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Water Supply, Sanitation and Housing in Relation to the Risk of Infant Mortality from Diarrhoea

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In a population-based case-control study in the metropolitan areas of Porto Alegre and Pelotas in southern Brazil children dying in infancy from diarrhoea were compared to neighbourhood controls in terms of several social and environmental variables. Factors found to be significantly associated with an increased risk of death from diarrhoea included the non-availability of piped water, the absence of a flush toilet, residence in a poorly built house and household overcrowding. When adjustment was made for confounding variables and the mutual confounding effect of the environmental variables on each other, the only association that remained statistically significant was that with the availability of piped water. The association with poor housing was almost significant ($p=0.052$). Compared to those with water piped to their house, those without easy access to piped water were found to be 4.8 times more likely to suffer infant death from diarrhoea (95% confidence interval 1.7 to 13.8) and those with water piped to their plot but not to their house had a 1.5 times greater risk (95% confidence interval 0.8 to 3.0).

There are few published studies relating under-fives mortality to the quality of sanitation and water supply. Esrey *et al*[1] identified eight studies of the impact of such variables on early childhood mortality from all causes. In these studies the mortality of children with improved water supply and excreta disposal facilities was reported to be 0 to 81% lower (median 21%) than that of children without such facilities. More recent studies have also confirmed this association.[2-4]

Only two studies focused on the effect of type of water supply on mortality from diarrhoea, and these provided no information on the effects of other environmental variables such as sanitation and housing. Wagner and Lanoix[5] report on a proportional mortality study in north-eastern Brazil in which diarrhoea was found to be the underlying cause of 20% of deaths of infants aged under four months in households with piped water inside the house, whereas in other households approximately 60% of such deaths were due to diarrhoea. There was no difference in the proportion of deaths due to diarrhoea between households drawing water from wells or from an outside tap. In a study in India in the 1950s, Zaheer[6] showed that the introduction of treated and piped water in 14 towns of Uttar Pradesh was associated with a 43% reduction in the diarrhoea mortality rate at all ages in the five years following the improvements, compared to the previous five years. Although both these studies suggest a considerable impact of improved water supplies, they are difficult to evaluate as the methodologies are poorly described. For example, in neither is there discussion of the completeness of the coverage of the death registration systems, nor of the criteria used to establish the underlying causes of death. In addition, the Indian study did not have a control group of towns with no intervention, and both studies failed to consider the possible influence of other variables that might have a confounding effect with water supply facilities.

The lack of published data on the effects of improved water and sanitation facilities and other environmental variables on the risk of diarrhoea mortality prompted us to investigate these factors in a population-based case-control study in two urban areas of southern Brazil.

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POPULATION AND METHODS

An attempt was made to ascertain all infant deaths occurring from 24 December 1984 to 23 December 1985 in the metropolitan areas of Porto Alegre and Pelotas, Brazil (combined population 2 500 000). A monitoring system was set up which included weekly visits to all hospitals, coroners' services and death registries in the areas. This approach has been shown to provide nearly complete coverage of infant deaths.[7,8]

Whenever one of the above sources mentioned an infectious disease as the possible cause of death, or when the cause of death was unknown or ill-defined, a physician visited the parents or guardians of the deceased infant to collect further data on the terminal illness; 96.5% of eligible parents were interviewed. During this visit, information was also collected on possible risk factors for infant mortality, including environmental variables. The same information was collected for two 'control' infants who lived in the same neighbourhood as the cases. The controls were selected by proceeding in a clockwise manner around the block in which the case's home was situated. If this procedure did not identify two infants, controls were taken from the next block (or blocks). The controls were chosen in such a way that their mean age was similar to that of the cases.[9]

The underlying cause of death was assessed independently by two reviewers who went through the hospital case notes, death certificates, post-mortem reports and the data collected through interviewing the parents. In the case of disagreement between the reviewers a third assessor (CGV) took the final decision. All three were kept blind to the data on the environmental variables under study. Diarrhoea deaths included those coded 001 to 009 according to the ninth revision of the International Classification of Diseases.[10]

Cases and controls who had important perinatal risk factors were excluded from the study as follows: those with a birthweight under 1500 g; twins; those with major malformations or cerebral palsy; and those whose initial stay in hospital exceeded 15 days. Fourteen per cent of potential deaths from infectious diseases were thus excluded. Also excluded were cases and controls aged under seven days, as there were very few diarrhoea deaths in this age group.

Information on environmental variables was collected by questioning the parents. Where appropriate their replies were confirmed or supplemented by observation of the house and its surroundings. Data on the following variables were collected:

—type of water supply: piped inside house; piped to plot; other.

—source of water; treated (from a public supply); untreated (from a well (11% of households studi… or river (1% of households)).

—type of latrine: flush toilet; pit latrine; or none.

—type of housing: well built (including those made … bricks, cement or regular boards); or shack (bui… with improvised materials such as irregular boar… cardboard or cans).

—crowding: number of people per bedroom (analys… in approximate quartiles: 1−, 2.6−, 3.1−, 5+).

The interviewers collected information on the termin… disease episode only after recording the data o… environmental variables.

The data were analysed using logistic regressio… methods for matched studies.[11] Several variables we… studied which may be associated both with enviro… mental factors and with the risk of death from di… rhoea. These included family income, materna… education, social status of the head of the family, an… the type of milk consumed by the infant. In the an… lyses, we examined whether adding these 'co… founding' variables to the logistic model resulted in … more than minor change in the estimates of relativ… risks. This was the case for the variables social statu… (casual labourers; regularly employed; businessmen … and self-employed) and type of milk consumed (breas… only; breast plus formula or cow's milk; and formula o… cow's milk only) but not for family income or materna… education. In addition, the infant's age (coded 0–, 2–… 4–, 6– and 9–11 months) was included in all analyses. … Relative risks (based on the odds ratios) and their 95% … confidence intervals were calculated.

