The magnitude of the global problem of acute diarrhoeal disease: a review of active surveillance data

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Data from 24 published studies were analysed in order to estimate the annual morbidity and mortality from acute diarrhoeal disease in the developing world. Twenty-two of the studies involved frequent surveillance through home visits to families in communities; the other two were multi-country studies in which diarrhoea mortality was calculated on the basis of death certificate information. Morbidity rates were found to be highest in the 6 – 11-month age group, while the mortality rates were greatest in infants under 1 year of age and children 1 year old. For children under 5 years old, the median incidence of diarrhoea was 2.2 episodes per child per year for all studies and 3.0 episodes per child per year for the studies that had the smallest populations and most frequent surveillance. Using 1980 population estimates, the estimated total yearly morbidity and mortality from diarrhoeal disease for children under 5 years of age in Africa, Asia (excluding China), and Latin America were 744 – 1000 million episodes and 4.6 million deaths.

Diarrhoeal disease has long been recognized as a leading cause of morbidity and mortality, especially in developing countries (*1*). International efforts to combat this worldwide problem include the recent initiation by the World Health Organization of a Diarrhoeal Diseases Control Programme, whose objectives are to reduce diarrhoeal morbidity and mortality (*2*). To help measure the impact of this Programme, an accurate quantification of the current incidence of diarrhoeal illness and the associated mortality is needed. Previous estimates of morbidity and mortality have been extrapolated from the results of a limited number of studies without attempting to evaluate such factors as frequency of surveillance, size and location of study population, and definition of diarrhoea used (*3*). In an attempt to arrive at a better estimate of the global problem of acute diarrhoeal disease, an analysis was undertaken of data on morbidity and mortality from selected studies conducted in Africa, Latin America, and Asia, in the last three decades.

METHODS

The initial studies selected for this review were identified by a computer search of the scientific literature in English and French since 1966—using three categories: "diarrhoea", "diarrhoea occurence", and "diarrhoea mortality". Additional references were found by reviewing the references cited in these articles.

In order to obtain the most valid data, only longitudinal, prospective, community-based studies of stable populations with low migration rates were selected for analysis. In order to compare mortality data for large populations, two multi-country mortality studies (*4, 5*) were also included, in which death certificates provided a basis for investigating the cause of death. Except for these two, all those included were studies in which morbidity surveillance was carried out at least once every two weeks and mortality surveillance at least once a month. Because of seasonal variations in the incidence of diarrhoea, only studies that involved surveillance for at least one full year were analysed. Although the design of the selected studies afforded increased access to medical care to the populations surveyed, portions of studies designed to evaluate specific environmental, nutritional, or treatment interventions were not included.

For all the selected studies a number of design factors were compared: age groups studied, geographical location, definition of diarrhoea, frequency of surveillance, size of study population, urban or rural setting, and climatic conditons. In order to compare the morbidity and mortality results obtained in the various studies, morbidity rates were calculated in terms of episodes of diarrhoea per person per year,

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using when possible the age categories 0 – 5 months, 6 – 11 months, 1 year, 2 years, 3 years, 4 years, 5 – 14 years, and 15 years and over. Mortality rates were calculated as deaths per 1000 population for the age groups less than 1 year, 1 year, 2 – 4 years, 5 – 9 years, and 10 years and over. The cause of death was determined by the study physicians' clinical findings.

Using the median incidence and mortality rates derived from the active surveillance studies, population totals obtained from the 1980 *World health statistics annual* (6), and age distribution data from the 1976 *Demographic yearbook* (7), an overall estimate of the number of diarrhoeal episodes and deaths in children less than 5 years of age in Africa, Asia (excluding China), and Latin America was then obtained. Case–fatality ratios were also calculated for

the less than 1 and 1 – 4-year age groups from studies in which the frequency of episodes was recorded and in which at least 10 deaths occurred. This ratio was additionally estimated by dividing the estimated number of episodes obtained from the above calculations for all children under 5 years old.

