THE SEASONALITY OF INFANT DEATHS DUE TO DIARRHEAL AND RESPIRATORY DISEASES IN SOUTHERN BRAZIL, 1974-1978[1]

Cesar G. Victora,[2,3] J. Patrick Vaughan,[2] and Fernando C. Barros[4]

A study of 40,219 infant deaths in the Brazilian state of Rio Grande do Sul affirmed the existence of marked seasonal variations in infant mortality from respiratory and diarrheal diseases. This article reports the results of that study.

Introduction

There are few areas in the Third World where the registration of infant deaths is complete enough to permit studies of age and seasonal patterns. Such studies, however, are of great importance in helping to gain an understanding of causal factors, and in identifying high-risk groups and periods upon which preventive and therapeutic measures can be focused *(1)*.

The state of Rio Grande do Sul has a death registration system that is regarded as one of the most complete in Brazil. Its infant mortality rates are low relative to the rest of the country, although there are important variations between districts within the state. These differentials can be partly explained in terms of agricultural production patterns *(2)*.

This southern state is also one of the most developed areas of the country. Its population of approximately 7,800,000 is mainly of Southern European origin and is about two-thirds urban *(3)*. The state is located at 30° South and has a subtropical climate with four well-differentiated seasons. The mean temperature ranges from about 14°C in the winter months (June-July) to about 24°C in the summer (December-February) *(4)*. There are no marked wet and dry seasons, as rainfall is fairly evenly spread throughout the year *(5)*.

For the period 1974-1978, the state's apparent infant mortality derived from death certificates and birth records (43.5 deaths per thousand live births) was comparable to an estimate of approximately 47 deaths per thousand (C. Victora, unpublished data) obtained by indirect methods *(6,7)* from the results of the 1980 Census *(8)*. Thus, underregistration of deaths seems to have been reasonably low, and studies based on death certificates in this period are therefore feasible.

The study reported here was designed to analyze the age and seasonal distribution of infant deaths due to diarrheal and respiratory diseases in the state during the 1974-1978 period. These were the last five years in which the Eighth Revision of the International Classification of Diseases *(9)* was used.

Methodology

The Statistics Unit of the Secretariat of Health collects all death certificates issued in the state. These are coded according to the current revision of the International Classification of Diseases by a specially trained team, and their data are transferred to a magnetic tape. A copy of this tape was kindly released to the authors for the present analysis.

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[2] Evaluation and Planning Center, London School of Hygiene and Tropical Medicine, United Kingdom.

[3] Department of Social Medicine, Universidade Federal de Pelotas, Brazil.

[4] Department of Maternal and Child Health, Universidade Catolica de Pelotas, Brazil.

Classification of Causes

Communicable intestinal diseases were considered those listed in categories 000 through 009 of the International Classification of Diseases (Eighth Revision). Similarly, diseases of the respiratory system were considered those listed in categories 460 through 519. Deaths ascribed to respiratory disorders specific to the early neonatal period were not included.

Month of Birth

The deceased infant's exact date of birth was not recorded on the death certificates studied. However, the infant's date of death and age (coded in hours for those dying the first day, in days for those dying the first week, in weeks for those dying the first month, and in months for those dying the first year) were recorded. Therefore, it was possible to determine the deceased's month of birth with a small margin of error. Taking into account the day of the month when death occurred and the infant's age (measured as described), we estimated that about 14.5% of the deceased infants' true birth months were likely to have been the months immediately before or immediately after the month identified as the birth month. Since this birth information was used to examine seasonal variations, such a rate of misclassification is acceptable. (The death rates by month of birth described below may be regarded as three-point weighted moving averages of the actual rates.)

The Number of Live Births

The birth registration system in Rio Grande do Sul seems affected by underregistration to a greater degree than the death registry (C. Victora, unpublished data). Therefore, in order to find the approximate number of infants at risk, we first estimated the state's infant population on the last day of each of the years concerned by geometric interpolation from the results of the demographic censuses of 1970 and 1980.

Assuming no underenumeration, the number of live births in a given calendar year is equal to the number of infant deaths in that calendar year plus the number of infants counted by a census taken at the end. Taking into account the age distribution of infant deaths and ignoring minor seasonal fluctuations in the number of births, it was possible to estimate the proportion of infant births and deaths occurring within the same calendar year *(7)*. For the five years studied, there were 40,219 infant deaths, 79.3% of which appear likely to have occurred in the calendar year of the deceased infant's birth. Adding these deaths to the estimated year-end infant populations based on census data, we were able to estimate that some 924,583 live births occurred in the years 1974–1978. This estimate is useful despite the limitations imposed by lack of precision, because the results being reported are of a sort not greatly affected by small fluctuations in this denominator.

