Estimating child mortality due to diarrhoea in developing countries

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Objective The major objective of this study is to provide estimates of diarrhoea mortality at country, regional and global level by employing the Child Health Epidemiology Reference Group (CHERG) standard.
Methods A systematic and comprehensive literature review was undertaken of all studies published since 1980 reporting under-5 diarrhoea mortality. Information was collected on characteristics of each study and its population. A regression model was used to relate these characteristics to proportional mortality from diarrhoea and to predict its distribution in national populations.
Findings Global deaths from diarrhoea of children aged less than 5 years were estimated at 1.87 million (95% confidence interval, CI: 1.56–2.19), approximately 19% of total child deaths. WHO African and South-East Asia Regions combined contain 78% (1.46 million) of all diarrhoea deaths occurring among children in the developing world; 73% of these deaths are concentrated in just 15 developing countries.
Conclusion Planning and evaluation of interventions to control diarrhoea deaths and to reduce under-5 mortality is obstructed by the lack of a system that regularly generates cause-of-death information. The methods used here provide country-level estimates that constitute alternative information for planning in settings without adequate data.

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Une traduction en français de ce résumé figure à la fin de l'article. Al final del artículo se facilita una traducción al español. الترجمة العربية لهذه الخلاصة في نهاية النص الكامل لهذه المقالة.

Introduction

The Millennium Development Goals (MDGs) were adopted in 2000 with the aim of reducing the severe gaps between rich and poor populations. Most countries have endorsed Goal 4 of the MDGs to "*reduce by two thirds* [between 1990 and 2015] *the mortality rate among children under-five*".[1,2] Reliable information on the magnitude, patterns and trends of causes of death of children aged less than 5 years helps decision-makers to assess programmatic needs, prioritize interventions and monitor progress. It is also crucial for planning and evaluating effectiveness of health services and interventions. Yet, data are very scarce in low-income settings where they are most needed and estimations are necessary for these areas.

In the 1980s, Snyder and Merson[3] generated one of the earliest attempts to estimate the worldwide burden of diarrhoeal diseases, demonstrating the substantial health onus due to diarrhoeal diseases on mortality among children aged less than 5 years. In the following decades, subsequent reviews updated these initial estimates using similar methods of assessment.[4,5] These initial estimates were based on average values derived from a limited set of studies without taking into account the epidemiological variations across different regions. Responding to international demand and to the need for better evidence-based cause-specific mortality, the Child Health Epidemiology Reference Group (CHERG) – an independent group of technical experts jointly coordinated by WHO and the United Nations Children's Fund (UNICEF) – was established in 2001. CHERG has undertaken a systematic, extensive and comprehensive literature review of published information and developed a methodological approach that is transparent and consistent across different diseases and conditions to produce estimates of the major causes of childhood deaths.[6–10] This study is an essential part of the overall CHERG efforts. Its main objective is to provide estimates of deaths from diarrhoea in 2004 at all levels, mainly for countries with incomplete or non-existing civil registration data.

Methods

Data sources

Common sources of data for cause-specific mortality include vital registration systems, sample registration systems, nationally representative household surveys, sentinel Demographic Surveillance Sites (DSS) or epidemiological studies of cause-specific mortality. In countries that account for 98% of under-5 deaths worldwide, there is very limited or virtually no functioning vital registration system in place to support attribution of causes of deaths.[11–14] A sample registration system, which reports causes of death on a regular basis, is currently available only in China and its coverage and quality for under-5 deaths is challenging.[15] Nationally representative household surveys such as Demographic Health Surveys (DHS) and UNICEF's Multiple Indicator

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Cluster Surveys (MICS) do not usually report on causes of death, and DSS data were not available until very recently.[16] Epidemiological studies currently constitute the main source of data available and were therefore used in this review for estimating diarrhoea-specific mortality.

Search strategy

Studies included in the analysis were identified through a systematic search of the scientific literature published since 1980. Medline was searched using the terms: "developing countries", "mortality/death", different spellings of "diarrhoea" and combinations of these terms. No restriction was placed on publication language.

The search identified a total of 804 papers of which 207 were kept for review of abstracts. The reference sections of the studies retrieved were reviewed to identify additional papers. Studies were then assessed to ensure that they met the main inclusion criteria: (i) direct or derivable diarrhoea-specific proportional mortality data; (ii) a minimum of 25 total deaths; (iii) a maximum of 25% of unknown or undetermined causes of death; (iv) community-based studies with at least 1 year of follow-up; and (v) follow-up time multiple of 12 months to minimize seasonal effects. Data were abstracted onto standardized paper forms by two independent abstractors, double-entered into an electronic database, and validated. Table 1 (available at: http://www.who.int/bulletin/volumes/86/9/07-050054/en/index.html) summarizes the main characteristics of the studies retained for the final analysis.

Adjustment of age groups

As not all studies reported on age ranges that were suitable for immediate inclusion in the analysis, we developed and applied a correction algorithm to adjust for age groups. By doing so, all data referred to the same age group (0–59 months), allowing for the inclusion of a greater number of studies in the analysis.

Proportional mortality model

A traditional approach to estimating cause-specific mortality is to model mortality rates. Instead, we have decided to model proportional mortality as this is the measure of interest when assessing causes of death by country. Moreover, as the WHO process for estimating causes of death is based on the estimation of under-5 mortality level, followed by the allocation of the causes of under-5 mortality,[6] proportional mortality is a more pertinent outcome that can be used in the completion of the estimation process.

We employed a weighted regression model to assess the relationship between the observed proportion of deaths from diarrhoea and potential explanatory variables, in an approach similar to those previously used for estimating proportion of deaths from pneumonia.[6,10,17]

Covariates included in the final model were those available from the studies selected, so that the model could reflect the relationship more accurately than in the conventional approach of using national averages. The variables included were: under-5 all-cause mortality and dummy variables for mid-year of study and for nine WHO subregions.[18]

All-cause under-5 mortality was obtained for the same (or comparable) site from which the proportional diarrhoea mortality information was derived, as follows: (i) directly abstracted or calculated from available data in the study (30 studies); (ii) obtained from the authors when not possible to calculate from published data (three studies); (iii) obtained from DHS data (11 studies); or (iv) obtained using a method similar to that used for the adjustment of age groups (three studies). As under-5 mortality rates were reported in different measures (rates, risks or ratios) in the publications, we have transformed those provided as mortality rates ($_5m_0$) into a single metric – the probability (risk) of a child dying before reaching the age of 5 years ($_5q_0$).

WHO subregions are defined on the basis of levels of child and adult mortality: A, very low child and very low adult mortality; B, low child and low adult mortality; C, low child and high adult mortality; D, high child and high adult mortality; E, high child and very high adult mortality.[18] The nine low- and middle-income subregions included in the model are: African Region (AFR) D and E; Region of the Americas (AMR) B and D; South-East Asia Region (SEAR) B and D, Eastern Mediterranean Region (EMR) B and D and Western Pacific Region (WPR) B.

