American Journal of Epidemiology Advance Access published November 17, 2016

American Journal of Epidemiology

DOI: 10.1093/aje/kww129

Practice of Epidemiology

Improving Estimates of Numbers of Children With Severe Acute Malnutrition Using Cohort and Survey Data

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Initially submitted February 7, 2016; accepted for publication September 21, 2016.

Severe acute malnutrition (SAM) is reported to affect 19 million children worldwide. However, this estimate is based on prevalence data from cross-sectional surveys and can be expected to miss some children affected by an acute condition such as SAM. The burden of acute conditions is more appropriately represented by cumulative incidence data. In the absence of incidence data, a method for burden estimation has been proposed that corrects available prevalence estimates to account for incident cases using an "incidence correction factor." We used data from 3 West African countries (Mali, Niger, and Burkina Faso, 2009–2012) to test the hypothesis that a single incidence correction factor may be used for estimation of SAM burden. We estimated the incidence correction factor and performed meta-analysis to calculate summary estimates for each country and for all 3 countries. Heterogeneity between countries and years was assessed using the I^2 statistic. We estimated a pooled incidence correction factor of 4.82 (95% confidence interval: 3.15, 7.38), although there was substantial between-country heterogeneity (I^2 = 69%). Knowing how many children in a particular area will be malnourished is fundamental to planning an effective operational response. Our results show that the incidence correction factor varies widely and suggest that estimating the burden of SAM with a common incidence correction factor is unlikely to be adequate.

disease burden; incidence; malnutrition; prevalence; severe acute malnutrition

Abbreviations: CI, confidence interval; MSF, Médecins Sans Frontières; MUAC, mid-upper arm circumference; SAM, severe acute malnutrition; SMART, Standardized Monitoring and Assessment of Relief and Transitions.

Editor's note: *An invited commentary on this article appears on page 000.*

Child malnutrition contributes to almost half (45%) of all deaths among children under age 5 years worldwide and to increased frequency, severity, and duration of life-threatening infectious diseases (1, 2). Cost-effective nutrition interventions have great potential to improve child health and survival, but donor support for nutrition-specific activities represented less than 5% of all international health assistance in 2010 (3, 4). Global efforts, such as the Scaling Up Nutrition movement (5), have increased international and national engagement in improving the provision of effective nutrition services. Despite this push for greater action and investment in nutrition, progress in scaling up policy and programs is being challenged by a poor understanding of the burden of child malnutrition.

Severe acute malnutrition (SAM), the most lethal form of malnutrition, is reported to affect 19 million children worldwide (1). This estimate is an extrapolation from 639 national surveys determining the prevalence of SAM in 142 countries. SAM is an acute condition, however, and affected children may recover or die within a few weeks. One consequence of this, recognized more than 40 years ago (6), is that estimation of the burden of SAM by means of prevalence data collected in occasional cross-sectional surveys will miss some cases and underestimate the number of children affected. The burden of acute conditions like SAM is more appropriately represented by a measure

of incidence that captures new cases over time, like those used for acute infectious diseases.

While prevalence estimates are relatively easy to obtain using cross-sectional surveys, estimates of incidence require longitudinal follow-up of a cohort and are more costly and time-consuming to obtain. In the absence of incidence data, a simple method for estimating disease burden has been proposed that corrects available prevalence estimates to account for incident cases using an "incidence correction factor" (7). While this correction improves upon the use of simple prevalence-based estimates alone, global guidance is weakened by the assumption that the proposed incidence correction factor is common to all places, times, and contexts. In the current study, we used data from 3 West African countries to test the hypothesis that a common incidence correction factor may be used for estimation of SAM burden in all settings. To our knowledge, this analysis represents the first use of field data to investigate variability in the incidence correction factor underlying current global guidance for estimating the burden of SAM.

METHODS

Epidemiologic framework for estimation of disease burden

In a steady-state population and when a disease is uncommon and duration of disease is constant, prevalence is a function of incidence and the inverse of the average duration of the disease (equation 1) (8). When 2 of the measures are known, the third can be calculated (equation 2). Specifically, incidence can be approximated with data only on prevalence and the incidence correction factor, K (equation 3).

$$\text{Prevalence } (p) = \text{incidence } (i) \times \text{average duration of disease } (D). \quad (1)$$

$$\text{Incidence } (i) = \text{prevalence } (p) \times \frac{t}{\text{average duration of disease } (D)}. \quad (2)$$

$$\text{Incidence } (i) = \text{prevalence } (p) \times K, \text{ where } K = \frac{t}{\text{average duration of disease } (D)} \quad (3)$$

and

$$t = \text{the period for which incidence is estimated (e.g., 12 months).}$$

The burden of SAM is defined as the total number of SAM cases in a population during a specific period. The burden of SAM is therefore calculated as shown in equation 4. Through substitution using the incidence correction factor, the burden calculation simplifies to equation 5 and equation 6.

$$\text{Burden} = \text{population}_{6-59\text{ months}} \times [\text{prevalence} + \text{incidence}]. \quad (4)$$

$$\text{Burden} = \text{population}_{6-59\text{ months}} \times [\text{prevalence} + \text{prevalence} \times K]. \quad (5)$$

$$\text{Burden} = \text{population}_{6-59\text{ months}} \times [\text{prevalence} \times (1 + K)]. \quad (6)$$

Current guidance recommends the use of $K = 1.6$ to calculate the 1-year incidence from a given prevalence (where 1.6 is 12 months/7.5 months and 7.5 months is the only empirical estimate of the average duration of untreated SAM (9)). The generalizability of this incidence correction factor, calculated from 2 cohorts from the 1980s and 1990s, has not been investigated.