RESULTS

Twenty-two studies described in 25 publications (8 – 32) met the criteria of having frequent home surveillance of stable, community-based populations for at least one full year and were selected for the analysis. Two multi-country mortality studies (4, 5)

Table 1. Annual number of episodes of diarrhoea per person, by age group

Region	Country	Reference	Period of study	0–5 months	6–11 months	1 year	2 years	3 years	4 years	5–14 years	≥ 15 years
Africa	Egypt	*8, 9*	1954	3.6		3.0	2.6	2.6	1.7		
	Ethiopia	*10*	1972	2.9		2.6	0.9	0.7	0.4	0.2	
	Kenya	*12*	1976–77	4.1	6.4	1.9	1.0				
	Nigeria	*13*	1963–65	1.1	2.1	1.4	0.7	0.5	0.3		
		median		2.6	4.3	2.3	1.0	0.7	0.4	0.2	
Asia	Bangladesh	*14*	1976			(0–4) 1.8		(5–9) 1.1		(10–14) 0.5	0.6
	Bangladesh	*16*	1977–79	0.3		(1–4) 0.2		(5–9) 0.1		(≥ 10) 0.1	
	India	*18*	1962–67	4.9	3.5	2.8	1.8	1.1	0.8		
	India	*19*	1964–66	2.2	2.7	2.7					
	India	*20*	1965–67	4.4	7.3	4.7	3.4	1.7	1.6	(5–9) 0.6	(≥ 10) 0.3
	India	*21*	1970–73	4.9	5.0	4.8	2.8				
	Indonesia	*22*	1961–63	2.5	3.3	3.4					
	Indonesia	*23*	1972	0.9	0.6	0.3	0.1	0.1			
	Indonesia	*24*	1973	1.0		(1–4) 1.6		(5–9) 0.4		(10–14) 0.2	0.1
		median		4.4	3.5	3.1	2.3	1.1	0.8	0.6	0.3
Latin America	Costa Rica	*26, 27*	1965	1.6	2.3	2.0	1.2	1.0	0.6	0.2	0.1
	Costa Rica	*28*	1972	5.0		5.8		4.0			
	Guatemala	*29*	1956–57	1.0	2.7	3.0	1.9	1.2	0.3	(5) 0.4	
			1957–59	0.2	0.6	0.6	0.6	0.3	0.2	(5) 0.1	
	Guatemala	*30, 31*	1959–64	0.8	1.3	1.7	1.4	1.2	1.0		
	Guatemala	*32*	1964–69	3.8	7.1	8.9	6.4				
		median		1.0	2.3	2.0	1.4	1.1	0.5	0.2	0.1

a Where different age groups are used these are shown in parentheses in the body of the table.

in which death certificates were used as a basis for investigating the cause of death were also included. These 24 studies were carried out in 18 developing countries. In 7 studies only diarrhoeal morbidity was measured, in 6 only diarrhoeal mortality, and in 11 cases both morbidity and mortality data were available. All the studies were felt to include primarily or exclusively cases of acute diarrhoea; 3 studies also included cases of chronic diarrhoea.

Morbidity rates

Several general patterns of diarrhoeal morbidity were evident in almost all the studies evaluated (Table 1). All studies reported the highest incidence of diarrhoea in children under 2 years old. On the basis of the 15 studies for which the incidence of diarrhoea was reported for age groups with intervals of 12 months or less for the first several years of life, median rates were highest for children 6 – 11 months old[a] (Fig. 1). For the under 5-years age group, the median incidence of diarrhoea, obtained by combining data from all the studies shown in Table 1, was 2.2 episodes per child per year. For persons over 5 years old, most studies reported less than 1 episode of diarrhoea per person per year.
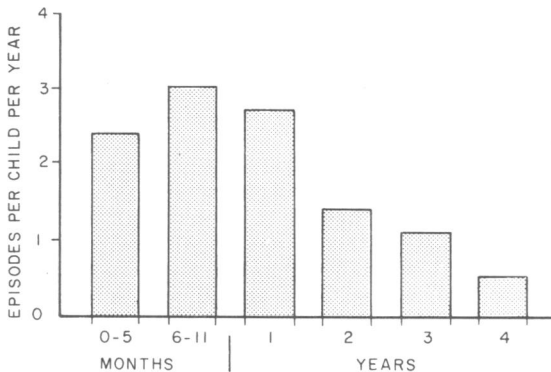

Fig. 1. Estimated median diarrhoeal morbidity rates for children under 5 years of age, by age group. Based on 15 studies (see text) in developing countries.

Six factors were analysed for their influence on diarrhoea incidence: geographical location, definition of diarrhoea, frequency of surveillance, size of the study population, urban or rural location, and climate. Another factor, breast-feeding, was not examined as it was widely practised in all the study populations.