Other potentially important variables considered for inclusion in the model, such as coverage of oral rehydration therapy, access to clean water, and health system indicators, were only available for a very limited number of studies at site level and thus could not be incorporated in the model.

The regression coefficients obtained from the final model were used to predict the proportion of deaths from diarrhoea at country level by using national information on under-5 mortality in 2004 and data for the corresponding subregion. The number of deaths from diarrhoea in the year 2004 was estimated by applying the model-predicted diarrhoea-proportional mortality to the number of under-5 deaths in each country. These were then aggregated to provide subregional, regional, and global (low- and middle-income countries) estimates. Detailed information on the estimates of all-cause under-5 deaths can be found elsewhere.[19]

Uncertainty analysis

Uncertainty estimates were generated using the standard errors obtained from the prediction model and running 10 000 Monte Carlo simulations.

Results

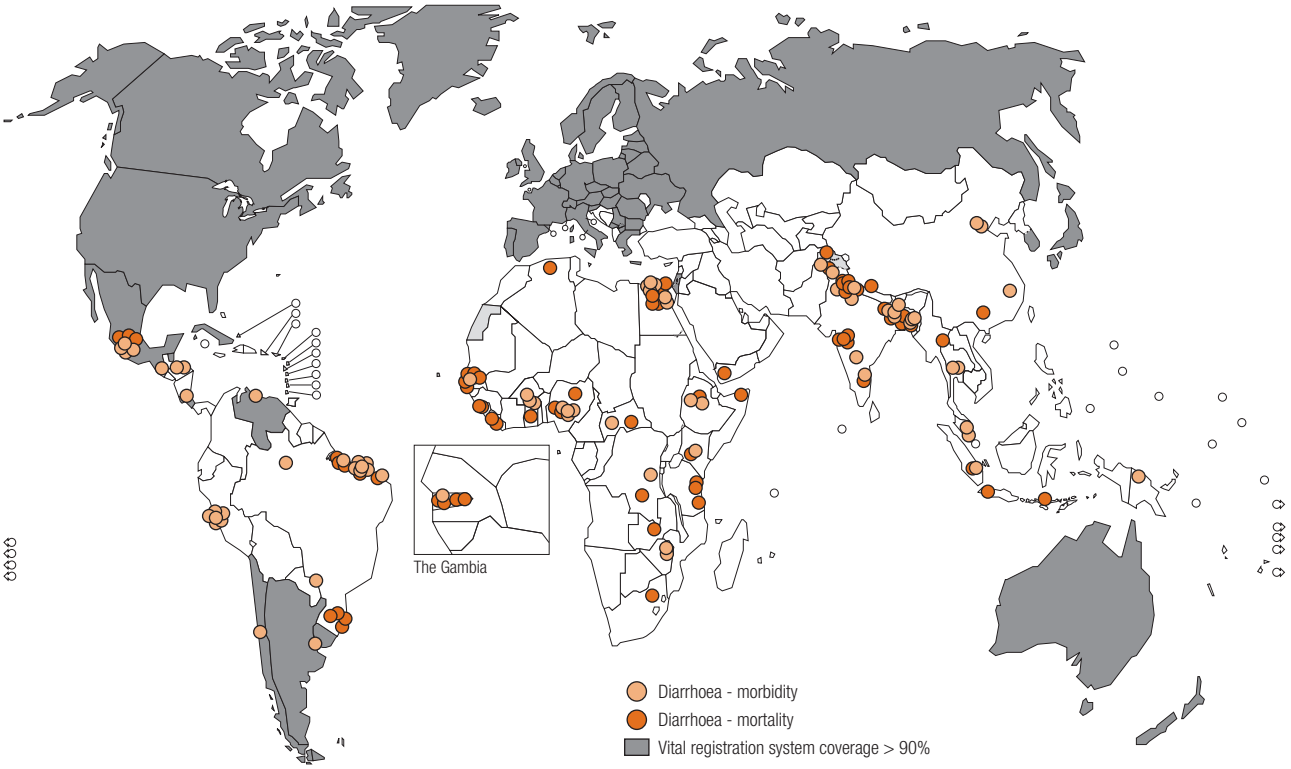
Study characteristics

Of the 68 studies that met the inclusion criteria, 47 were kept in the analysis because they provided data that enabled us to either abstract or calculate site-specific under-5 mortality rates (Table 1).

Seven studies presented data for more than one point in time, and one study provided data for different study populations, adding up to 56 data points and representing a total of 210 000 all-cause deaths and 33 500 diarrhoea deaths. Three data points were from nationally representative studies, seven from studies carried out in urban settings and 43 (77%) from those carried out in rural areas. This distribution compares well with that of the rural and urban populations in the countries studied.

Fig. 1 shows the location of the 47 studies retained from the literature search, revealing the regional distribution of study sites as follows: 23 data points (41%) in AFR, 17 (30%) in SEAR, and 12 (21%) in AMR. There

Fig. 1. **Distribution of epidemiological studies used in the analysis**



Source: ref 13.

were very few studies or information available from EMR or WPR. The scarcity of information in these two regions is a fact, not only for diarrhoea mortality, but for other diseases and conditions as well.[8,13]

Studies were distributed around an average mid-surveillance year of 1990. Two studies were carried out in the 1970s. As for the remaining 54 data points, the mid-year of data collection was between 1980 and 1984 for 14 observations, between 1985 and 1989 for 26 observations and between 1990 and 1994 for 13 observations. Only one study was completely carried out after 1995. In recent years, low-mortality studies were seen more than high-mortality studies, reflecting the secular downward trend in child mortality that has been accompanied by a decrease in the proportion of deaths due to diarrhoea. The age-adjusted (0–59 months) diarrhoea-proportional mortality ranged from 4.6% in Brazil in 1997[20] to 47.7% in Egypt in 1980.[21]

Model specifications

The final regression model was (standard errors in brackets):

$$\text{logit}(\%\ \textit{diarrhoea deaths}) = 5.31 + 2.38(\textit{ln}_5q_0) + 2.01(\textit{time}) + 8.56(\textit{subregion})$$
$$[3.67, 1.02, 0.97, 1.92]$$

where ln_5q_0 is the natural logarithm of the risk of dying between birth and 5 years in the study site, *time* is a dummy variable for mid-year of study (1 for 1990 and after, 0 for before 1990) and *subregion* is a dummy variable for WHO subregions (1 for SEAR B and D combined, 0 for the other subregions). The goodness-of-fit was satisfactory, as reflected by the R^2 of 0.60. There was no systematic deviation among the residual.