Data sources

Data from Médecins Sans Frontières (MSF; Doctors Without Borders) provided estimates of prevalence and incidence for the empirical calculation of K in 3 African settings where both prevalence data and cohort or program data were available (Table 1). Longitudinal cohort data included repeated anthropometric measurements from 2 sites: Konseguela, Mali, and Maradi, Niger. In Mali, children below age 24 months were measured every 3 months at health facilities as part of a comprehensive pediatric health program in the Konseguela Health District from 2010 to 2013. In Niger, children 60–80 cm in length (approximately 6–24 months of age) were measured every month as part of 2 community-based research studies in the Maradi region from 2010 to 2012 (10, 11). Both cohorts were open, such that children aged into and out of follow-up according to the program or study criteria. In the absence of cohort data at the third site (Burkina Faso), prevalence was estimated from Standardized Monitoring and Assessment of Relief and Transitions (SMART) nutritional anthropometry surveys (12), and incidence was estimated using routine program data from the MSF therapeutic feeding program, treating children under age 85 months with mid-upper arm circumference (MUAC) less than 120 mm or edema from 2007 to 2011.

Collection of MSF cohort data in Mali and Niger was approved by the respective national ethical review committees, and routine monitoring program data in Burkina Faso were collected in collaboration with the Ministry of Health of Burkina Faso via a memorandum of understanding. Individual informed consent was obtained from all parents or caregivers prior to data collection.

Definition of parameters and statistical approach

SAM was defined as weight-for-height z score <-3 according to the 2006 World Health Organization Growth Standards (13), MUAC <115 mm, or the presence of edema. Using cohort data, the starting prevalence of SAM was

Table 1. Data Sources Used to Estimate the Prevalence, Incidence, and Duration of Severe Acute Malnutrition (SAM) and the Incidence Correction Factor for SAM Among Young Children in Mali, Niger, and Burkina Faso, 2009–2012

Prevalence Data					Incidence Data				
Child's Age, months	Survey Type	Region	Date	Definition of SAM	Child's Age, months	Region	Dates of Follow-up	Frequency of Follow-up	Definition of SAM
				Mali					
6–23	Cohort	KHD	July 2010	All	6–23	KHD	August 2010–June 2011	Quarterly	All
6–23	Cohort	KHD	July 2011	All	6–23	KHD	August 2011–June 2012	Quarterly	All
6–23	Cohort	KHD	September 2012	All	6–23	KHD	October 2012–August 2013	Quarterly	All
6–23	SMART	Sikasso region	July 2011	All	6–23	KHD	August 2011–June 2012	Quarterly	All
6–59[a]	SMART	Sikasso region	September 2012	WHZ <−3 or edema; MUAC <115 mm or edema	6–23	KHD	October 2012–August 2013	Quarterly	All
				Niger					
6–23	Cohort	MHD and GRHD	July 2010	All	6–23	MHD and GRHD	August 2010–June 2011	Monthly	All
6–23	Cohort	MHD	August 2011	All	6–23	MHD	September 2011–July 2012	Monthly	All
6–59[b]	SMART	Maradi region	June 2010	WHZ <−3 or edema	6–23	MHD and GRHD	August 2010–June 2011	Monthly	All
6–23	SMART	Maradi region	June 2011	WHZ <−3 or edema	6–23	MHD	September 2011–July 2012	Monthly	All
				Burkina Faso					
6–59	SMART	Lorum and Passore provinces	September 2009	MUAC <110 mm	6–59	THD and YHD	October 2009–August 2010		MUAC <120 mm or edema
6–59	SMART	SMART northern region	August 2010	MUAC <110 mm	6–59	THD and YHD	September 2010–July 2011		MUAC <120 mm or edema

Abbreviations: GRHD, Guidan Roumji Health District; KHD, Konseguela Health District; MHD, Madarounfa Health District; MUAC, mid-upper arm circumference; SAM, severe acute malnutrition; SMART, Standardized Monitoring and Assessment of Relief and Transitions; THD, Titao Health District; WHZ, weight-for-height *z* score; YHD, Yako Health District.

[a] Raw data with which to directly calculate *p*(SAM) among children aged 6–23 months in September 2012 were not available. An allocation factor equal to *p*(SAM) in children aged 6–23 months/*p*(SAM) in children aged 6–59 months in July 2011 was applied to the available September 2012 estimate of *p*(SAM) among children aged 6–59 months to approximate *p*(SAM) in children aged 6–23 months in September 2012.