The Number of Infants at Risk, by Age

A life table was constructed for the purpose of estimating the number of infants at risk at any particular age (in weeks or months). In doing so, the number of deaths occurring before each age involved was subtracted from the estimated number of live births to give a suitable denominator for determining mortality.

The Number of Live Births, by Month

There have been no statistics available regarding the number of live births by month for the years studied. We have therefore taken the monthly variations in hospital births for the years 1979 and 1980 (comprising approximately 85% of all births in those years), and have assumed that these variations are repre-

sentative of the seasonal variations in all births within the whole state of Rio Grande do Sul for the years 1974–1978. We have then applied the estimated proportions of births occurring in each month to the estimated total number of live births obtained as described above. This calculation indicated that the seasonal variations were very small, the ratio of the lowest number to the highest being 1:1.08, and did not markedly affect the results described below.

The Number of Infants at Risk, by Month

The monthly mortality figures have been corrected for the number of days in each month (setting that number equal to 30), and also for the fact that 1976 was a leap year. The denominator for these monthly rates was the number of infants alive at the midpoint of the five-year period, estimated from the aforementioned censuses. Because the annual rate of growth in the number of infants was very small (0.91%) and the seasonal variations in overall infant mortality were also relatively small, we have used the same denominator for deaths occurring in all months.

Meteorologic Data

The average air temperature for the year 1976 was obtained from the state's six weather stations *(4)*. Because rainfall patterns tended to show more variation from year to year than did temperatures, we averaged the rainfall readings in the state's capital for the years 1974–1978 *(5)*.

Results

A total of 40,219 infant deaths were reported to the State Secretariat of Health in the years 1974–1978. In 258 cases (0.64% of the total), the infant's age at death was not declared on the certificate, and these cases have been excluded from the tabulations by age and month of birth. With that exception, the results reported here refer to all deaths occurring in this five-year period and registered up to the end of 1980.

Table 1 shows that when the recorded causes of death were considered by major groups, the group "certain causes of perinatal mortality" (ICD categories 760–779) accounted for the largest share (26.7%) of all deaths, the next most important groups of causes being respiratory diseases (accounting for 19.8% of all deaths) and intestinal infectious diseases (accounting for 16.2%).

Of the 6,511 deaths attributed to intestinal infectious diseases, 98.3% were ascribed to diseases diagnosed as unspecified diarrheal diseases (ICD category 009). However, in the account that follows we have used the terms "diarrhea" and "diarrheal diseases" to refer to all intestinal infectious diseases (ICD categories 000–009).

Diseases of the respiratory system were found responsible for 7,949 deaths. Of these, 66.0% were ascribed to unspecified bronchopneumonia (ICD category 485), 16.5% to unspecified pneumonia (ICD category 486), 4.2% to acute bronchitis and bronchiolitis (ICD category 466), 3.6% to influenza with

Table 1. Main groups of causes of infant deaths in Rio Grande do Sul, 1974–1978.

Groups of causes	ICD categories	% of deaths
Certain causes of perinatal mortality	760–779	26.7
Diseases of the respiratory system	460–519	19.8
Intestinal infectious diseases	000–009	16.2
Symptoms and ill-defined conditions	780–796	10.6
Other infective and parasitic diseases	010–136	9.4
Congenital anomalies	740–759	6.5
Avitaminoses and other nutritional deficiencies	260–269	6.0
All other causes		4.8
All causes (40,219 deaths)		100.0

pneumonia (ICD category 471), 3.4% to other bacterial pneumonias (ICD category 482), and the remaining 6.3% to other respiratory causes.

Figure 1 indicates that the mortality caused by diarrhea was greatest in the first four months of life (shown as months 0-3 in the figure) and that it declined sharply after that time had passed. By the twelfth month (month 11 in the figure) only 7.5 deaths per 100,000 infants were ascribed to this cause, as compared to roughly 120 deaths per 100,000 in each month of the first trimester.

The distribution of diarrheal deaths in the neonatal period (days 1-28) is shown in Table 2. An important number of deaths occurred even in the first week, though the highest mortality was recorded during the third week.