External validation

A simple validation technique that is commonly used is to compare the model outputs with empirical data other than those used in the model. We searched the latest data from DHS and other nationally representative surveys in which verbal autopsy was used to obtain information on causes of death among children aged less than 5 years. We have identified three recently published surveys with available information from Bangladesh (DHS 2005),[22] Cambodia (DHS 2005)[23] and Liberia (Food Security and Nutritional Survey 2006).[24] The difference in cause categories made direct comparison difficult, particularly for Bangladesh and Cambodia. The only comparable data set was that from Liberia where the model-based estimate and empirically observed figure for the proportion of diarrhoea deaths were 15.9% (95% CI: 12.4–19.3) and 16.1%, respectively. This is not sufficient to validate the entire set of extrapolations but it does illustrate the performance of our method in countries where a vital registration system does not exist or is incomplete.

Subregional, regional and global estimates

Estimates of diarrhoea-proportional mortality for nine low-and middle-income WHO subregions are shown in Table 2, together with point estimates of the number of deaths due to diarrhoea and corresponding uncertainty ranges. The model-based global point estimate of 1.87 million (uncertainty range: 1.56–2.19) diarrhoea deaths corresponds to nearly 19% of the 10

million under-5 deaths that occurred in the world in 2004.[14] AFR and SEAR assemble together 78% (1.46 million) of all diarrhoea deaths occurring in the developing world (Fig. 2).

SEAR D suffers the highest average burden of diarrhoea-proportional mortality (25%) as well as highest numbers of death (651 000 diarrhoea deaths). It follows AFR D (402 000 deaths), AFR E (365 000 deaths), and EMR D (221 000). In SEAR B, AFR D, and AFR E, the median of diarrhoea-proportional mortality is around 17%. The lowest proportions and numbers of death were observed in the low child mortality region of the Americas (AMR B) and in EMR B.

Country estimates

Table 3 shows the top 15 countries ranked according to the number of under-5 deaths due to diarrhoeal diseases. These 15 countries account for 73% of all under-5 diarrhoeal deaths occurring worldwide. India alone is responsible for more than half a million diarrhoeal deaths.

Table 2. **Estimates of diarrhoea deaths among children aged less than 5 years in low- and middle-income regions of the world, 2004**

WHO region	Mortality stratum[a]	Average of diarrhoea-proportional mortality (%)	Estimated diarrhoea deaths (thousands)	Uncertainty ranges (thousands)
African (AFR)	D	17.8	402	346–455
	E	17.5	365	315–413
Americas (AMR)	B	13.3	35	30–40
	D	14.9	14	12–16
Eastern Mediterranean (EMR)	B	13.4	12	10–14
	D	16.9	221	190–250
South-East Asia (SEAR)	B	22.3	44	34–53
	D	24.5	651	500–793
Western Pacific (WPR)	B	13.8	105	90–118
World		**18.7**	**1870**	**1558–2193**

[a] WHO subregions are defined on the basis of levels of child and adult mortality: A, very low child and very low adult mortality; B, low child and low adult mortality; C, low child and high adult mortality; D, high child and high adult mortality; E, high child and very high adult mortality.

Discussion

Despite several attempts to estimate mortality from diarrhoea over the past decades and in recent years, the uncertainty surrounding its current level remains quite high. This occurs partly because of the lack in quality and number of available data and partly because of the lack of consistency in methods. We systematically reviewed studies that provided child cause-specific mortality published since 1980 and employed a rigorous and transparent approach to estimate current country, regional, and global diarrhoea mortality.

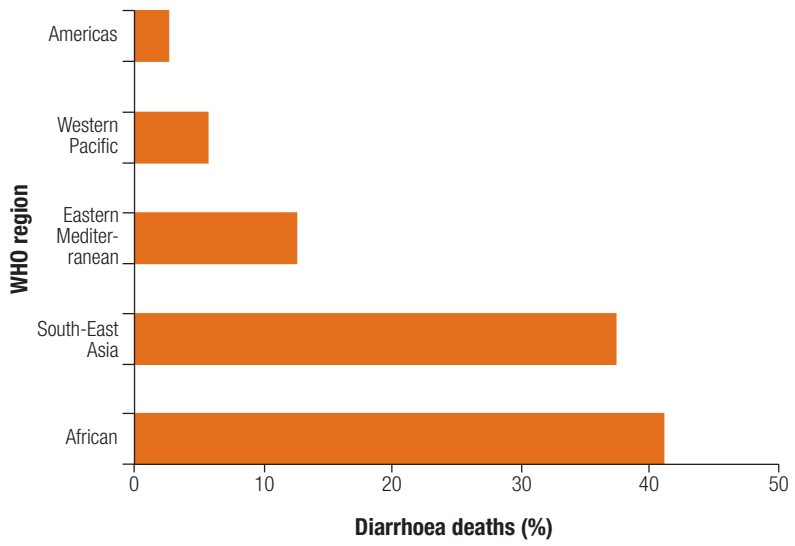
Recent estimates

Two recent studies presented global estimates of child deaths due to diarrhoea that were equal to 2.5 million[5] and 2.1 million.[25] A third review has estimated that 22% of all deaths among under-5s in sub-Saharan Africa and 23% in south Asia were caused by diarrhoeal diseases in the year 2000.[8]

The point estimate in our study resulted in 1.87 million deaths with an uncertainty range of 1.56 and 2.19 million deaths. These results are slightly lower than those calculated in the three other recent reviews. The main reasons for the differences encountered between this study and those by Kosek et al.[5] and Parashar et al.[25] are most probably due to the different data and methods employed.

In the present study, we performed a thorough literature review and took advantage of best available data to adjust for age, time, all-cause under-5 mortality, and regional mortality strata. Our approach has four major advantages when compared to earlier estimates. First, the method used here is transparent with all data sources available on the web. In addition, it is consistent with the CHERG systematic review protocol and comparable to the method used across different causes of under-5 deaths.[6–10] Second, the adjustment for age groups had not been previously used in the estimation of deaths from diarrhoea and has enabled the inclusion of a larger number of data points in the analysis. Third, our study did not assume that the locations where studies were carried out were representative of the whole country. The use of local covariates to relate to proportional diarrhoea mortality and the use of national level variables to extrapolate estimates to national levels

Fig. 2. **Distribution of deaths due to diarrhoea in low- and middle-income countries in 5 WHO regions**



is intended to provide a correction for this common biased assumption. Finally, our approach enables estimation of diarrhoea mortality at country level, not just of regional averages.