[b] Information on *p*(SAM) among children aged 6–23 months was not available in June 2010. An allocation factor equal to *p*(SAM) in children aged 6–23 months/*p*(SAM) in children aged 6–59 months in June 2011 was applied to the available June 2010 estimate of *p*(SAM) among children aged 6–59 months to approximate *p*(SAM) in children aged 6–23 months in June 2010.

defined as the number of children with SAM divided by the total population at risk at the time of the first assessment. Incidence of SAM was defined as the number of children with SAM in the 11 months following the prevalence assessment divided by the total at-risk population under study in the following 11 months. SAM episodes considered in the numerator of incidence were classified as 2 separate episodes if there was an interval of 2 or more consecutive SAM-free months between the episodes. The total at-risk population was approximated using the actuarial method of taking the arithmetic mean of the total number of children under follow-up at the start and end of the follow-up period.

In Burkina Faso, the numerator of incidence was estimated as the number of admissions to the MSF nutritional program meeting the published SMART survey definition of SAM (e.g., MUAC <110 mm) over the 11-month period following SMART data collection, adjusted for program coverage (42.7%, estimated by MSF using the centric systematic area sampling method (14) in December 2009). The denominator of incidence (e.g., total number of children aged 6–59 months in the program catchment area) was approximated from the most recent (2006) census data for Lorum and Passoré provinces (15), assuming 12% of the population to be aged 6–59 months (16) and annual population increases of 2.9% (17).

Summary estimates and 95% confidence intervals for K, overall and by country, were obtained through bootstrapping, drawing prevalence and incidence estimates with replacement from binomial distributions, with the number of trials (n) equal to the sample size used to estimate prevalence or incidence and the probability equal to the observed point estimate of prevalence or incidence. A small amount of zero-centered uniformly distributed random "smoothing" noise ranging between $-1/n$ and $1/n$ was added to each replicate of prevalence and incidence in order to reduce discreteness in the bootstrap distributions of each. One million replicates of K were calculated, with the point estimate and 95% confidence limits taken as the median value and the 2.5th and 97.5th percentiles of the 1 million replicates of K, respectively. Meta-analysis was performed to calculate summary estimates for K by country and overall across the 3 countries using the DerSimonian and Laird random-effects estimator (18, 19). Evidence for statistical heterogeneity between countries and years was assessed using the I^2 statistic (20, 21), where $I^2 > 0.50$ was taken to indicate substantial heterogeneity (22).

We also calculated the incidence correction factor for all available countries/years with a MUAC-only SAM case definition: MUAC <115 mm or edema. Because survey data are often more readily available than cohort data in practice, we also calculated K with prevalence estimated from available SMART nutritional surveys for comparison to explore variability in the estimation of K according to the source of prevalence data (cohort data vs. SMART survey data). SAM case definitions were taken as published in the available SMART reports, if raw survey data were not available for direct estimation. All meta-analyses were conducted using STATA 12 (StataCorp LP, College Station, Texas).

RESULTS

Prevalence and incidence data were available for multiple years in 3 countries: Mali (2010–2012), Niger (2010–2011), and Burkina Faso (2009–2010). Table 2 presents all available incidence correction factor estimates. We estimated a pooled incidence correction factor of 4.82 (95% confidence interval (CI): 3.15, 7.38), although there was a substantial amount of between-country heterogeneity ($I^2 = 69\%$, $P = 0.004$) (Figure 1). Within countries, there was evidence of heterogeneity over time in Niger ($I^2 = 80\%$, $P = 0.02$), where the country-specific incidence correction factor ranged from 5.00 to 8.10. In contrast, there was no evidence of substantial heterogeneity across years in Mali or Burkina Faso; the pooled estimate of the incidence correction factor was 2.53 (95% CI: 1.64, 3.89) in Mali and 13.25 (95% CI: 4.34, 40.48) in Burkina Faso.

In secondary analysis, we found that application of a MUAC-only definition of SAM (e.g., MUAC <115 mm or edema) resulted in little change in the incidence correction factor compared with the primary analysis in Niger ($K = 6.17$ (95% CI: 3.86, 9.87) vs. $K = 6.71$ (95% CI: 4.81, 9.36)) or Mali ($K = 2.53$ (95% CI: 1.64, 3.89) vs. $K = 2.67$ (95% CI: 1.57, 4.57)) (Figure 2). A comparison of estimates by source of prevalence data (cohort vs. survey) is shown in Figure 3. Variability in estimates was greater with cohort data than with survey data in Niger but lesser with cohort data in Mali.

DISCUSSION

This analysis was a multicountry examination of the incidence correction factor used to estimate the burden of SAM. To our knowledge, this is the first empirical analysis to have estimated the incidence correction factor since the introduction of community-based management of SAM and to have explored variability across time and place. Our findings of substantial heterogeneity within the region suggest that current guidance regarding estimation of the burden of SAM with a single incidence correction factor may not be appropriate.