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[a] The median for this age group is based on 13 studies.

The median incidence of diarrhoea was higher in most age groups in studies in Asia than in studies in Africa or Latin America (Table 1). However, the age distribution of diarrhoea incidence was similar in the three regions and there was often a wide range of incidence within each age group in each region.

Specific definitions of diarrhoea were described in only 10 of the studies (Table 2). Eight different definitions were used; 2 studies used the mother's definition and 8 studies used 7 different combinations of stool frequency and appearance. There was no clear-cut association between incidence and the methods used for quantifying and describing stools.

Table 2. Definitions of diarrhoea used in studies of morbidity rates

Country	Reference	Definition
Bangladesh	16	more than 2 watery or loose motions in 24 hours
Costa Rica	26	mother's definition
Egypt	8	5 or more stools in 1 day preceded and followed by 1 week of normal stools
Ethiopia	10	4 loose stools/day or 1 watery or bloody stool/day
Guatemala	29, 30	< 1 year of age – 5 or more liquid or semi-liquid stools/24 hours; > 1 year of age – 3 or more liquid or semi-liquid stools preceded by 2 weeks of normal stools
India	19	3 or more loose stools of altered consistency or with blood or mucus in 24 hours
India	20	3 or more liquid stools in 12 hours with or without blood, pus, or mucus
Indonesia	22	more than 4 stools in 24 hours
Kenya	12	mother's definition

More frequent surveillance was associated with a high median incidence of infection. The median value for 9 studies[b] in which surveillance was done at least once a week was 0.5 – 1.5 episodes per person per year higher, up to and including the 5 – 14-year age group, than the median value obtained in 9 studies[c] in which surveillance was done at 10 – 14-day intervals.

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[b] References 9, 14, 19—22, 24, 27, and 28.

[c] References 10, 12, 13, 16, 18, 23, 29, 31, 32.

The median diarrhoea incidence rates were inversely related to the size of the study population. Four studies[d] with study populations of less than 200 children had median incidence rates higher than those found in 5 studies[e] involving populations of more than 1000 children.

When frequency of surveillance and size of study population were considered together, the highest median incidence rates were observed in the smallest and most frequently sampled populations. Five studies[f] involving surveillance at least every week and populations of 600 or less children showed rates of (in episodes per person per year): 4.4 (0 – 5 months), 5.0 (6 – 11 months), 3.4 (1 year), 2.5 (2 years), 1.7 (3 years), and 1.6 (4 years). The median incidence for the under 5-years' age group in these studies was 3.0 episodes per child per year. There was no apparent difference in median rates for rural and urban populations, although rates tended to be slightly higher for rural populations. Both the largest and smallest populations studied were in rural areas.

All the areas studied in Asia and Africa were in tropical zones, whereas those in Latin America were in the temperate zone. No differences in morbidity rates were noted between tropical and temperate zones.

Mortality rates

Diarrhoeal mortality rates were compared for groups in 15 national and 2 multi-country studies in 16 developing countries (Table 3).[g] In all the studies the highest mortality rates were in children under 2 years of age; in 18 of 22 studies in which the age grouping distinguished between infants under 1 year of age and children aged 1 year and over, the highest rates were in infants under 1 year of age.

The median annual mortality rate from diarrhoea found in studies involving active surveillance was about 20 deaths/1000 population in children under 2 years of age (Table 3). An approximately 3-fold reduction in the mortality rate was seen in the 2 – 4-year-old group (Fig. 2). The median annual mortality rate found in studies involving active surveillance of children 5 years old or less was 13.6 deaths/1000 population.

The median mortality rate for infants under 1 year of age in the Latin American studies, in which death certificates provided a basis for investigating the cause of death, was comparable with the median annual rate obtained in studies inolving active surveillance (17.1 and 20.2, respectively). However, the median rates for the 1-year-old and 2 – 4-year-old
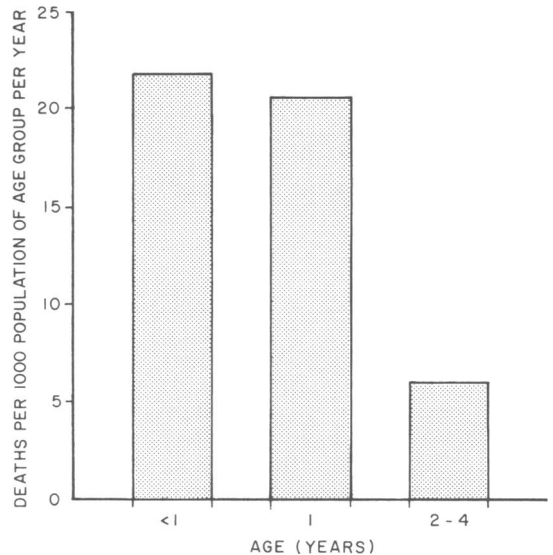