The method employed in our study is closer to that used by Morris et al.,[8] also developed within CHERG. One of the possible reasons for the somewhat lower estimates calculated in our analysis are the different sources of data. We have included 57 data points in our analysis as opposed to the 38 included in the review by Morris et al., mostly from sub-Saharan Africa and south Asia. In our review, there is a larger number of studies from the Americas, where the proportions of deaths due to diarrhoea are lower than in sub-Saharan Africa and south Asia. Other likely reasons for the differences are the different covariates included for modelling and the different models employed, which have diverse assumptions and statistical properties. It is worth noting that the multicause model has also provided higher estimates for the proportion of malaria deaths in sub-Saharan Africa (24%) than the 18% estimated by the single-cause model proposed by Rowe et al.[9] Besides, the all-cause model has not taken into account the high proportion of HIV mortality in the AFR E subregion. It is likely that this may have resulted in an overestimation of the proportion of the other causes of death.

Limitations

There are some limitations intrinsic to the type of review and meta-analysis used in our assessment. Locations where special population studies are conducted are rarely representative of the entire countries as they are usually carried out in populations that are either easy to access or have atypical mortality patterns. However, using local variables in the model and national level variables to predict country estimates should account, at least in part, for this potential site bias.

The inclusion of mid-year of study in the model could be seen as reflecting both time and place of study as studies conducted in different years could also be from different places. Yet, time distribution of the studies within each region is very similar. Furthermore, the use of a dichotomous dummy variable for controlling for time in the regression model makes them equivalent for all countries.

Our estimates, as well as those obtained from other reviews, rely on published epidemiological studies that used mostly verbal autopsy methods in their assessment of causes of death. Consequently, they have limitations that are inherent to this type of data such as misclassification of causes of death due to imperfect sensitivity and specificity of the instrument. Misclassification of causes of death is likely to be random; therefore it does not necessarily imply that the distribution of these causes will be biased. We have not attempted to correct for the possible measurement errors introduced by the use of verbal autopsy[26,27] because there was not enough site-specific information from validation studies to enable an adequate adjustment.[27]

It is also worth noting that most (68%) of the data used in this review refer to studies that were carried out between the late 1980s and early 1990s and that the latest mid-year of observation was 1997. This represents a lag time of almost 10 years. Currently, available data are unable to capture possible recent changes in diarrhoea mortality either due to changes in interventions, their coverage, or new emerging diseases and competing causes of death, with the exception of HIV/AIDS which is captured by the use of subregional levels of mortality.

Table 3. **Countries accounting for three-quarters of deaths due to diarrhoea in the developing regions of the world, 2004**

Country	WHO subregion[a]	Deaths due to diarrhoea (thousands)
India	SEAR D	535
Nigeria	AFR D	175
Democratic Republic of the Congo	AFR E	95
Ethiopia	AFR E	86
Pakistan	EMR D	77
China	WPR B	74
Bangladesh	SEAR D	69
Afghanistan	EMR D	65
Indonesia	SEAR B	39
Angola	AFR D	34
Niger	AFR D	33
Uganda	AFR E	28
Myanmar	SEAR D	26
United Republic of Tanzania	AFR E	25
Mali	AFR D	24
Total of 15 countries		**1384**

AFR, WHO African Region; AMR, WHO Region of the Americas; EMR, WHO Eastern Mediterranean Region; SEAR, WHO South-East Asia Region; WPR, Western Pacific Region.

[a] WHO subregions are defined on the basis of levels of child and adult mortality: A, very low child and very low adult mortality; B, low child and low adult mortality; C, low child and high adult mortality; D, high child and high adult mortality; E, high child and very high adult mortality.

Public health implications

Estimates obtained here can be used as the starting point for the monitoring of cause of death at country, regional and global levels in the future. Clearly, such estimates do not replace empirical data. Nevertheless, they are an invaluable tool for guiding decision-making and prioritizing interventions in child health strategies and planning in countries where vital registration or other sources of community-based data on causes of death are not available. Importantly, such an estimation process is exceptionally useful for identifying gaps in information and for developing approaches to tackling data problems.

Conclusion

Information on causes of death for children aged less than 5 years has not increased significantly since the late 1980s. The lack of systems able to generate representative quality data

on a regular basis is one of the major obstacles for international and national planning to reduce under-5 mortality. By providing best possible estimates of the distribution of causes of death, CHERG methods have proven to be a transient alternative to countries without adequate information. The main CHERG standards for estimating the burden of mortality, used in this review include: (i) thorough literature search; (ii) data abstraction exercise performed by two independent data abstractors and with two independent data entries; (iii) very strict inclusion and exclusion criteria; and (iv) use of local covariates to predict national estimates. We strongly believe that these rigorous criteria ensured that inputs for the current estimates consisted of the most valid information available and that the modelling of local variables to predict national estimates was performed using an innovative and best possible approach. Results presented here should thus allow settings without adequate information to draw a reasonable picture of the burden of under-5 diarrhoea mortality that should ultimately result in practical planning for the prioritization of interventions and decision-making. ■

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Résumé

Estimation de la mortalité infanto-juvénile due à la diarrhée dans les pays en développement

Objectif Le principal objectif de cette étude est de fournir des estimations de la mortalité par diarrhée aux niveaux mondial, régional et national, en utilisant la norme du Groupe de référence pour l'épidémiologie de la santé de l'enfant (CHERG).

Méthodes Une revue systématique et exhaustive de la littérature a été réalisée sur l'ensemble des études publiées depuis 1980 et traitant de la mortalité par diarrhée des moins de cinq ans. Des informations ont été recueillies sur les caractéristiques de chaque étude et de sa population. Un modèle par régression a été utilisé pour relier ces caractéristiques à la mortalité proportionnelle par diarrhée et pour prédire sa distribution dans les populations nationales.

Résultats A l'échelle mondiale, le nombre de décès par diarrhée chez les moins de cinq ans a été estimé à 1,87 million (intervalle de confiance à 95 %, IC : 1,56-2,19), soit approximativement 19 % du nombre total de décès d'enfants. La Région africaine et la Région de l'Asie du Sud-est de l'OMS totalisent 78 % (1,46 millions) des décès par diarrhée se produisant chez les enfants du monde en développement et 73 % de ces décès se concentrent dans 15 pays en développement seulement.

Conclusion La planification et l'évaluation des interventions pour endiguer la mortalité par diarrhée et pour réduire la mortalité des moins de cinq ans se heurtent à l'absence de système générant régulièrement des données sur les causes de décès. Les méthodes utilisées dans cette étude fournissent des estimations nationales, qui constituent des données de substitution pour la planification dans les pays ne disposant pas de données appropriées.

Resumen

Mortalidad en la niñez por diarrea en los países en desarrollo

Objetivo El principal objetivo de este estudio fue aportar estimaciones de la mortalidad por diarrea a nivel de país, regional y mundial aplicando los criterios del Grupo de Referencia en Epidemiología de la Salud Infantil (CHERG).