SAM is a life-threatening condition that contributes to significant morbidity and mortality among young children. The 2006 shift from hospital-based management of acute malnutrition to community-based management has the potential to greatly increase the capacity to treat SAM, but fewer than 10% of children currently in need receive care (7). Although there are multiple barriers to increasing access to treatment, data on the number of children affected remains a fundamental requirement for national planning and priority-setting, as well as program implementation and evaluation (23). Now that we are equipped with an effective community-based model for treatment with the capacity to treat a large proportion of children with SAM, appropriate estimates of the total burden are increasingly relevant for planning. Using the pooled incidence correction factor of 4.82 (95% CI: 3.15, 7.38) estimated here, the reported burden of 19 million children with SAM would be corrected to 110.6 million (95% CI: 78.9, 159.2) children affected. Given the variation in the incidence correction factor across place and time reported

Table 2. Prevalence, Incidence, and Duration of Severe Acute Malnutrition (SAM) and Estimates of the Incidence Correction Factor for SAM Among Young Children in Mali, Niger, and Burkina Faso, 2009–2012

SAM Definition and Cohort Year	Prevalence			Cumulative Incidence			Duration of SAM	Incidence Correction Factor (*K*)	Bootstrapping Estimate	
	No. of Cases	Total No. of Children	*p*	No. of Cases	Total No. of Children	*i*			Median *K*	95% CI
Mali										
MUAC <115 mm or WHZ <−3 or edema (prevalence from MSF cohort data)										
2010	3	110	0.027	107	964.5	0.111	3.0	4.1	4.1	1.5, 70.2
2011	14	516	0.027	107	1,655	0.065	5.0	2.4	2.4	1.4, 6.0
2012	21	580	0.036	162	1,797.5	0.090	4.8	2.5	2.5	1.6, 4.9
MUAC <115 mm or edema (prevalence from MSF cohort data)										
2010	2	110	0.018	88	964.5	0.091	2.4	5.0	4.7	1.5, 94.5
2011	12	516	0.023	88	1,655	0.053	5.2	2.3	2.3	1.2, 6.4
2012	14	580	0.024	121	1,797.5	0.067	4.3	2.8	2.8	1.6, 7.0
WHZ <−3 or edema (prevalence from MSF cohort data)										
2010	2	110	0.018	78	964.5	0.081	2.7	4.4	4.1	1.3, 83.9
2011	11	516	0.021	87	1,655	0.053	4.9	2.5	2.5	1.3, 7.6
2012	19	580	0.033	149	1,797.5	0.083	4.7	2.5	2.6	1.6, 5.3
MUAC <110 (prevalence from MSF cohort data)										
2010	1	110	0.009	19	964.5	0.020	5.5	2.2	1.6	0.4, 33.1
2011	3	516	0.006	14	1,655	0.008	8.2	1.5	1.4	0.4, 25.3
2012	1	580	0.002	14	1,797.5	0.008	2.7	4.5	3.4	0.8, 69.4
WHZ <−3 or edema (prevalence from SMART survey data)										
2011	17	403	0.042	87	1,655	0.053	9.6	1.2	1.3	0.7, 2.8
2012	11	397[a]	0.028	149	1,797.5	0.083	4.0	3.0	3.1	1.6, 9.1
MUAC <115 mm or edema (prevalence from SMART survey data)										
2011	13	403	0.032	88	1,655	0.053	7.3	1.6	1.7	0.9, 4.4
2012	4	381[a]	0.010	121	1,797.5	0.067	1.9	6.4	6.6	2.6, 88.9
WHZ <−3 or MUAC <115 mm or edema (prevalence from SMART survey data)										
2011	24	403	0.060	107	1,655	0.065	11.1	1.1	1.1	0.7, 2.0
MUAC <110 mm (prevalence from SMART survey data)										
2011	6	403	0.015	14	1,655	0.008	21.1	0.6	0.6	0.2, 4.1
Niger										
MUAC <115 mm or WHZ <−3 or edema (prevalence from MSF cohort data)										
2010	41	593	0.069	271	489	0.554	1.5	8.0	8.1	5.8, 12.4
2011	197	3,798	0.052	707	2,726.5	0.259	2.4	5.0	5.0	4.2, 6.0
MUAC <115 mm or edema (prevalence from MSF cohort data)										
2010	34	593	0.057	234	489	0.479	1.4	8.3	8.4	5.8, 13.7
2011	122	3,798	0.032	514	2,726.5	0.189	2.0	5.9	5.9	4.7, 7.5
WHZ <−3 or edema (prevalence from MSF cohort data)										
2010	22	593	0.037	222	489	0.454	1.0	12.2	12.4	7.9, 23.6
2011	135	3,798	0.036	440	2,726.5	0.161	2.6	4.5	4.5	3.7, 5.7