Figure 1. Distribution by age (in full months) of 39,961 infants dying from diarrheal and respiratory diseases in the state of Rio Grande do Sul, 1974-1978. The scale on the left is for diarrheal and respiratory deaths and that on the right for deaths from all causes.

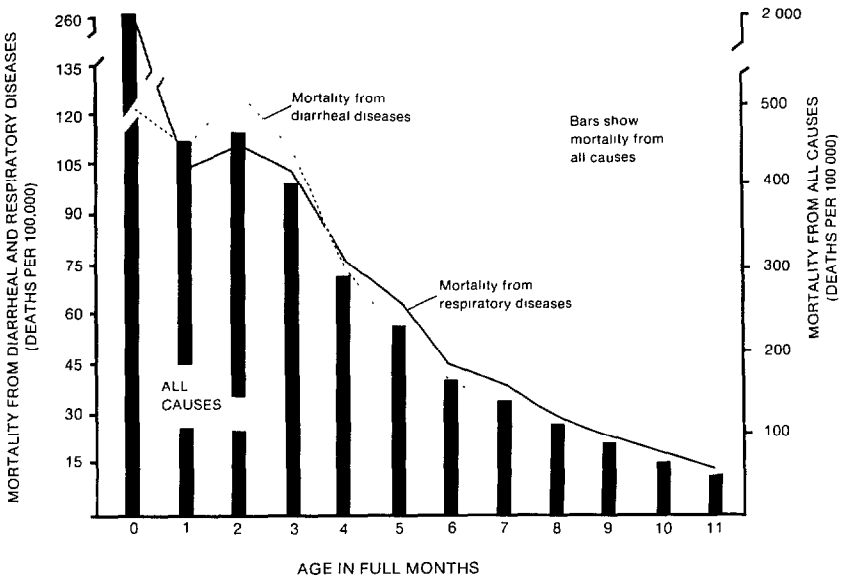


Table 2. Number and rate (per 100,000 live births) of neonatal deaths ascribed to diarrheal diseases, respiratory diseases, and all causes by the age of the subject in complete weeks at the time of death. Rio Grande do Sul, Brazil, 1974-1978.

Age in weeks	Diarrheal disease deaths		Respiratory disease deaths		Deaths from all causes	
	No.	Rate (per 100,000)	No.	Rate (per 100,000)	No.	Rate (per 100,000)
0	236	25.5	1,326	143.5	13,459	1,456.9
1	311	34.2	471	51.7	2,340	257.0
2	375	41.3	394	43.4	1,696	186.0
3	194	21.4	233	25.7	899	99.2

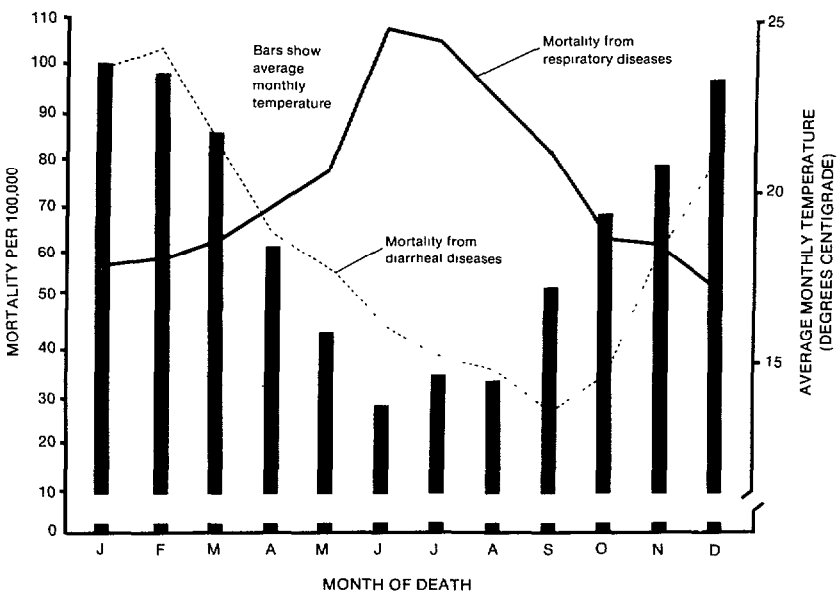
Regarding the day of death during the first week, the deaths were fairly evenly distributed—with around 30 occurring each day—except during the seventh day, when only six deaths occurred.