Métodos Se llevó a cabo una revisión sistemática y detallada de la bibliografía para identificar todos los estudios publicados desde 1980 en los que se notificaran cifras de la mortalidad por diarrea entre los menores de cinco años. Se reunió información sobre las características de cada estudio y la población estudiada, y se usó un modelo de regresión para relacionar esas características con la mortalidad proporcional por diarrea y predecir su distribución en la población de cada país.

Resultados La mortalidad mundial por diarrea entre la población menor de cinco años se estimó en 1,87 millones (intervalo de confianza del 95%: 1,56–2,19), lo que supone aproximadamente el 19% de la mortalidad total en la niñez. Las regiones de África y Asia Sudoriental de la OMS acumulan entre ambas el 78% (1,46 millones) de todas las muertes por diarrea registradas entre los niños en el mundo en desarrollo; y el 73% de estas defunciones se concentran en sólo 15 países en desarrollo.

Conclusión La planificación y evaluación de las intervenciones encaminadas a controlar la mortalidad por diarrea y reducir la mortalidad de los menores de cinco años se ve dificultada por la falta de un sistema que genere información sobre las causas de mortalidad de manera regular. Los métodos aquí utilizados aportan estimaciones a nivel de país a modo de información alternativa para las actividades de planificación en los entornos que carecen de datos suficientes.

ملخص

تقدير معدَّل وفيات الأطفال الناجمة عن الإسهال في البلدان النامية

الغرض: استهدفت هذه الدراسة في المقام الأول الحصول على تقديرات لمعدَّل الوفيات الناجمة عن الإسهال على المستوى القطري والإقليمي والعالمي، باستخدام معيار المجموعة المرجعية لوبائيات صحة الطفل.

الطريقة: أُجريت مراجعة منهجية وشاملة لجميع الدراسات التي نُشِرَت منذ عام 1980 حول وفيات الأطفال الذين هم دون سن الخامسة بسبب الإسهال. وجُمِعَت معلومات حول خصائص كل دراسة وعدد المشاركين فيها. واستُخدم نموذَج للتحوُّف للربط بين هذه الخصائص وبين نسبة الوفيات الناجمة عن الإسهال، وللتنبُّؤ بتوزُّع نسبة الوفيات هذه في الفئات السكانية الوطنية.

الموجودات: قُدِّرت وفيات الأطفال، الذين هم دون سن الخامسة، بسبب الإسهال، على الصعيد العالمي، بنحو 1.87 مليون طفل (بفاصلة ثقة 95%، إذ تراوحت من 1.56 إلى 2.19)، ويمثِّل هذا العدد 19% من جميع وفيات الأطفال. واستأثر الإقليم الأفريقي وإقليم جنوب شرق آسيا معاً بنسبة 78% (1.46 مليون طفل) من جميع وفيات الأطفال الناجمة عن الإسهال في العالم النامي؛ وتركَّزت 73% من هذه الوفيات في 15 بلداً نامياً.

الاستنتاج: تتعرَّض مداخلات التخطيط والتقييم، الرامية إلى مكافحة الوفيات الناجمة عن الإسهال وإلى خفض وفيات الأطفال الذين هم دون سن الخامسة، للعراقيل بسبب الافتقار إلى نظام قادر على توليد معلومات منتظمة حول أسباب الوفاة. وتقدِّم الطريقة المستخدمة في هذه الدراسة تقديرات قطرية تمثِّل معلومات بديلة للتخطيط في الأماكن التي تفتقر إلى المعطيات الكافية.