Fig. 2. Estimated median diarrhoeal mortality rates for children under 5 years of age. Based on 12 studies with active surveillance in developing countries in Asia and Latin America.

groups were about 10 times lower than the median rates found in studies involving active surveillance (Table 3).

No regional differences in mortality rates were seen in 14 studies involving active surveillance—Africa, 13.8; Asia, 13.1; and Latin America, 15.1 deaths/1000 population. In addition, no differences in rates were noted when the definition of diarrhoea (each study used medical criteria), frequency of surveillance, size of population, urban or rural location, and climatic conditions of the study area were taken into consideration.

Calculation of the global number of diarrhoeal episodes and deaths

The total annual number of acute diarrhoeal episodes for children under 5 years old in Africa, Asia (excluding China), and Latin America was estimated to be 744 million, using the global median morbidity rate and population totals for this age group for 1980 (Table 4). An annual total of 1004 million episodes was obtained for children under 5 years of age if the estimate was based on median morbidity rates obtained in the 5 studies[f] with the smallest populations and the most frequent surveillance (3.0 episodes/child/year).

[d] References 9, 20, 22, 28.

[e] References *12, 14, 16, 18, 24.*

[f] References *9, 20, 21, 22, 28.*

[g] 31 sets of data.

Table 3. Annual number of deaths due to diarrhoea per 1000 population, by age group

Region	Country	Reference	< 1 year	1 year	2–4 years	5–9 years	≥ 10 years
					Age group[a]		
Africa							
	The Gambia	*11*	(0–1½) 19.4				
	Kenya	*12*	(0–4) 3.6				
	Nigeria	*13*	(0–4) 24.0				
Asia							
	Bangladesh	*15*	19.6	(1–4) 15.1			
	Bangladesh	*16*	17.4	(1–4) 5.7		1.3	1.4
	India	*17*	34.4[b]	21.0			
	India	*18*	26.5[b]	12.8	7.0		
	India	*20*	45.4[b]				
	Indonesia	*22*	53.8	88.0			
	Indonesia	*23*	0.0	11.2	3.7		
		median	26.5	16.9	5.4	1.3	1.4
Latin America							
Studies with active surveillance							
	Colombia	*25*		(0–2) 22.2			
	Costa Rica	*28*		(0–4) 14.6			
	Guatemala	*29*	20.2	34.0	17.1		
	Guatemala	*30, 31*	28.8	36.3	9.2		
	Guatemala	*32*	8.7	7.5	3.9		
		median	20.2	34.0	9.2		
Studies using death certificate case ascertainment							
	Argentina	*5*	28.0[b] 21.8[b]	5.1 1.1	0.5 0.1		
	Bolivia	*5*	16.2[b]	9.8	1.2		
	Brazil	*5*	37.5[b] 16.9[b] 20.0[b]	3.4 1.2 0.7	0.5 0.2 0.1		
	Chile	*5*	11.4[b]	0.8	0.1		
	Colombia	*5*	17.1[b] 12.4[b] 14.9[b]	5.8 4.5 4.4	0.5 0.5 0.8		
	Colombia	*4*					0.05 0.04
	El Salvador	*5*	41.8[b]	10.9	2.9		
	Guatemala	*4*					0.1
	Jamaica	*5*	8.1[b]	1.4	0.1		
	Mexico	*5*	17.9[b]	1.7	0.3		
		median	17.1[b]	3.4	0.5		0.05

[a] Where different age groups were used these are shown in parentheses in the body of the table.

[b] Deaths per 1000 live births.