Table continues

Table 2. Continued

SAM Definition and Cohort Year	Prevalence			Cumulative Incidence			Duration of SAM	Incidence Correction Factor (*K*)	Bootstrapping Estimate	
	No. of Cases	Total No. of Children	*p*	No. of Cases	Total No. of Children	*i*			Median *K*	95% CI
MUAC <110 (prevalence from MSF cohort data)										
2010	14	593	0.024	181	489	0.370	0.8	15.7	15.9	9.1, 39.0
2011	24	3,798	0.006	180	2,726.5	0.066	1.1	10.4	10.5	6.7, 19.8
WHZ <−3 or edema (prevalence from SMART survey data)										
2010	39	411[b]	0.095	222	489	0.454	2.5	4.8	4.8	3.4, 7.5
2011	16	414	0.039	440	2,726.5	0.161	2.9	4.2	4.2	2.5, 9.4
Burkina Faso										
MUAC <110 mm (prevalence from SMART survey data)										
2009	6	1,247	0.005	2,138	60,937	0.082	0.7	16.4	17.0	7.8, 111.4
2010	2	392	0.005	1,046	62,704	0.039	1.5	7.8	7.3	2.4, 147.0

Abbreviations: CI, confidence interval; MSF, Médecins Sans Frontières; MUAC, mid-upper arm circumference; SAM, severe acute malnutrition; SMART, Standardized Monitoring and Assessment of Relief and Transitions; WHZ, weight-for-height *z* score.

[a] Raw data with which to directly calculate the total number of children aged 6–23 months in September 2012 were not available. An allocation factor equal to number of children aged 6–23 months/number of children aged 6–59 months in July 2011 was applied to the available September 2012 estimate of children aged 6–59 months to approximate the number of children aged 6–23 months in September 2012.

[b] Raw data with which to directly calculate the total number of children aged 6–23 months in June 2010 were not available. An allocation factor equal to number of children aged 6–23 months/number of children aged 6–59 months in June 2011 was applied to the available June 2010 estimate of children aged 6–59 months to approximate the number of children aged 6–23 months in June 2010.

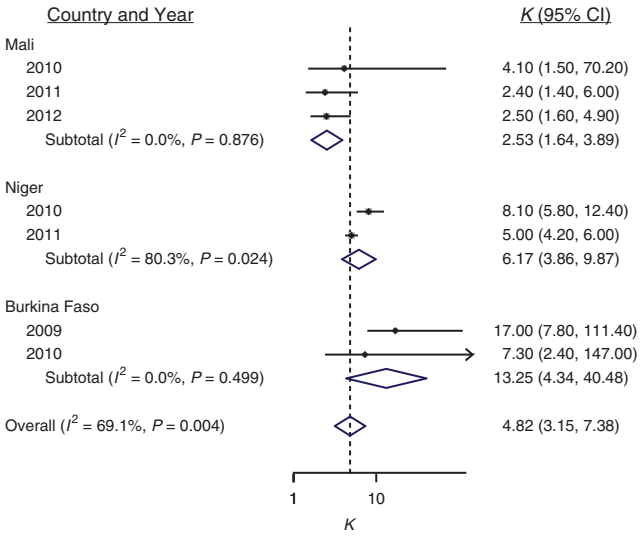

Figure 1. Median incidence correction factor (*K*) for severe acute malnutrition in Mali, Niger, and Burkina Faso, 2009–2012. Severe acute malnutrition was defined as mid-upper arm circumference (MUAC) <115 mm, weight-for-height *z* score <−3, or edema in Mali (2010–2012) and Niger (2010–2011) and as MUAC <110 mm or edema in Burkina Faso (2009–2010). CI, confidence interval.

here, use of a common correction factor of 1.6 may still substantially underestimate the number of children in need and the importance of this condition.

Statistical heterogeneity suggests differences in the incidence correction factor across settings: The pooled estimate in Mali ($K = 2.57$, 95% CI: 1.65, 4.00) was lower than that in Niger ($K = 5.59$, 95% CI: 3.31, 9.44). This between-country heterogeneity is consistent with the hypothesis that the relationship between prevalence and incidence is context-specific and may be related to differences across data sources or more general contextual differences. For example, the cohort in Mali included younger children aged 6–23 months and follow-up every 3 months. If incident cases were more likely to be missed in this context—for example, due to the frequency of follow-up—the incidence correction factor would have been underestimated here. Similarly, if cases were systematically identified earlier or with fewer medical complications due to improved community-based screening or health infrastructure in Niger, the duration of SAM may generally be shorter and the incidence correction factor larger in Niger.

There has been great interest in the expanded use of MUAC in the management of SAM. It has been suggested that use of MUAC as the single anthropometric criterion for screening, admission, monitoring, and discharge would simplify management protocols, as well target those children at highest risk of death (24), but the transition to MUAC-based management has been slowed by uncertainty surrounding the operational implications of such a change. We showed here that use of a