References

1. *United Nations Millennium Declaration 2000*. Available from: http://www.un.org/millennium/declaration/ares552e.htm [accessed on 19 May 2008].
2. *United Nations Millennium Development Goals*. Available from: http://www.un.org/millenniumgoals/ [accessed on 19 May 2008].
3. Snyder JD, Merson MH. The magnitude of the global problem of acute diarrhoeal disease: a review of active surveillance data. *Bull World Health Organ* 1982;60:604-13. PMID: 6982783
4. Bern C, Martines J, de Zoysa I, Glass RI. The magnitude of the global problem of diarrhoeal disease: a ten-year update. *Bull World Health Organ* 1992;70:705-14. PMID:1486666
5. Kosek M, Bern C, Guerrant R. The global burden of diarrhoeal disease as estimated from studies published between 1992 and 2000. *Bull World Health Organ* 2003;81:197-204. PMID:12764516
6. Bryce J, Boschi-Pinto C, Shibuya K, Black RE. WHO estimates of the causes of death in children. *Lancet* 2005;365:1147-52. PMID:15794969 doi:10.1016/S0140-6736(05)71877-8
7. Lawn JE, Cousens S, Zupan J. 4 million neonatal deaths: When? Where? Why? *Lancet* 2005;365:891-900. PMID:15752534 doi:10.1016/S0140-6736(05)71048-5
8. Morris SS, Black RE, Tomaskovic L. Predicting the distribution of under-five deaths by cause in countries without adequate vital registration systems. *Int J Epidemiol* 2003;32:1041-51. PMID:14681271 doi:10.1093/ije/dyg241
9. Rowe AK, Rowe SY, Snow RW, Korenromp EL, Armstrong Schellenberg JRM, Stein C, et al. The burden of malaria mortality among African children in the year 2000. *Int J Epidemiol* 2006;35:691-704. PMID:16507643 doi:10.1093/ije/dyl027
10. Williams BG, Gouws E, Boschi-Pinto C, Bryce J, Dye C. Estimates of world-wide distribution of child deaths from acute respiratory infections. *Lancet Infect Dis* 2002;2:25-32. PMID:11892493 doi:10.1016/S1473-3099(01)00170-0
11. Black RE, Morris SS, Bryce J. Where and why are 10 million children dying every year? *Lancet* 2003;361:2226-34. PMID:12842379 doi:10.1016/S0140-6736(03)13779-8
12. Mathers CD, Ma Fat D, Inoue M, Rao C, Lopez AD. Counting the dead and what they died of: an assessment of the global status of cause of death data. *Bull World Health Organ* 2005;83:171-7. PMID:15798840
13. Rudan I, Lawn J, Cousens S, Rowe AK, Boschi-Pinto C, Tomaskovic L, et al. Gaps in policy-relevant information on burden of disease in children: a systematic review. *Lancet* 2005;365:2031-40. PMID:15950717 doi:10.1016/S0140-6736(05)66697-4
14. *World Health Statistics*. Geneva: WHO; 2006.
15. Rao C, Lopez AD, Yang G, Begg S, Ma J. Evaluating national cause-of-death statistics: principles and application to the case of China. *Bull World Health Organ* 2005;83:618-25. PMID:16184281
16. Adjuik M, Smith T, Clark S, Todd J, Garrib A, Kinfu Y, et al. Cause-specific mortality rates in sub-Saharan Africa and Bangladesh. *Bull World Health Organ* 2006;84:181-8. PMID:16583076 doi:10.2471/BLT.05.026492
17. Garenne M, Ronsmans C, Campbell H. The magnitude of mortality from acute respiratory infections in children under 5 years in developing countries. *World Health Stat Q* 1992;45:180-91. PMID:1462653
18. *The world health report 2004: changing history*. Geneva: WHO; 2004.
19. Mathers CD, Stein C, Ma Fat D, Rao C, Inoue M, Tomijima N, et al. *Global Burden of Disease 2000*, version 2, methods and results. [Global Programme on Evidence for Health Policy Discussion Paper No 50]. Geneva: WHO; 2002. Available from: http://www.who.int/healthinfo/paper50.pdf [accessed on 19 May 2008].
20. Antunes JL, Waldman EA. Trends and spatial distribution of deaths of children aged 12-60 months in São Paulo, Brazil, 1980-98. *Bull World Health Organ* 2002;80:391-8. PMID:12077615
21. Tekçe B. Oral rehydration therapy: an assessment of mortality effects in rural Egypt. *Stud Fam Plann* 1982;13:315-27. PMID:6965183 doi:10.2307/1965803
22. *Bangladesh Demographic and Health Survey 2004*. Dhaka, Bangladesh, and Calverton, MD, USA: National Institute of Population Research and Training, Mitra and Associates, and ORC Macro; 2005.
23. *Cambodia Demographic and Health Survey 2005*. Phnom Penh, Cambodia, and Calverton, MD, USA: National Institute of Public Health, National Institute of Statistics and ORC Macro; 2006.
24. *Food Security and Nutritional Survey*. Liberia: World Food Programme; 2006. Available from: http://www.humanitarianinfo.org/liberia/assessments/others/doc/Grand%20Gedeh%20April%2005.pdf [accessed on 27 May 2008].
25. Parashar UD, Hummelman EG, Bresee JS, Miller MA, Glass RI. Global illness and deaths caused by rotavirus disease in children. *Emerg Infect Dis* 2003;9:565-72. PMID:12737740
26. Anker M. The effect of misclassification error on reported cause-specific mortality fractions from verbal autopsy. *Int J Epidemiol* 1997;26:1090-6. PMID:9363532 doi:10.1093/ije/26.5.1090
27. Chandramohan D, Setel P, Quigley M. Effect of misclassification error of causes of death in verbal autopsy: can it be adjusted? *Int J Epidemiol* 2001;30:509-14. PMID:11416073 doi:10.1093/ije/30.3.509
28. Amin R. Immunization coverage and child mortality in two rural districts of Sierra Leone. *Soc Sci Med* 1996;42:1599-604. PMID:8771643 doi:10.1016/0277-9536(95)00024-0
29. Becker SR, Diop F, Thornton JN. Infant and child mortality estimates in two counties of Liberia. Results of a survey in 1988 and trends since 1984. *Int J Epidemiol* 1993;22 Suppl.1;S56-63. PMID:8307676
30. De Francisco A, Hall AJ, Armstrong Schellenberg JRM, Greenwood AM, Greenwood BM. The pattern of infant and childhood mortality in Upper River Division, The Gambia. *Ann Trop Paediatr* 1993;13:345-52. PMID:7506881
31. Fontaine O, Diop B, Beau JP, Briend A, Ndiaye M. La diarrhée infantile au Sénégal. *Med Trop* (Mars) 1984;44:27-31. PMID:6738335
32. Ghana VAST Study Team. Vitamin A supplementation in northern Ghana: effects on clinic attendances, hospital admissions, and child mortality. *Lancet* 1993;342:7-12. PMID:8100345 doi:10.1016/0140-6736(93)91879-Q