Regarding the respiratory diseases, 30.5% (2,424) of the deaths attributed to them occurred in the first month of life. Furthermore, the Table 2 data indicate that over 54% of these first-month deaths occurred in the first week of life, so that these first-week deaths accounted for some 16.7% of all the recorded infant deaths ascribed to respiratory causes. The bulk of these first-week respiratory deaths were attributed to causes ICD 485 (unspecified bronchopneumonia, 66.4%) and ICD 486 (unspecified pneumonia, 27.4%). Within the first week, deaths were concentrated in the first few days (322 occurring on the first day, 316 on the second, 253 on the third, 159 on the fourth, and less than 100 on each of the last three days).

Turning to another matter, the share of all infant deaths due to respiratory diseases remained remarkably constant from the second month onwards—at around 25 to 30% of the total. In a similar vein, the share of deaths due to diarrhea remained at just over 25% of all deaths from the second to the fifth month and declined slowly thereafter, descending to 16% in the eleventh month. However, the percentages of all deaths due to these causes were much lower in the first month of life, when early neonatal causes of death predominated.

Regarding seasonal variations in diarrheal and respiratory disease mortality, Figure 2 shows the monthly variations in mortality from both these causes together with the average monthly air temperatures involved. As may be seen, the highest incidence of diarrhea deaths occurred in the summer months of January and February, while the lowest occurred from July through October. In contrast, mortality from respiratory diseases was highest in the winter (June-July) and lowest in the summer (December-February). There was nearly a fourfold seasonal variation in di-

Figure 2. The monthly distribution of 40,219 infant deaths due to diarrheal and respiratory diseases and monthly variations in the average air temperature in the state of Rio Grande do Sul, 1974-1978.



arrhea deaths; the seasonal change in respiratory deaths was less, amounting to only a little more than a twofold variation.

Overall, the data confirmed the expectation of finding a strong correlation between mean temperatures and deaths from these two causes. Specifically, Pearson's correlation coefficients were found to be 0.830 for diarrheal disease mortality ($P = 0.0008$) and -0.921 for respiratory disease mortality ($P = 0.00002$). On the other hand, no significant associations were found between mortality due to either group of causes and rainfall levels (the correlation coefficients being 0.060 for diarrheal disease mortality and 0.167 for respiratory disease mortality). Moreover, a multiple linear regression analysis revealed that, after the effect of temperature was accounted for, rainfall "explained" less than 2% of the variation in diarrheal and respiratory disease mortality throughout the year. Temperature, however, "explained" 68.9% and 85.9% of these respective variations.

Mortality from all causes was found to be highest from January to March and again in June-July, reflecting both of the peaks in diarrheal and respiratory deaths. No significant correlation was found between all-causes mortality and temperature ($r = 0.078$;NS); a numerically greater correlation was found between all-causes mortality and rainfall, but this was still statistically non-significant. A multiple regression analysis showed that temperature and rainfall variations together "explained" only 7.9% of the variation in the total death rate throughout the year.

Figure 3 shows the variations in the risk of death from diarrheal and respiratory diseases by month-of-birth cohorts. As these risks represent the risk of death any time in the first year for the members of each cohort, they are considerably higher than mortality at any spe-

Figure 3. Distribution by birth-month of 39,961 infant deaths due to diarrheal and respiratory diseases in the state of Rio Grande do Sul, 1974-1978.

