence of vitamin A deficiency worldwide (referred to here as the MI/UNICEF/TU estimates) [19]. These estimates were developed by using interpolation models built on a data set that included 42 vitamin A deficiency surveys (3 national and 39 subnational surveys) conducted in 36 countries worldwide between 1987 and 1995. The models that maximized the concordance between the observed and predicted values for countries that actually had vitamin A deficiency survey data were selected to generate country-level estimates of the prevalence of vitamin A deficiency for countries where no survey data were available.

Although these estimates have been critical in advancing policies and programs for the control of vitamin A deficiency over the past five years, we hypothesize that they significantly underestimate the true prevalence of children at risk for vitamin A deficiency in sub-Saharan Africa and thus underplay the contribution of vitamin A deficiency to child mortality in this region. The objectives of our analysis were to estimate the current prevalence of children at risk for vitamin A deficiency in sub-Saharan Africa, to estimate the potential child-survival benefits of effective and sustained policies and programs aiming at controlling vitamin A deficiency in this region, and to outline the key components of an integrated regional strategy for the effective control of vitamin A deficiency among children under five years of age (0 to 59 months old).

Methods

To estimate the current prevalence of children at risk for vitamin A deficiency in sub-Saharan Africa, we proceeded in five steps.

First, we identified the countries in sub-Saharan Africa in which a nationally representative vitamin A deficiency survey had been conducted between 1997 and 2003. For each of these countries, we estimated the number of children under five years of age with vitamin A deficiency, combining the observed prevalence of vitamin A deficiency and the population of children in this age group. To estimate the average observed prevalence of vitamin A deficiency in this set of countries, we calculated the proportion of the total population of children under five years of age who were observed to have vitamin A deficiency.

Second, for each of these countries we estimated the predicted number of children with vitamin A deficiency, combining the prevalence of vitamin A deficiency predicted by MI/UNICEF/TU and the population of children under five years of age. To estimate the average predicted prevalence of vitamin A deficiency in this set of countries, we calculated the proportion of the total population of children under five years of age who were predicted to have vitamin A deficiency.

Third, we divided the average observed prevalence of vitamin A deficiency in this set of countries by the average predicted prevalence of vitamin A deficiency to estimate the observed/predicted vitamin A deficiency underestimation factor.

Fourth, we applied this factor to the MI/UNICEF/TU average predicted prevalence of vitamin A deficiency to obtain a corrected estimate that would better reflect the true prevalence of children at risk for vitamin A deficiency in sub-Saharan Africa.

Fifth, by combining the corrected prevalence of vitamin A deficiency and the measured effects of vitamin A deficiency on child mortality, we estimated the potential contribution of vitamin A deficiency to child mortality by the equation

$$PAR = PREV\ (RR–1) / 1+ [PREV\ (RR–1)]$$

where PAR (population attributable risk) is the proportion of all-cause child mortality attributable to vitamin A deficiency, PREV is the corrected prevalence of children at risk for vitamin A deficiency, and RR is the increased risk of death in vitamin A–deficient children relative to vitamin A–sufficient children. On the basis of data from the eight population-based studies of vitamin A deficiency and child mortality [4–11], it has been estimated that the risk of death in vitamin A–deficient children is 1.75 times higher than that in vitamin A–sufficient children [20]. This relative risk (RR = 1.75) was used to estimate the contribution of vitamin A deficiency to child mortality in sub-Saharan Africa.

Results

Table 1 shows the prevalence of vitamin A deficiency predicted by MI/UNICEF/TU for the countries included in our analysis. Estimates for Cape Verde, Equatorial Guinea, Gambia, Guinea Bissau, and São Tomé and Príncipe in the West and Central Africa Region (WCAR) were not available. These countries account for 1.1% of the total population of the WCAR. Estimates for Comoros, Eritrea, Seychelles, and Swaziland in the East and Southern Africa Region (ESAR) were not available. These countries account for 1.7% of the total population of the ESAR.