33. Greenwood BM, Greenwood AM, Bradley S, Tulloch S, Hayes R, Oldfield FSJ. Deaths in infancy and early childhood in a well-vaccinated, rural, West African population. *Ann Trop Paediatr* 1987;7:91-9. PMID:2441658
34. Greenwood BM, Bradley AK, Byass P, Greenwood AM, Menon A, Snow RW, et al. Evaluation of a primary health care programme in The Gambia. II. Its impact on mortality and morbidity in young children. *J Trop Med Hyg* 1990;93:87-97. PMID:2325198
35. Jaffar S, Leach A, Greenwood AM, Jepson A, Muller O, Ota MOC, et al. Changes in the pattern of infant and childhood mortality in Upper River Division, The Gambia, from 1989 to 1993. *Trop Med Int Health* 1997;2:28-37. PMID:9018300 doi:10.1046/j.1365-3156.1997.d01-131.x
36. Jinadu MK, Olusi SO, Agun JI, Fabiyi AK. Childhood diarrhoea in rural Nigeria. I. Studies on prevalence, mortality and socio-environmental factors. *J Diarrhoeal Dis Res* 1991;9:323-7. PMID:1800564
37. Molbak K, Aaby P, Ingholt L, Hojlyng N, Gottschau A, Andersen H, et al. Persistent and acute diarrhoea as the leading causes of child mortality in urban Guinea Bissau. *Trans R Soc Trop Med Hyg* 1992;86:216-20. PMID:1440794 doi:10.1016/0035-9203(92)90580-6
38. Pison G, Trape JF, Lefebvre M, Enel C. Rapid decline in child mortality in a rural area of Senegal. *Int J Epidemiol* 1993;22:72-80. PMID:8449650 doi:10.1093/ije/22.1.72
39. Victora CG, Huttly SRA, Fuchs SC, Barros FC, Garenne M, Leroy O, et al. International differences in clinical patterns of diarrhoea deaths: a comparison of children from Brazil, Senegal, Bangladesh, and India. *J Diarrhoeal Dis Res* 1993;11:25-9. PMID:8315250
40. Delacollette C, Van der Stuyft P, Molima K, Delacollette-Lebrun C, Wery M. Étude de la mortalité globale et de la mortalité liée au paludisme dans le Kivu montagneux, Zaire. *Rev Epidemiol Sante Publique* 1989;37:161-6. PMID:2772361
41. Delacollette C, Barutwanayo M. Mortalité et morbidité aux jeunes âges dans une région à paludisme hyperendémique stable, commune de Nyanza-Lac, Imbo Sud, Burundi. *Bull Soc Pathol Exot* 1993;86:373-9. PMID:8124110
42. Georges MC, Roure C, Tauxe RV, Meunier DMY, Merlin M, Testa J, et al. Diarrhoeal morbidity and mortality in children in the Central African Republic. *Am J Trop Med Hyg* 1987;36:598-602. PMID:3578657
43. Kahn K, Tollman SM, Garenne M, Gear JSS. Who dies from what? Determining cause of death in South Africa's rural north-east. *Trop Med Int Health* 1999;4:433-41. PMID:10444319 doi:10.1046/j.1365-3156.1999.00415.x
44. Mtango FDE, Neuvians D. Acute respiratory infections in children under five years. Control project in Bagamoyo District, Tanzania. *Trans R Soc Trop Med Hyg* 1986;80:851-8. PMID:3603635 doi:10.1016/0035-9203(86)90241-5
45. Mtango FDE, Neuvians D, Broome CV, Hightower AW, Pio A. Risk factors for deaths in children under 5 years old in Bangamoyo District, Tanzania. *Trop Med Parasitol* 1992;43:229-33. PMID:1293726
46. Shamebo D, Muhe L, Sandström A, Wall S. The Butajira rural health project in Ethiopia: mortality pattern of the under fives. *J Trop Pediatr* 1991;37:254-61. PMID:1784061
47. Watts T, Ngändu N, Wray J. Children in an urban township in Zambia. A prospective study of children during their first year of life. *J Trop Pediatr* 1990;36:287-93. PMID:2280435
48. Diarrheal diseases in Mexico. Morbidity, mortality and management, 1990-1993 [in Portugese]. *Salud Publica Mex* 1994;36:243-6.
49. Antunes JL, Waldman EA. Trends and spatial distribution of deaths of children aged 12-60 months in São Paulo, Brazil, 1980-98. *Bull World Health Organ* 2002;80:391-8. PMID:12077615
50. Bailey P, Tsui AO, Janowitz B, Dominik R, Araujo L. A study of infant mortality and causes of death in a rural north-east Brazilian community. *J Biosoc Sci* 1990;22:349-63. PMID:2401677
51. Barreto IC, Kerr Pontes L, Correa L. Vigilância de óbitos infantis em sistemas locais de saúde; avaliação da autópsia verbal e das informações de agentes de saúde. [Surveillance of infant deaths in local health systems: assessment of verbal autopsy reports and of information gathered from health agents]. *Rev Panam Salud Publica* 2000;7:303-12. PMID:10893970 doi:10.1590/S1020-49892000000500003
52. Barros FC, Victora CG, Vaughan JP, Teixeira AM, Ashworth A. Infant mortality in southern Brazil: a population based study of causes of death. *Arch Dis Child* 1987;62:487-90. PMID:3606182
53. Campos G de J. dos Reis Filho SA, da Silva AA, Novochadlo MA, da Silva RA, Galvão CE. Infant morbimortality due to acute diarrhea in a metropolitan area of northeastern Brazil, 1986-1989 [in Portuguese]. *Rev Saude Publica* 1995;29:132-9.
54. Victora CG, Barros FC, Huttly SR, Teixeira AM, Vaughan JP. Early childhood mortality in a Brazilian cohort: the roles of birthweight and socioeconomic status. *Int J Epidemiol* 1992;21:911-5.
55. Victora CG, Vaughan JP, Barros FC. The seasonality of infant deaths due to diarrhoeal and respiratory diseases in southern Brazil, 1974-1978. *Bull Pan Am Health Organ* 1985;19:29-39. PMID:4027452
56. Victora CG, Barros FC, Vaughan JP, Teixeira AM. Birthweight and infant mortality: a longitudinal study of 5914 Brazilian children. *Int J Epidemiol* 1987;16:239-45. PMID:3610450 doi:10.1093/ije/16.2.239
57. Ibrahim MM, Omar HM, Persson LA, Wall S. Child mortality in a collapsing African society. *Bull World Health Organ* 1996;74:547-52. PMID:9002335
58. Khan AJ, Khan JA, Akbar M, Addiss DG. Acute respiratory infections in children: a case management intervention in Abbottabad District, Pakistan. *Bull World Health Organ* 1990;68:577-85. PMID:2289294
59. Tekçe B. Oral rehydration therapy: an assessment of mortality effects in rural Egypt. *Stud Fam Plann* 1982;13:315-27. PMID:6965183 doi:10.2307/1965803
60. Nazir M, Pardede N, Ismail R. The incidence of diarrhoeal diseases and diarrhoeal diseases related mortality in rural swampy low-land area of south Sumatra, Indonesia. *J Trop Pediatr* 1985;31:268-72. PMID:3877814
61. Anand K, Kant S, Kumar G, Kapoor SK. "Development" is not essential to reduce infant mortality rate in India: experience from the Ballabgarh project. *J Epidemiol Community Health* 2000;54:247-53. PMID:10827906 doi:10.1136/jech.54.4.247
62. Awasthi S, Pande VK, Glick H. Under fives mortality in the urban slums of Lucknow. *Indian J Pediatr* 1996;63:363-8. PMID:10830012 doi:10.1007/BF02751529
63. Bang AT, Bang RA, Tale O, Sontakke P, Solanki J, Wargantiwar R, et al. Reduction in pneumonia mortality and total childhood mortality by means of community-based intervention trial in Gadchiroli, India. *Lancet* 1990;336:201-6. PMID:1973770 doi:10.1016/0140-6736(90)91733-Q
64. Khalique N, Sinha SN, Yunus M, Malik A. Early childhood mortality - a rural study. *J R Soc Health* 1993;113:247-9. PMID:8230076 doi:10.1177/146642409311300507
65. Baqui AH, Black RE, Arifeen SE, Hill K, Mitra SN, al Sabir A. Causes of childhood deaths in Bangladesh: results of a nationwide verbal autopsy study. *Bull World Health Organ* 1998;76:161-71. PMID:9648357
66. Baqui AH, Sabir AA, Begum N, Arifeen SE, Mitra SN, Black RE. Causes of childhood deaths in Bangladesh: an update. *Acta Paediatr* 2001;90:682-90. PMID:11440104 doi:10.1080/080352501750258775
67. Bhatia S. Patterns and causes of neonatal and postneonatal mortality in rural Bangladesh. *Stud Fam Plann* 1989;20:136-46. PMID:2734810 doi:10.2307/1966568
68. Chen LC, Rahman M, Sarder AM. Epidemiology and causes of death among children in a rural area of Bangladesh. *Int J Epidemiol* 1980;9:25-33. PMID:7419328 doi:10.1093/ije/9.1.25
69. Fauveau V, Yunus M, Zaman K, Chakraborty J, Sarder AM. Diarrhoea mortality in rural Bangladeshi children. *J Trop Pediatr* 1991;37:31-6. PMID:2023300
70. Rahmathullah L, Underwood BA, Thulasiraj RD, Milton RC, Ramaswamy K, Rahmathullah R, et al. Reduced mortality among children in southern India receiving a small weekly dose of Vitamin A. *N Engl J Med.* 1990;323:929-35. PMID:2205798
71. Pandey MR, Daulaire NM, Starbuck ES, Houston RM, McPherson K. Reduction in total under-five mortality in western Nepal through community-based antimicrobial treatment of pneumonia. *Lancet* 1991;338:993-7. PMID:1681351 doi:10.1016/0140-6736(91)91847-N
72. Reddaiah VP, Kapoor SK. Socio-biological factors in under five deaths in a rural area. *Indian J Pediatr* 1992;59:567-71. PMID:1459678 doi:10.1007/BF02832992
73. Tandon BN, Sahai A, Balaji LN, Vardhan VA. Morbidity pattern and cause specific mortality during infancy in ICDS projects. *J Trop Pediatr* 1987;33:190-3. PMID:3669135
74. Huang W, Yu H, Wang F, Li G. Infant mortality among various nationalities in the middle part of Guizhou, China. *Soc Sci Med* 1997;45:1031-40. PMID:9257395 doi:10.1016/S0277-9536(97)00019-1