Table 4. Estimates of annual number of cases of acute diarrhoeal illness and of deaths in 1980 for children under 5 years old in Africa, Asia (excluding China), and Latin America

	Total
Population under 5 years of age (in millions)[a]	338
Median annual diarrhoeal morbidity rate for children under 5 years of age (episodes/child)	2.2
Diarrhoeal illnesses/year (in millions)	744
Median diarrhoeal mortality rate for children under 5 years of age (deaths/1000 population)	13.6
Diarrhoeal deaths/year (in millions)	4.6
Case–fatality ratio (deaths/100 episodes)	0.6

[a] Calculated from the total population of each region obtained from 1980 *World health statistics manual* and the percentage of each regional population < 5 years of age obtained from the 1976 *Demographic yearbook*.

The total annual number of deaths from acute diarrhoeal illness for children under 5 years of age was estimated to be 4.6 million for 1980, using the median mortality rates from the studies involving active surveillance and the 1980 population total for this age group (Table 4). Eighty percent of these deaths were in children aged 2 years or younger.

Case–fatality ratio

To assess the relationship between morbidity and mortality rates, it was possible to calculate case–fatality ratios using data from 5 studies involving active surveillance in which at least 10 children under 5 years of age died from diarrhoeal illness

(*12, 16, 17, 22, 31*). A wide range of age-specific case–fatality ratios was reported from the different studies (Table 5). The lowest case–fatality ratios were in the 2 – 4-year olds in three of the four studies which had these age groupings.

When the case–fatality ratio was calculated using the number of deaths and illnesses estimated from data from 22 active surveillance studies (Table 4), a ratio of 0.6 deaths per 100 illnesses was obtained for children less than 5 years of age.

DISCUSSION

There are obvious limitations inherent in estimating the global incidence of diarrhoeal illness and death on the basis of data obtained in studies conducted by different researchers using different methods to study discrete populations. However, given these limitations, it has been possible to estimate the magnitude of the problem of acute diarrhoeal diseases in the developing world.

Morbidity data

The selection of only longitudinal, community-based studies involving active surveillance enabled several important variables of study design to be controlled and provided a basis for comparing results. Enough data were available from the 18 studies selected to allow most study design factors to be compared and morbidity rates to be calculated. In all the studies, the highest rates of illness and death found were for the youngest children— the 6 – 11-month-old and 1-year-old groups for morbidity, and infants under 1 year of age for mortality.

Table 5. Case–fatality ratios for diarrhoeal disease from studies reporting 10 or more deaths, by age group[a]

Country	Reference	Population		No. of deaths		No. of cases		Case–fatality ratio[b]	
		< 1 year	1–4 years	< 1 year	1–4 years	< 1 year	1–4 years	< 1 year	1–4 years
Kenya	*12*	816	3 083	(0–4) 14		4 307	6 371	(0–4) 0.1	
Bangladesh	*16*	460	1 058	8	6	127	255	6.3	2.3
India	*18*	(0–4) 1 964		52	21	11 191	15 326	0.5	0.1
Indonesia	*22*	50	(1) 46	7	(1) 6	341	(1) 277	2.1	(1) 2.2
Guatemala	*31*	249	796	8	17	293	1 185	2.7	1.4

[a] Where different age groups were used, these are shown in parentheses in the body of the table.
[b] Deaths per 100 cases.

Comparisons of study design factors indicate that frequency of surveillance and size of the study population both affect the estimates of incidence of diarrhoeal disease. It seems that in smaller populations that are surveyed more often, it is more probable that all episodes will be reported. Some regional differences in morbidity rates were also noted, but these may have been influenced more by the small number of studies available for examination than factors such as the nature of, and infection rate associated with, the local pathogens.

The lack of agreement on an appropriate definition of diarrhoea is highlighted by the fact that among the 10 studies for which a definition is reported, different criteria were used in 8 of them. Because of this and the fact that in over half the studies no definition was given, the effect of using different definitions of diarrhoea in determining incidence could not be assessed. The comparisons of diarrhoea incidence would have been much more valid had one uniform definition been used.

The total annual number of diarrhoeal episodes estimated from these data is greater than the estimates obtained in earlier studies involving less frequent surveillance (3). Since severe episodes are likely to be remembered longer, this increase probably reflects the inclusion of more of the relatively mild episodes.