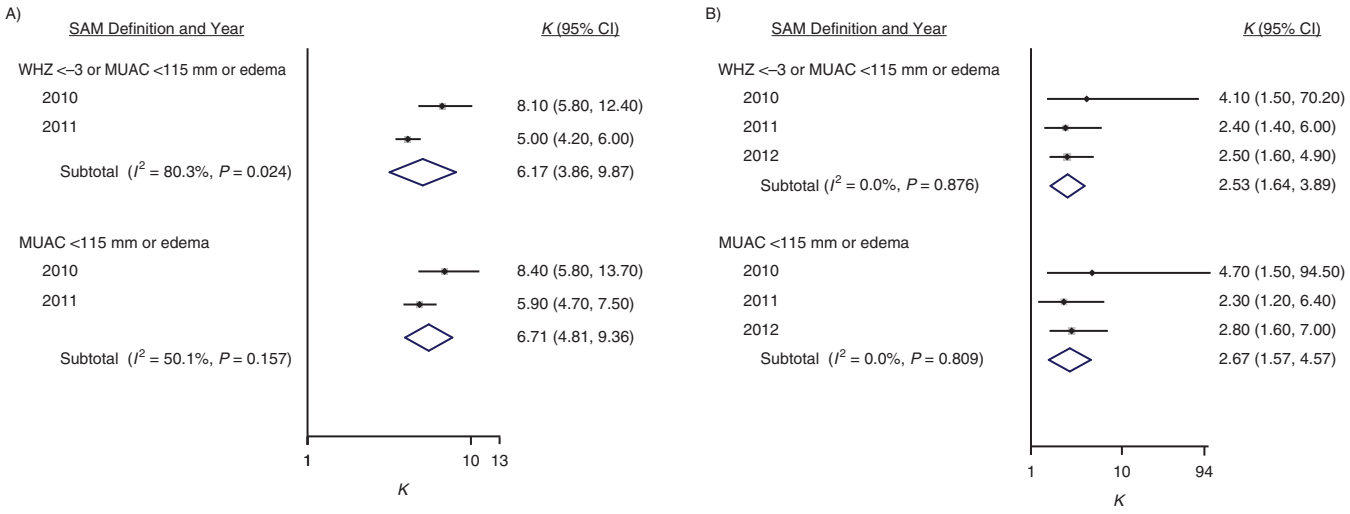

Figure 2. Median incidence correction factor (*K*) for severe acute malnutrition (SAM) in Niger and Mali, estimated using alternative case definitions of SAM, 2010–2012. A) Niger, 2010–2011; B) Mali, 2010–2012. CI, confidence interval; MUAC, mid-upper arm circumference; WHZ, weight-for-height *z* score.

SAM case definition employing MUAC as the sole anthropometric criterion did not materially change the estimates of the incidence correction factor for burden estimation.

The incidence correction factor for SAM has been estimated only twice before. Garenne et al. (9) used data from over 5,100 children followed every 3 or 6 months at 2 African sites in the 1980s and 1990s, before community-based treatment of SAM and before the scale-up of immunization programs and treatments for diarrhea, malaria, and other infectious diseases. Those historical data yielded a duration of untreated SAM of 7.5 months, the single estimate used to inform current guidance for an incidence correction factor of 1.6 (e.g., 12 months/7.5-month duration of illness). Isanaka et al. (25) used more recent cohort data from 1,689 children in Niger in 2006 and 2007 and suggested a SAM duration of 1.5 months and, by substitution, an incidence correction factor of 8. Results from the study by Isanaka et al. (25) were not substantially different from those presented for Niger here.

Given the potential for considerable variation in the prevalence-incidence relationship across place and time, our study reinforces the need for, at least, country-level estimation