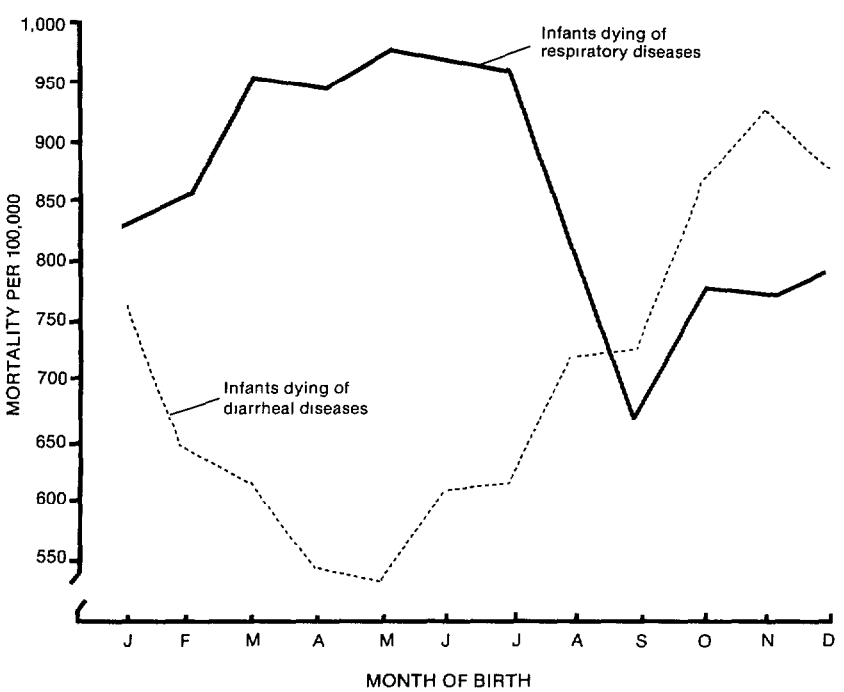


Figure 4. Distribution by birth-month and month of death of 6,435 infants dying of diarrheal diseases in the state of Rio Grande do Sul, 1974-1978.

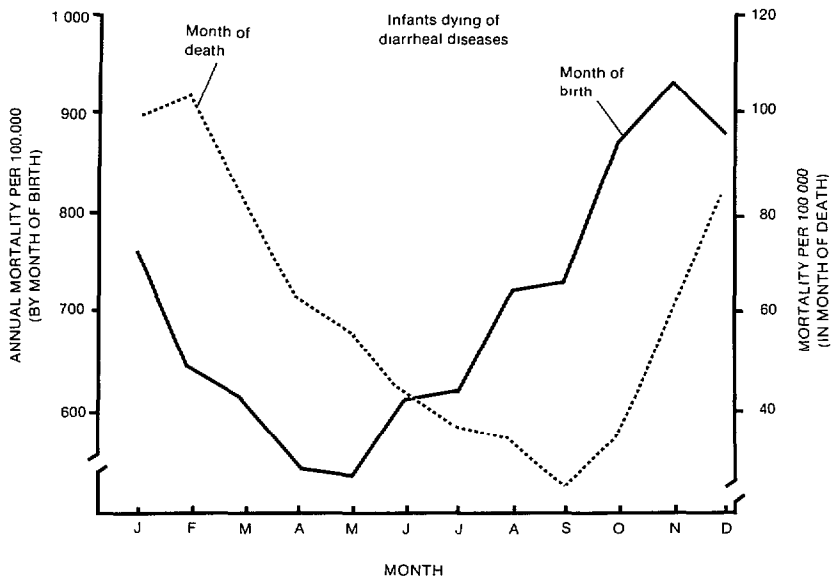
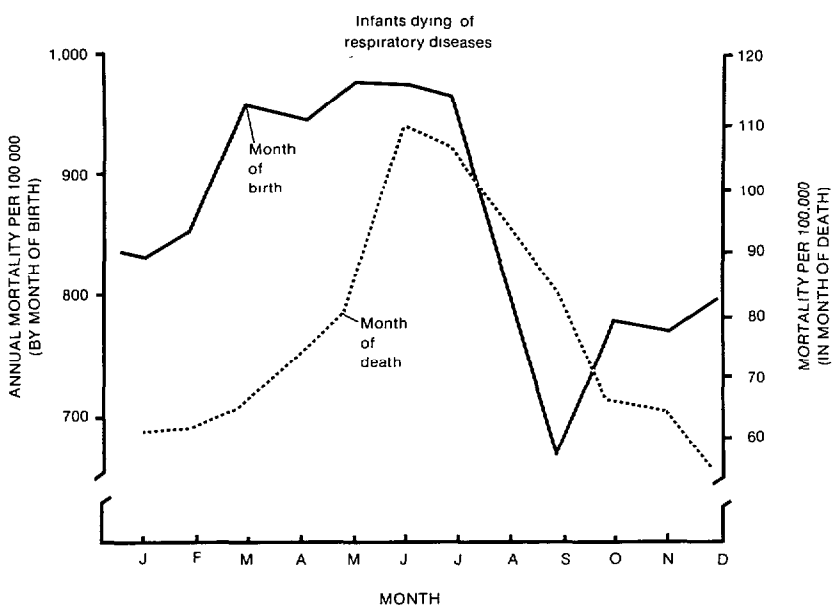


Figure 5. Distribution by birth-month and month of death of 7,948 infants dying of respiratory diseases in the state of Rio Grande do Sul, 1974-1978.



cific age (in months) or the mortality occurring during any specific month. In general, the risk of death from diarrheal diseases seems highest for the children born between October and December, while those born in April and May appear to experience the lowest risk, one which is only a little more than half as great. In contrast, infants born from March through July appear to experience the greatest risk of death from respiratory diseases, while the lowest risk (about two-thirds the maximum risk) appears to be experienced by those born in September.