Table 1. **Main characteristics of the studies included in the analysis**

Reference	Country	Site	WHO subregion[a]	Period of study[b]	No. of under-5 deaths	Proportion of diarrhoea deaths[c] (%)
28	Sierra Leone	Rural areas of the districts of western Area and Porto Loko	AFR D	1988–93	251	12.7
29	Liberia	Robertsport and Bomi – urban areas; Grand Mountain and part of Lofa counties – rural areas	AFR D	1984–85	414	13.7
29	Liberia	Robertsport and Bomi – urban areas; Grand Mountain and part of Lofa counties – rural areas	AFR D	1986–88	491	12.1
30	Gambia	Upper River Division – rural area	AFR D	1988–89	856	18.0
31	Senegal	Pikine-Guédiawaye – urban suburb of Dakar	AFR D	1983	42	26.2
32	Ghana	Kassena-Nankana District	AFR D	1989–91	685	29.7
33	Gambia	Rural area	AFR D	1982	150	16.3
34	Gambia	Rural area	AFR D	1984–86	171	15.8
34	Gambia	Rural area	AFR D	1985	316	26.7
35	Gambia	Upper River Division – rural area	AFR D	1989–93	3 776	9.3
36	Nigeria	Akoko North	AFR D	1987	120	32.5
37	Guinea-Bissau	Bandim – urban area	AFR D	1987–90	153	32.2
38	Senegal	Mlomp – rural area in Ziguinchor region	AFR D	1987	69	20.3
39	Senegal	Niakhar district	AFR D	1986	1 517	35.0
40	Democratic Republic of the Congo	Kivu – rural area	AFR E	1986–87	358	8.4
41	Burundi	Nyanza-Lac district – rural area	AFR E	1990–91	160	19.7
42	Central African Republic	Bangui city – urban area	AFR E	1983	188	19.1
43	South Africa	Rural area	AFR E	1994	156	38.9
44	United Republic of Tanzania	Bagamoyo district – rural area	AFR E	1983–84	325	16.9
44	United Republic of Tanzania	Bagamoyo district – rural area	AFR E	1985	347	12.7
45	United Republic of Tanzania	Bagamoyo district – rural area	AFR E	1987	596	14.8
46	Ethiopia	Butajira district – rural lowlands and highlands; urban highland	AFR E	1988	436	8.7
47	Zambia	Lusaka – Lima Ward	AFR E	1985	26	18.2
48	Mexico	Nationally representative	AMR B	1990	85 957	16.3
48	Mexico	Nationally representative	AMR B	1993	50 492	12.8
49	Brazil	S. Paulo, metropolitan area – urban area	AMR B	1980–82	…	11.7
49	Brazil	S. Paulo, metropolitan area – urban area	AMR B	1996–98	…	4.6
50	Brazil	Trairi, Ceará – rural area	AMR B	1984–85	101	32.0
51	Brazil	Ceará – three municipalities in rural areas	AMR B	1993–94	215	39.1
52	Brazil	Pelotas city – urban area	AMR B	1982–83	244	11.9
53	Brazil	S. Luis capital city, Maranhão – three urban areas	AMR B	1989	32	44.0
53	Brazil	S. Luis capital city, Maranhão – three urban areas	AMR B	1986	92	46.0
54	Brazil	Pelotas city – urban area	AMR B	1985	29	20.0
55	Brazil	State of Rio Grande do Sul – two-thirds of urban population	AMR B	1976	40 219	14.7

(Table 1, cont.)

Reference	Country	Site	WHO subregion[a]	Period of study[b]	No. of under-5 deaths	Proportion of diarrhoea deaths[c] (%)
56	Brazil	Pelotas city – urban area	AMR B	1983	215	10.6
57	Somalia	Two rural communities	EMR D	1988	88	27.5
58	Pakistan	Abbottabad district – rural area	EMR D	1986	46	23.9
59	Egypt	Menoufia governorate – rural area	EMR D	1980	174	47.7
60	Indonesia	Banyuasin district – five villages in rural area	SEAR B	1983	51	21.6
61	India	Ballabgarth, Haryana state – rural area	SEAR D	1982–84	385	29.1
61	India	Ballabgarth, Haryana state – rural area	SEAR D	1992–94	221	25.3
62	India	Lucknow – urban slums	SEAR D	1993–94	71	18.3
63	India	Gadchiroli district – rural area	SEAR D	1988–89	161	11.1
64	India	Jawan – nine villages in rural area	SEAR D	1989	64	30.4
39	India	Ballabgarh – rural area	SEAR D	1989	811	18.0
65	Bangladesh	Nationally representative	SEAR D	1989–93	828	14.7
66	Bangladesh	Nationally representative	SEAR D	1992–96	678	15.5
67	Bangladesh	Matlab – rural area	SEAR D	1982–83	926	9.9
68	Bangladesh	Matlab – rural community	SEAR D	1975–77	7 858	26.7
69	Bangladesh	Matlab – rural community	SEAR D	1986–87	1 354	51.1
70	India	Trichy district	SEAR D	1985	80	41.8
71	Nepal	Jumla district – mountainous rural area	SEAR D	1988	2 101	42.2
72	India	Rural area of Haryana	SEAR D	1986	281	19.9
73	India	Six rural and three urban areas representing eight major states	SEAR D	1984	241	30.8
39	Bangladesh	Matlab – rural area	SEAR D	1989	1 573	15.0
74	China	Guizhou province – three counties in a remote mountainous province	WPR B	1986	3 075	10.0

AFR, WHO African Region; AMR, WHO Region of the Americas; EMR, WHO Eastern Mediterranean Region; SEAR, WHO South-East Asia Region; WPR, Western Pacific Region.

[a] WHO subregions are defined on the basis of levels of child and adult mortality: A, very low child and very low adult mortality; B, low child and low adult mortality; C, low child and high adult mortality; D, high child and high adult mortality; E, high child and very high adult mortality.

[b] Some studies did not report mid-year of study and those have been either informed by contacting authors or approximately estimated from other available information in the study.

[c] Proportion of diarrhoea deaths adjusted for age 0–59 months.