The predicted prevalence of vitamin A deficiency for sub-Saharan Africa was estimated by combining the predicted prevalence of vitamin A deficiency and the population of children under five years of age in the 36 countries for which MI/UNICEF/TU estimates were available. This calculation yielded an average predicted prevalence of vitamin A deficiency

TABLE 1. Predicted prevalence of vitamin A deficiency (VAD) among children under five years of age (0–59 months) and predicted population of children in that age group with VAD in sub-Saharan African countries in 1995

West and Central Africa	Predicted VAD prevalence[a] (%)	Predicted population 0–59 mo with VAD[b]	East and Southern Africa	Predicted VAD prevalence[a] (%)	Predicted population 0–59 mo with VAD[b]
Benin	15.2	16,7200	Angola	23.6	519,200
Burkina Faso	26.8	509,200	Botswana	8.7	17,400
Cape Verde[c]	18.1	18,100	Burundi	20.0	240,000
Côte d'Ivoire	15.4	446,600	Comoros[c]	20.1	20,100
Gambia[c]	18.1	36,200	Eritrea[c]	20.1	120,600
Ghana	15.2	456,000	Ethiopia	26.9	2,824,500
Guinea	25.9	336,700	Kenya	11.6	614,800
Guinea Bissau[c]	18.1	36,200	Lesotho	13.4	40,200
Liberia	23.3	139,800	Madagascar	17.9	465,400
Mali	36.0	756,000	Malawi	31.3	657,300
Niger	25.1	476,900	Mauritius	6.5	6,500
Nigeria	16.0	3,296,000	Mozambique	32.9	954,100
Senegal	11.8	165,200	Namibia	11.1	22,200
Sierra Leone	40.3	322,400	Rwanda	21.9	306,600
Togo	15.3	122,400	Seychelles[c]	20.1	2,010
Cameroon	10.7	246,100	Somalia	24.1	433,800
Central African Republic	18.5	111,000	South Africa	9.2	524,400
Chad	24.3	267,300	Swaziland[c]	20.1	20,100
Congo (Republic of)	15.9	79,500	Tanzania	15.6	826,800
Congo (Democratic Republic of)	16.5	1,419,000	Uganda	22.2	976,800
Equatorial Guinea[c]	18.1	18,100	Zambia	20.0	340,000
Gabon	15.8	31,600	Zimbabwe	11.8	224,200
São Tomé and Principé[c]	18.1	1,810			
Total for West and Central Africa	18.1	9,459,310	Total for East and Southern Africa	20.1	10,157,010

a. Data are from MI/UNICEF/TU [19]. Data refer to 1995.
b. Predicted populations were calculated on the basis of 1995 child population data from UNICEF [21].
c. No estimate is available from MI/UNICEF/TU [19]. The regional (weighted) average was used as proxy.

in sub-Saharan Africa of 19.1% (18.1% in the WCAR and 20.1% in the ESAR).

The predicted number of children at risk for vitamin A deficiency in sub-Saharan Africa was estimated by combining the predicted prevalence of vitamin A deficiency and the population of children under five years of age in the 45 countries included in the analysis. In the absence of estimates of vitamin A deficiency for Cape Verde, Gambia, Guinea Bissau, Equatorial Guinea, and São Tomé and Príncipe, the average predicted prevalence in the WCAR (18.1%) was used as a proxy. Similarly, in the absence of estimates of vitamin A deficiency for Comoros, Eritrea, Seychelles, and Swaziland, the average predicted prevalence of vitamin A deficiency for the ESAR (20.1%) was used as a proxy. **Table 1** shows that according to the MI/UNICEF/TU estimates, in 1995 (before the onset of large-scale vitamin A supplementation programs) an estimated 19.6 million children under five years of age in sub-Saharan Africa were suffering from vitamin A deficiency (9.5 million in the WCAR and 10.1 million in the ESAR).

Between 1997 and 2003, 15 sub-Saharan African countries conducted nationally representative vitamin A deficiency surveys (**table 2**). Although the observed prevalence of vitamin A deficiency varies across countries, it is consistently and significantly higher in all 15 countries than that predicted by MI/UNICEF/TU.

The average observed prevalence of vitamin A deficiency in these 15 countries was calculated by combining the observed prevalence of vitamin A deficiency in children and the population of children under five years of age in each country. This calculation yielded an average observed prevalence of vitamin A deficiency (weighted) of 42.9% in this set of countries. Similarly, the average predicted prevalence of vitamin A deficiency was calculated by combining the prevalence

TABLE 2. Observed and predicted prevalence of vitamin A deficiency (VAD) among children under five years of age (0–59 months) and observed and predicted population of children in that age group with VAD in sub-Saharan African countries in which a national VAD survey was conducted between 1997 and 2003