Mortality data

Mortality rates may be underestimated when data from prospective community-based studies are used because of the easier access to medical intervention. Two general patterns of mortality were apparent when studies involving active surveillance were evaluated. First, similar median mortality rates for the under 5-year-old population were reported from each region of the developing world regardless of study population size, location, or frequency of active surveillance. Secondly, similar median mortality rates were observed in both the first and second year of life. In individual studies, the rates for children under 2 years old were 3 – 5 times higher than those for the 2 – 4-year-olds, this difference being greater than the $1\frac{1}{2}$ – 2-fold difference in the morbidity rates for these age groups. The difference may be explained in part by factors such as different rates of infection caused by the various enteric pathogens and the greater susceptibility to dehydration, or electrolyte imbalance in younger children.

The median mortality rates reported from studies in which death certificates provided the basis for surveillance were 10 times lower than the rates for the studies with active surveillance for both 1-year-olds and 2 – 4-year-olds. The difference in the rates reported may have been due at least in part to the different methods of case ascertainment used. The recording of a higher percentage of all deaths would be expected from studies in which information on deaths was actively sought by means of frequent family interviews, as compared with studies in which mortality totals were acquired only from death certificates. It is not evident why the rates determined by the two methods for infants under 1 year old were similar, though this similarity perhaps implies that deaths of infants were more likely to be reported through death certificates than deaths of older children.

Calculation of the number of diarrhoeal episodes and deaths

Because data from studies involving active surveillance were used, they should provide a basis for making fairly accurate estimates of the total number of acute diarrhoeal illnesses and deaths that occur in the under 5-year-old populations in Africa, Asia, (excluding China), and Latin America. The relatively uniform results obtained from studies involving active surveillance in the three regions of the developing world indicate that the morbidity and mortality totals are probably fairly accurate. However, for reasons already mentioned, the total annual mortality of 4.6 million may be an underestimate of the true number of deaths. The enormity of these totals emphasizes the need for immediate and effective efforts to reduce morbidity and mortality caused by acute diarrhoeal disease.

Case–fatality ratios

In only 5 of the studies in which morbidity data were collected, were there 10 or more deaths; therefore, a small change in the number of deaths reported could greatly affect the calculated case–fatality ratio. The calculated ratios may also reflect the effects of study design. As discussed earlier, mortality rates obtained in studies involving active surveillance are probably underestimates because of easier access to medical intervention, and morbidity rates are probably higher because of more complete reporting of mild episodes. These factors would combine to produce a lower case–fatality ratio. The highest case–fatality ratios reported from these 5 studies are 60 times higher than the lowest values, and consequently case–fatality ratios cannot be extrapolated to larger populations because there is no evidence to indicate which portion of this range of values most accurately reflects the true global rate.

However, the case–fatality ratio of 0.6 deaths per 100 illnesses calculated from the estimated number of deaths and illnesses for children under 5 years old in the 22 active surveillance studies may serve as a reasonable approximation.

ACKNOWLEDGEMENTS

RÉSUMÉ

AMPLEUR DU PROBLÈME DES DIARRHÉES AIGUËS : ANALYSE DES DONNÉES DE SURVEILLANCE ACTIVE

A partir des données fournies par 24 études de morbidité et de mortalité, on a établi le nombre annuel des cas de diarrhée aiguë et des décès par diarrhée dans le monde en développement. Vingt-deux de ces études avaient comporté des visites fréquentes à domicile dans des populations stables vivant en collectivité, et les deux autres étaient des études de mortalité multi-pays, comportant l'analyse des certificats de décès.

L'incidence estimée des diarrhées a été influencée par deux facteurs liés au type des études, à savoir la fréquence de la surveillance et la taille de la population étudiée. Les taux de diarrhée les plus élevés ont été notés dans les études portant sur les populations les plus petites, avec surveillance la plus fréquente. Chez les enfants de moins de cinq ans, l'incidence médiane annuelle des diarrhées était de 2,2 épisodes par enfant en Afrique, en Asie (à l'exclusion de la Chine) et en Amérique latine, et de trois épisodes par enfant dans les études portant sur les populations les plus petites, avec la surveillance la plus fréquente.

Les études de surveillance active ont fait apparaître un taux de mortalité d'environ 20 pour 1000 chez les enfants de deux ans et en dessous. Le taux médian de mortalité pour les enfants de moins de cinq ans était de 13,6 décès pour 1000.

Sur la base des estimations de la population de 1980, on a établi que le nombre total des diarrhées chez les enfants de moins de cinq ans, en Afrique, en Asie (à l'exclusion de la Chine) et en Amérique latine se situait entre 744 millions et un milliard d'épisodes tandis que le nombre des décès était de 4,6 millions.

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