Figure 4 shows that when the curves of diarrhea mortality by month of birth and month of death are superimposed, a four-month lag becomes apparent. The shapes of both curves are very similar. The similarity is not so marked when the curves of respiratory disease mortality by month of birth and month of death are compared (Figure 5). In particular, mortality by month of birth reaches an initial peak in March and thereafter remains a little above or below this level through July. Mortality by month of death, in contrast, reaches a sharp peak in June and July and thereafter diminishes quite fast.

Discussion

The foregoing tabulations of infant deaths due to diarrheal and respiratory diseases in Southern Brazil during 1974-1978 have shown that approximately half of the infant deaths due to either group of causes occurred in the first three months of life.

The data also showed a marked seasonal variation in diarrheal deaths, there being almost a fourfold difference between the relatively high mortality of the summer months and the relatively low mortality of the winter months. This pattern is very similar to that observed in England at the beginning of this century *(10)* and that found in many developing countries today *(11)*. This correlation increases from 0.830 to 0.933 ($P < 0.00001$) if a one-month lag is introduced between the month in which the air temperature is taken and the month of the diarrhea-related mortality to which it is compared. This improved correlation is in agreement with the following observation made by Ballard over a century ago: "I do not wish it to be inferred that the air temperature and the temperature of the more superficial layers of the earth, exert no influence on diarrhoea. Their influence, however, is little if at all apparent until the temperature recorded by the four-foot earth thermometer has risen ..." *(10)*. Our introduction of a one-month lag merely allows for the relatively slower rise of the soil temperature, and the improved correlation indicates that the association between soil temperature and diarrheal disease mortality that was observed by Ballard remains valid.

These findings provide clues for further investigation of causal agents. They suggest, for instance, that agents such as rotavirus—which show winter incidence peaks—are not likely to be implicated in the majority of deaths *(12)*. It should also be noted that the close association with temperature rather than with rainfall is in agreement with observations from other Third World areas *(11)*.

Regarding respiratory causes of mortality, the winter months show a mortality twice as high as that of the summer months. Again, there is no clear association with rainfall such as that observed between rainfall and the incidence of respiratory diseases in Trinidad *(13)*.

This combination of the age and seasonal distributions shows an interesting pattern of mortality by month of birth, one that has not been investigated by earlier Latin American studies such as the major one led by Puffer and Serrano *(4)*. Specifically, the children at higher risk of dying from diarrhea were those born just before the summer (October to December). They spent their most vulnerable period—the first four months—in the hot season and were therefore more likely to die of diarrhea than those born in the months of highest incidence (January-February). On the other hand, the children born just after the end of the hot season (April-May) experienced the smallest diarrhea mortality, about half of the peak rate.

With respect to respiratory diseases, the cohorts born from March through July experienced highest risks of death, with the highest risk affecting the cohort born in May, just before the beginning of winter. As many deaths from respiratory disease tended to occur in the very first month of life, mortality was high among children born in the middle of the cold season and was also high among those born in the months just preceding winter. The cohort of children experiencing the lowest relative risk was that born in September, whose members were about 70% as likely to die of respiratory disease as were members of the cohort born in May.

The overall level of infant mortality attributed to respiratory diseases (860.4 deaths per 100,000) appears fairly comparable to the findings of the Inter-American Investigation of Mortality in Childhood in different parts of Brazil (537.3 deaths per 100,000 live births in Riberão Prêto, 1,038.5 per 100,000 in São Paulo, and 1,039.5 per 100,000 in Recife—*14*, p. 229). The overall diarrhea mortality rate of 704.8 per 100,000, however, was lower than that found in all the Latin American and Caribbean areas covered by that study (*14*, p. 141). In making these comparisons, it is important to observe that these two studies' data are not strictly comparable, since the Inter-American Investigation made a great effort to ensure that the deaths analyzed were correctly classified, while the findings of our study are based exclusively on information obtained from death certificates.

Some caution is therefore recommended when interpreting the present results. Although underregistration of deaths in Brazil seems to be very low for a developing country, up to 10% of the infant deaths may never be certified, and the age distribution and seasonal patterns of these deaths may be different from those reaching the vital statistics system.