Country	Year	Observed VAD prevalence[a] (%)	Observed population 0–59 mo with VAD[b]	Predicted VAD prevalence[a] (%)	Predicted population 0–59 mo with VAD[b]	Underestimation factor
Angola	1998	64.3	1,414,600	23.6	519,200	2.7
Benin	1999	70.2	772,200	15.2	167,200	4.6
Cameroon	2000	40.0	919,310	10.7	246,100	3.7
Central African Republic	1999	68.2	409,200	18.5	111,000	3.7
Gambia	1999	64.0	128,000	18.7	37,400	3.4
Democratic Republic of the Congo	1998	61.1	5,254,600	16.5	1,419,000	3.7
Kenya	1999	60.2	3,243,600	11.6	614,800	5.2
Liberia	1999	52.9	317,400	23.3	139,800	2.3
Madagascar	2000	41.8	1,086,800	17.9	465,400	2.3
Malawi	2001	59.2	1,243,200	31.3	657,300	1.9
Mozambique	2002	71.2	2,064,800	32.9	954,100	2.2
Nigeria	2001	26.8	5,520,800	16.0	3,296,000	1.7
Tanzania	1997	24.0	1,272,000	15.6	826,800	1.5
Uganda	2001	27.9	1,227,600	22.2	976,800	1.3
Zambia	1997	65.7	1,116,900	20.0	340,000	3.3
Average (weighted)		42.9	25,938,010	17.8	10,770,900	2.4

a. All 15 VAD surveys were based on a national-level representative sample of children. In all surveys, the sample was obtained by using a random, multistage, proportional-to-size, cluster sampling method. In all surveys (as in those included in the data set used for the MI/UNICEF/TU predictions), VAD in children was defined as a serum retinol level below 0.70 μmol/L. The surveys were conducted at the time of the year when the risk of VAD in children was expected to be the highest.

b. For comparison purposes, we used 1995 child population data as published in UNICEF [21].

c. Data are from MI/UNICEF/TU [19]. Data refer to 1995.

of vitamin A deficiency among children under five years of age predicted by MI/UNICEF/TU with the population in this age group for each country. This calculation yielded an average predicted prevalence of vitamin A deficiency (weighted) of 17.8%. This means that in the 15 countries with recent nationally representative vitamin A deficiency surveys (1997–2003), the prevalence of vitamin A deficiency predicted by MI/UNICEF/TU underestimated the true (observed) prevalence of vitamin A deficiency by a factor of 2.4. In other words, the prevalence of vitamin A deficiency observed was 2.4 times higher than that hypothesized (predicted).

Four of the nationally representative vitamin A deficiency surveys conducted between 1995 and 2003 (in the Central Africa Republic, Democratic Republic of the Congo, Liberia, and Malawi) did not include children 36 to 59 months old in their samples. Using data on the prevalence of vitamin A deficiency among children under three years of age as a proxy for its prevalence in children under five years of age could lead to an overestimation of the prevalence of vitamin A deficiency among children under five years of age. To avoid this potential bias, the average observed and predicted prevalence of vitamin A deficiency was calculated for the 11 countries with nationally representative data on the prevalence of vitamin A deficiency among children under five years of age.*

Each of the 11 vitamin A deficiency surveys used a national-level representative sample of children under five years of age. In all 11 surveys, the sample was obtained by using a random, multistage, proportional-to-size, cluster sampling method. In all 11 surveys (as in those included in the data set used for MI/UNICEF/TU predictions), vitamin A deficiency in children was defined as a serum retinol concentration below 0.70 μmol/L. As recommended, the surveys were conducted at the time of the year when children were expected to be at the highest risk of vitamin A deficiency. These 11 national vitamin A deficiency surveys provide us with a geographically balanced (47% and 53% of the total population in the WCAR and ESAR regions respectively) representative sample of 49.2 million children under five years of age (48% of the total under-five population in sub-Saharan Africa). In this set of 11 countries, the average child mortality rate and the predicted prevalence of vitamin A deficiency (174

* Reports of the 15 nationally representative vitamin A deficiency surveys are not referenced here but can be obtained from the Ministries of Health of the respective countries.

per 1,000 live births and 17.4%, respectively) were not significantly different from those in the rest of sub-Saharan Africa (177 per 1,000 live births and 19.1%).

In this set of 11 countries, the prevalence of vitamin A deficiency predicted by MI/UNICEF/TU (17.4%) underestimates the true (observed) prevalence of vitamin A deficiency (38.6%) by a factor of 2.2. In other words, the prevalence of children under five years of age with vitamin A deficiency is 2.2 times higher than that hypothesized (predicted).