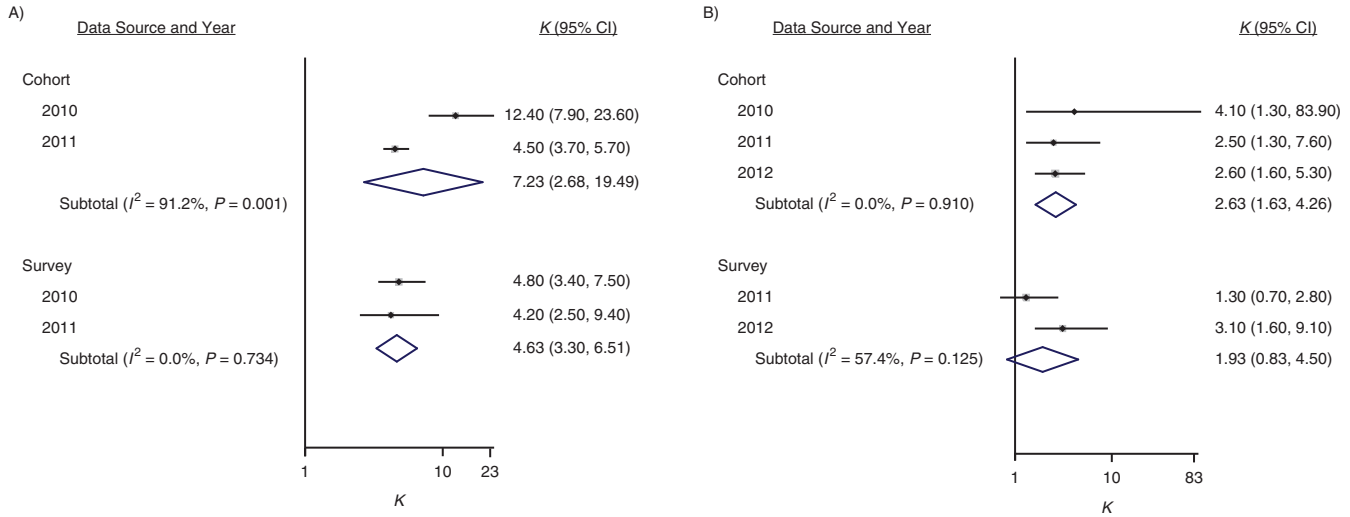

Figure 3. Median incidence correction factor (*K*) for severe acute malnutrition in Niger and Mali, estimated using alternative data sources, 2010–2012. A) Niger, 2010–2011; B) Mali, 2010–2012. Severe acute malnutrition was defined as weight-for-height *z* score <–3 or edema throughout. CI, confidence interval.

of the incidence correction factor. We showed here that the combination of survey and routine program data with an estimate of program coverage may provide a feasible alternative to the optimal prospective (e.g., cohort) investigations. The Integrated Disease Surveillance and Response approach proposed by the World Health Organization Regional Office for Africa, which promotes the integration of multiple surveillance systems and recommends routine MUAC assessment, may also represent a practical platform with which to obtain routine data on SAM incidence, defined as MUAC <115 mm or edema, throughout the region (26).

Our study had several limitations. First, there was inconsistency in terms of case definitions, study populations, and follow-up, which complicated comparisons across all available countries/years. Second, the mathematical relationship between incidence and prevalence used to estimate burden assumed a stable incidence over time. This assumption is unlikely to hold for a condition, such as SAM, in which strong seasonal variation in prevalence is observed. Estimates of the incidence correction factor are likely to be lowest when surveys are taken at times of highest prevalence and vice versa. Surveys used in this analysis were conducted during the "lean season," the period with the highest expected prevalence, as is common for surveys of this type. Therefore, the incidence correction factors estimated here may have been lower than those that would have been derived if one were using survey data collected at other times. Additional data from an open cohort on the monthly prevalence of malnutrition, with complementary information on morbidity and food insecurity, could be used to better understand the influence of seasonality. Third, all data in this analysis were drawn from contexts in which SAM treatment was available, whereas the theoretical relationship between incidence, prevalence, and the duration of illness is set within a context of untreated disease. Finally, while this analysis highlights the importance of heterogeneity in considering SAM burden and shows the potential for vast underestimation of the SAM burden under current guidelines, it does not yet identify a more appropriate incidence correction factor. The few data points in this analysis preclude any definitive statements about the most appropriate estimate.

Moving forward, we encourage policy-makers and program managers to explore inclusion of routine data collection, such as that proposed in the World Health Organization Integrated Disease Surveillance and Response approach (26), so that context-specific estimates can be developed. In the absence of forthcoming data, estimates provided in this analysis may be considered for estimation of SAM burden in the countries studied.

ACKNOWLEDGMENTS

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No funding was provided for this study.

We thank Michel Olivier Lacharité for his support of the conception of this analysis and Médecins Sans Frontières–France for providing the data.

Conflict of interest: none declared.

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American Journal of Epidemiology Advance Access published November 17, 2016

American Journal of Epidemiology

DOI: 10.1093/aje/kww131

Invited Commentary

Invited Commentary: Improving Estimates of Severe Acute Malnutrition Requires More Data

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Initially submitted July 7, 2016; accepted for publication September 21, 2016.

In this issue of the *Journal,* Isanaka et al. (*Am J Epidemiol*. 2016;000(00):000–000) set out to update an incidence correction factor used for estimating numbers of cases of severe acute malnutrition (SAM) in children aged 6–59 months. The total number of current SAM cases (prevalent cases) increases by the number of new (incident) cases and decreases as a result of recovery or death. Prevalence estimates are obtained from cross-sectional surveys. Calculation of incidence typically requires longitudinal data, which evidently are rarely collected for SAM, and so a correction factor is applied instead. Isanaka et al. pool and meta-analyze data from longitudinal and community programs in 3 West African countries (Mali, Niger, and Burkina Faso), covering the period 2009–2012. Heterogeneity and the ongoing lack of data undermine the use of a single incidence correction factor for SAM estimates. Routine data collection is recommended as a way forward and aligns with recommendations of the World Health Organization. This commentary helps to outline a context for the use of such data and provide some perspective on the inadequacy of data, relative to the importance of the issue.

child; correction factor; incidence; malnutrition; public health; severe acute malnutrition

Abbreviation: SAM, severe acute malnutrition.

Occasionally you read or review an article that occupies more of your mental space than most others. In this issue of the *Journal,* Isanaka et al. (1) tackle one small piece of the puzzle for a big issue in global public health: child malnutrition. Globally, severe acute malnutrition (SAM) contributes significantly to child morbidity and high child mortality.

What data are available?