Also, as Puffer and Serrano have shown (*14*, p. 328), the causes of infant deaths, especially diarrhea-related deaths, are quite often misclassified. We have tried to partly overcome this problem by studying only broad groups of causes spanning several ICD codes. (Since associated causes of death were not coded, our results refer only to underlying causes.)

The large number of deaths ascribed to respiratory diseases (mainly unspecified pneumonia and bronchopneumonia) in the first week of life (1,326 deaths, or 143.5 deaths per 100,000) raises the possibility that other perinatal causes leading to respiratory distress may have been wrongly ascribed to these more general respiratory disease categories. However, other studies have identified first-week respiratory death rates of similar magnitude. The pneumonia death rate found by the British Perinatal Mortality Survey of 1958 was 130 deaths per 100,000, although the 1970 British Births Survey cited a markedly decreased rate (10 deaths per 100,000—*15*). The rate of 143.5 deaths per 100,000 is also well within the range identified in the Puffer and Serrano study (from 11.2 deaths per 100,000 live births in California to 162.2 per 100,000 live births in Bolivia—*14*, p. 95). Overall, this latter study has shown that a considerable proportion of neonatal respiratory deaths (30.7% in the cases studied) occur in the first week (*14*, p. 122). However, some of these deaths may be a consequence of intrauterine infection or aspiration of amniotic fluid, with immaturity often being a contributing cause.

It is also of concern that approximately 10% of the infant deaths included in our study were certified as being due to "symptoms and ill-defined conditions" (ICD categories 780–796). In the Inter-American study, all but 14% of the deaths assigned to these categories were found to have been due to specific causes revealed by further investigation (*14*, p. 342).

Although our results may have been affected to some extent by misclassification, the age and seasonal patterns described above would only be affected if the diagnostic or coding practices varied with the age of the infant or throughout the year. This is unlikely

in the case of diarrheal diseases; but respiratory diseases could have been affected in the manner we have suggested. The concentration of respiratory deaths in the first month could thus be less pronounced than it appears. The effect of such misclassification, however, would be to dilute seasonal trends, since deaths due to perinatal causes show less seasonal variation than those due to respiratory diseases (unpublished results); therefore, when first-week deaths are excluded, the patterns described above become even more pronounced.

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SUMMARY

A study based on death certificate information was made of 40,219 infants dying in the state of Rio Grande do Sul, Brazil, during the years 1974-1978. This study indicated that a high proportion (46%) of the infants in the study population died during the first month of life. Also, most of the deaths attributed to diarrheal and respiratory diseases occurred in the first four months of life, after which the levels of mortality from these causes declined sharply.

Overall, the frequency of deaths caused by diarrheal diseases was several times greater in the summer months of January and February than in the winter months, while the frequency of deaths caused by respiratory diseases was two times greater in the winter than in the summer. There was a close direct association between diarrhea mortality and average air temperatures, and a close inverse association between respiratory disease mortality and average air temperatures. No associations were found between deaths from either of these causes and rainfall patterns.

Because of these seasonal variations, infants born just before the beginning of the summer (in October through December) experienced the highest risk of death from diarrheal diseases, while those born from early fall through mid-winter (in March through July) experienced the highest risk of death from respiratory diseases.

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FIRST WHO AWARD ON HEALTH EDUCATION IN PRIMARY HEALTH CARE

The First World Health Organization Award for Health Education in Primary Health Care will be presented at the 12th World Conference on Health Education to be held in Dublin, Ireland, on 1-6 September 1985. The winner of the award, to be selected from a group of nominees, will be that group, institution, or other organization that is deemed to have made the most innovative and effective contribution to the promotion of "health for all" through health education services, training, and/or research in the context of the "primary health care" approach.

Criteria for making the award, which is sponsored by the LISZ Foundation, Inc., will be guided by principles of the Alma-Ata Declaration on Primary Health Care and the Global Strategy for Health for All by the Year 2000. All nominations should be received by WHO Headquarters in Geneva no later than 1 July 1985.

The award will include a commemorative plaque and a cash prize of $5,000. The prize may be utilized by the winning group, institution, or organization as seed money for further promotion of Education for Health through Primary Health Care to facilitate community-level activity towards self-reliance, multisectoral action, mobilization of local resources, and application of appropriate technology in solving community-related development problems.