The average prevalence of children at risk for vitamin A deficiency in sub-Saharan Africa was estimated by applying a correction factor of 2.2 to the MI/UNICEF/TU prevalence estimates and combining this corrected prevalence with the under-five population. This yielded (**table 3**) an average prevalence of children 0 to 59 months at risk for vitamin A deficiency of 42.4% (40.2% in the WCAR and 44.8% in the ESAR) and says that in the absence of effective and sustained vitamin A deficiency-control policies and programs, an estimated 43.2 million children under five years of age in sub-Saharan Africa would be currently at risk for vitamin A deficiency.

The potential contribution of vitamin A deficiency to child mortality in sub-Saharan Africa was then estimated by combining the risk (RR) of death in children with vitamin A deficiency relative to that in children without vitamin A deficiency (RR = 1.75) and the corrected prevalence of vitamin A deficiency. Our analysis shows that in 1995, before the onset of large-scale vitamin A supplementation programs in many countries in sub-Saharan Africa, an estimated 25.1% of all-cause child mortality (more than 646,000 child deaths annually) was attributable to vitamin A deficiency.

Discussion

Our analysis used a systematic approach. However, three caveats must be acknowledged. In the absence of MI/UNICEF/TU estimates of the prevalence of vitamin A deficiency in Cape Verde, Comoros, Equatorial Guinea, Eritrea, Gambia, Guinea Bissau, São Tomé and Príncipe, Seychelles, and Swaziland (these countries represent 1.4% of the total population in sub-Saharan Africa), the average prevalence of vitamin A deficiency predicted for the corresponding region (WCAR or ESAR) was used as a proxy. Four of the 11 national-level vitamin A deficiency surveys conducted between 1995 and 2003 (Benin, Cameroon, Gambia, and Kenya) did not include infants 6 to 11 months old. For these countries, the prevalence of vitamin A deficiency among children 12 to 59 months old was used as a proxy for vitamin A deficiency among children 6 to 59 months old (without upward or downward adjustment). The rates of prevalence of vitamin A deficiency were not adjusted for potentially high infection rates in the surveyed populations. Errors generated from these three assumptions would affect our estimates.

However, despite these three limitations, our analysis provides a robust estimate of the potential current prevalence of children at risk for vitamin A deficiency in sub-Saharan Africa, and it shows that effective and sustained control of vitamin A deficiency may be among the most cost-effective and high-impact child survival interventions in sub-Saharan Africa. Improving the vitamin A status of children may reduce child mortality in sub-Saharan Africa by up to 25% from the 1995 levels. These results are in line with previous analyses showing that in developing countries, up to one-third of deaths in pre-school-age children could be averted by improving vitamin A nutriture [22]. Moreover, this should be considered a conservative estimate of the potential contribution of improved vitamin A nutriture to the survival of children in sub-Saharan Africa, for two reasons: first, our analysis did not account for the potential contribution of vitamin A deficiency to infant mortality in the first half of infancy (0 to 5 months), because the available data from which to derive estimates are inconclusive; and second, our analysis did not account for the contribution of vitamin A deficiency to the mortality of children in the sixth and seventh years of life, although trials have reported reductions in mortality in this age group following vitamin A repletion [1, 5].

It is possible that in areas with a high prevalence of both vitamin A deficiency and HIV infection, the reduc-

TABLE 3. Estimated prevalence of children at risk of vitamin A deficiency (VAD), child population at risk for VAD, and mortality attributable to VAD among children 0 to 59 months of age in sub-Saharan Africa

Region	Corrected current prevalence of VAD risk (%)	Population at risk for VAD (millions)	No. of deaths attributable to VAD in 1995[a]	% of deaths attributable to VAD in 1995
West and Central Africa	40.2	20.8	315,960	23.5
East and Southern Africa	44.8	22.4	330,295	26.9
Sub-Saharan Africa	42.4	43.2	646,255	25.1

a. Before the onset of large-scale vitamin A supplementation programs in numerous countries in sub-Saharan Africa. Calculations were made on the basis of infant and child mortality rates and population of children 0–59 months old as published in UNICEF [21].

tion in mortality following vitamin A repletion is lower than in regions with a high prevalence of vitamin A deficiency and a low prevalence of HIV infection. However, from the available evidence it appears that the impact of vitamin A repletion on disease progression and death depends largely upon the stage of HIV infection. In the early stages of HIV infection, vitamin A repletion could have a positive impact by slowing the progression of the disease and increasing survival rates in early childhood. In a trial in Tanzania, for example, vitamin A supplementation of a cohort of children 6 to 59 months old, in which 9% of the children were HIV-infected, resulted in a 49% reduction of all-cause mortality; among the HIV-infected children, all-cause mortality was reduced by 63% [23]. In the light of these findings, it has recently been concluded that vitamin A supplementation of HIV-infected children appears to be beneficial in reducing the incidence, severity, and mortality of diarrhea [24], one of the leading causes of child mortality in sub-Saharan Africa.