We were interested in and really surprised to learn about the lack of high-quality data supporting global estimates of the number of children with SAM. We even questioned whether the authors might have missed something. Surely there were a few more cohorts that could have contributed longitudinal data to their meta-analysis, were there not? A simple online search proved otherwise. It appears that Van den Broeck et al. (2) published the first longitudinal data on a cohort of 5,000 children in Bwamanda, northwestern Democratic Republic of Congo (formerly Zaire), for the period 1989–1992. Then Garenne et al. (3) published data on the same Bwamanda cohort, paired with data on an earlier cohort (1983–1985) from Niakhar, Senegal. There was optimism when we came across a 2014 paper by Kismul et al. (4), until it became obvious that the data were from the same historical Bwamanda cohort as described in the previous 2 papers. We identified 3 further longitudinal data sources, all of which had fairly inadequate follow-up and predated 1993, from a tiny footnote published in a joint statement on community-based management of SAM (5). These included data from Bangladesh (n = 4,927; participants were followed for 6 months and visited monthly; results published in 1987) (6), Uganda (n = 1,178; participants were followed for 1 year and visited twice; results published in 1987–1988) (7), and Yemen (n = 2,071; participants were followed for 1 year and visited twice; results published in 1982–1984) (8). Finally, there was one 2011 paper by Isanaka et al. (9) using more recent data collected in 2006–2007 for 1,689 children in Niger. At the end of this search,

the conclusion we reached is that Isanaka's et al. paper in this issue of the *Journal* (1) is making a huge contribution to the total available body of recent literature on SAM incidence in children.

What does this paper tell us?

It is relatively easy to comprehend a single-figure estimate of a big problem, such as "there are 19 million children with SAM worldwide," but it is much harder to derive this estimate. For example, that figure of 19 million is based on prevalence data reported for 142 countries (10). In actual fact, this figure of 19 million is different from the one presented in the recent United Nations Children's Fund program guidance document, which quotes an estimate of 17 million (11). It would be nice if that discrepancy of 2 million arose because effective intervention strategies are reaching children in need and the problem has genuinely diminished since 2013. An alternate hypothesis is that the estimates are underpinned by a large number of assumptions and the use of slightly different methods can lead to large discrepancies in the estimates. A good example of this is presented by Isanaka et al. when they extrapolate their pooled incidence correction factor to the reported burden of 19 million SAM-affected children, which corrects this figure to over 110 million (1).

What else was done?

We were interested in the authors' methods for estimating the correction factors and associated confidence intervals. Use of the parametric bootstrap approach for estimating the sampling distributions for prevalence and incidence is smart and valid; however, we were less clear about what was done in regards to estimates of the standard errors for the incidence/prevalence ratio (K)—specifically how a standard error was generated, for use in the random-effects meta-analysis, from this bootstrapped confidence interval, which in general is very nonnormal. Our thinking is that this could cause underestimation of the heterogeneity (I^2), but given that this was high anyway, it is not likely to meaningfully change the interpretation of the results. It would also be interesting to know just how many data were missing from the original data set.

How can this paper change practice?

> *"Whether a standard incidence correction factor is appropriate and what that value might be is still under debate."*
>
> United Nations Children's Fund, 2015 (10, p. 70)

This is an important paper that makes a valuable contribution to the debate on SAM and will undoubtedly act as a stepping stone, even though it doesn't provide a conclusive landing. A single and outdated incidence correction factor has now been updated to 3 distinct incidence correction factors, one per region. However, even the accuracy of these more specific values will vary depending on case definitions, seasonality of data, ages of the children assessed, follow-up interval, and many other variables.

The SAM incidence correction factor is essentially the inverse of the duration of the acute episode. As treatment opportunities and resources improve, it is to be hoped that SAM prevalence will decline over time and that the incidence correction factor will increase. However, the duration can also be shortened by increased mortality, so careful monitoring is needed. One recommended method and alternative to indirect estimates of SAM using an incidence correction factor, at least where SAM treatment programs and admission data already exist, is to extrapolate targets based on the number of admissions in the previous year. These should take into account seasonality, geographic expansion plans, predicted increases in treatment coverage based on program activities and adjustments, and completeness of reporting (11).

How can such an important problem be so poorly defined?

Aside from a gross lack of cohort studies contributing data, it is also important to consider within each cohort the duration of time to follow-up. Hopefully delays in pinning down the start date of the acute SAM episode are balanced by delays in pinning down the end date of the acute episode, but this may not always be so. More frequent monitoring would enhance confidence in the estimates.

We and our colleagues work in medical research that strives for both accuracy and precision, using strong epidemiologic methods—thousands of participants, randomization, blinding, data linkage, and so on (12). As reading the paper by Isanaka et al. (1) puts nicely into perspective, this is a luxury. To reconcile some of the limitations of the available SAM data, it is better to think of this work as public health in practice, rather than pure epidemiology. Plenty of food for thought is provided here by Isanaka et al.

ACKNOWLEDGMENTS

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A.H. was supported by a Public Health Postdoctoral Fellowship from the Hunter Medical Research Institute.

We are grateful to Dr. Damien Jackel for reviewing the first draft of this commentary.

Conflict of interest: none declared.

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