Implications

Our analysis shows that the implementation of effective and sustained policies and programs for the control of vitamin A deficiency can bring about a reduction of up to 25% in child mortality rates in sub-Saharan Africa, compared with the mortality rates in 1995, before the onset of large-scale vitamin A supplementation with National Immunization Days for polio eradication. In many countries in sub-Saharan Africa, one high-dose vitamin A capsule is given annually on National Immunization Days for polio eradication, thus ensuring a vitamin A reserve of four to six months to more than 80% of children 6 to 59 months old. This is a remarkable achievement. However, as National Immunization Days for polio eradication are phased out or scaled down, it is imperative to ensure that all children 6 to 59 months old receive preventive vitamin A supplementation twice yearly, as recommended by the World Health Organization (WHO) and UNICEF. Promising experiences such as those with National Micronutrient Days (Niger and Burkina Faso), Nutrition Weeks (Mali), Child Health Weeks (Zambia), Vitamin A Weeks (Ghana), or the integration of vitamin A supplementation into Community-Directed Treatment with Ivermectin (CDTI) for onchocerciasis control (Nigeria and Cameroon) demonstrate that countries in sub-Saharan Africa can deliver vitamin A supplements to children twice yearly. All these strategies have in common the periodic, active distribution of vitamin A supplements through existing permanent institutions [25]. In combination with the integration of vitamin A supplementation into the Expanded Program of Immunization (EPI) and the therapeutic dosing of children suffering from malnutrition, infectious diseases, or both, these strategies can effectively deliver vitamin A supplements to children. It is therefore crucial that this high-impact and cost-effective child survival intervention (human rights imperatives aside) be made available to all children in sub-Saharan Africa.

It is also important to ensure that vitamin A supplementation drives an integrated, effective, and sustained sub-Saharan Africa–wide assault on vitamin A deficiency that integrates improved infant and young child nutrition and improved vitamin A dietary intakes throughout the life-cycle. Mortality data from the eight population-based field trials included in the meta-analysis by Beaton et al. [12] show that the reductions in mortality among children 6 to 24 months old made up more than 70% of the number of lives saved as a result of improving the vitamin A status of children 6 to 59 months old. Optimal feeding practices in the first two years of life are therefore essential for optimal vitamin A nutrition. Breastmilk, in particular, is vital to keep infants adequately nourished with vitamin A in the first six months of life, and possibly throughout infancy [26]. Gambia and Ghana, among other countries in sub-Saharan Africa, have proved that well-designed community-based and/or facility-based behavioral change communications programs can bring about dramatic improvements in the rates of early initiation of breastfeeding and adoption of exclusive breastfeeding in the first six months of life.

Dietary improvement must be an integral part of a sustainable strategy to control vitamin A deficiency, particularly among women of reproductive age. Significant progress has been achieved in the past 10 years in the design and implementation of a new generation of approaches that integrate production, nutrition education, and behavioral change communication strategies [27]. Vitamin A fortification of locally available foods can be crucial in improving the vitamin A status of the population and that of women of reproductive age in particular. An increasing number of countries in sub-Saharan Africa have conducted national-level food-consumption surveys to identify potential food vehicles for vitamin A fortification programs, have assessed the capability of selected food industries to implement vitamin A fortification, and/or are implementing successful private–public partnerships for vitamin A fortification [28].

Conclusions

At the United Nations Millennium Summit in 2000, African and other world leaders made a commitment to reduce mortality rates in children by two-thirds between 1990 and 2015. A stronger political com-

mitment and a more appropriate level of investment in the effective control of vitamin A deficiency have the promise to be among the most cost-effective and high-impact policy and program actions towards the achievement of the Millennium Development Goal for the reduction of child mortality in sub-Saharan Africa. Among the many challenges that Africa needs to face in the coming years, the control of vitamin A deficiency is one that can be accomplished. The need is urgent, and the solutions are known, effective, and affordable.

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