RESULTS

During the one-year study period there were 170 … deaths in which the underlying cause was considered to … be diarrhoea. The age distributions of these 170 cases … and 340 controls were as follows: 7 days–1.9 months: … cases 17, controls 71; 2–3.9 months: 55, 85; 4–5.9 … months: 42, 67; 6–8.9 months: 45, 60; and 9–11.9 … months: 11, 57.

The distribution of these cases and controls in the … different categories of the five environmental variables … on which data were collected are shown in Table 1. … Also shown are the estimated relative risks derived … from the logistic regression analysis of the matched … case-control sets. Analyses are given for each variable … after adjusting for age only and also after adjusting for … social status, type of milk consumed and for the four … other environmental variables. In the analyses in … which only age adjustment was made there were statis… tically significant associations between the risk of death … from diarrhoea and the availability of piped water, the … type of toilet, the type of house and crowding. All …

TABLE 1 *D… env…*

…nvironmen… …riables	
…vailability … …iped in hou… …iped to plot	
Other	
…(2 df)	
Type of wate… Treated	
Untreated	
…(1 df)	
Type of toilet… Flush	
…it latrine	
None	
…(2 df)	
Type of house… Well built	
Shack	
…(1 df)	
Crowding (no./bedroom)	
…≤2.5	
2.6−	
3.1−	
5.0+	
…(1 df trend)	

…(a) adjusted for …
(b) adjusted for … environmental …
(c) 95% confide…
*p<0.05; † p<…

…these associa… …expected, th… …ditions being … …water were e… …death from d… …but this diffe… Because th… …with each oth… …rnative analy… …llow for the … …tatus and the …

TABLE 2 *Distrib…*

Case water supply piped?	
Yes	
No	

TABLE 1 *Distributions of diarrhoea cases and controls for different environmental variables and estimated relative risks.*

Environmental variables	Cases	Controls	Relative risk (a)	(b)	(c)
Availability of piped water					
Piped in house	59	168	1.0	1.0	
Piped to plot	52	91	1.9	1.5	(0.8–3.0)
Other	59	81	5.5	4.8	(1.7–13.8)
χ^2(2 df)			21.81†	9.36†	
Type of water					
Treated	146	303	1.0	1.0	
Untreated	24	37	2.5	1.4	(0.3–6.1)
χ^2(1 df)			2.66	0.25	
Type of toilet					
Flush	69	177	1.0	1.0	
Pit latrine	92	146	2.3	1.1	(0.5–2.3)
None	9	17	1.7	0.7	(0.2–2.5)
χ^2(2 df)			10.29†	0.92	
Type of house					
Well built	83	220	1.0	1.0	
Shack	87	120	2.5	1.9	(1.0–3.6)
χ^2(1 df)			13.45‡	3.77	
Crowding (no./bedroom)					
≤2.5	32	83	1.0	1.0	
2.6–	42	97	1.0	0.8	(0.4–1.7)
3.1–	44	88	1.3	1.0	(0.5–2.2)
5.0+	52	72	1.9	1.2	(0.5–2.5)
χ^2(1 df trend)			5.20*	0.45	

(a) adjusted for age only.
(b) adjusted for age, social status, type of milk consumed and all other environmental variables listed in the Table.
(c) 95% confidence interval for (b) above.
* $p<0.05$; † $p<0.01$, ‡ $p<0.001$.

these associations were in the direction that might be expected, those living in poorer or more crowded conditions being at greatest risk. Those using untreated water were estimated to be at 2.5 times greater risk of death from diarrhoea than those using treated water, but this difference was not statistically significant.

Because the environmental variables are associated with each other and also with poverty, the more informative analyses are those in which we attempted to allow for the confounding effects of socioeconomic status and the other environmental variables. We also adjusted for the type of milk consumed, as we have shown elsewhere[9] that this is an important risk factor for death due to diarrhoea, and milk feeding practices vary according to socioeconomic and environmental variables. When these adjustments were made the only association that remained statistically significant was that between the availability of piped water and the risk of death from diarrhoea. Those who did not have a piped water supply to their house or to their plot had a risk about five times greater than those with piped water in the house. The associations of mortality with the type of toilet and with crowding were eliminated by adjusting for the other variables, whereas that with type of water was reduced and was no longer statistically significant. The association with the type of housing was reduced after adjustment but was almost significant ($p=0.052$).

Clearly by choosing neighbours as controls there was a danger of 'over-matching' with respect to possible risk factors such as those relating to water supply. That is, those living in close proximity to each other are likely to have similar environments. For this reason it was essential to account for the matching in the analysis as if this had not been done the relative risk estimates would have been seriously biased towards unity. This is illustrated in Table 2 with respect to whether or not water was piped (to house or plot) or not piped to the homes of cases and controls. An unmatched analysis of these data yield a relative risk estimate of 1.7 associated with the lack of piped water, whereas the estimate based on the appropriate matched analysis is 3.6.

TABLE 2 *Distribution of water supply in matched case-control sets.*

Case water supply piped?	Number of matched controls with piped water supply: 0	1	2
Yes	1	12	98
No	26	15	18

DISCUSSION

Poor sanitation and water supply are generally assumed to increase the risk of morbidity and mortality from diarrhoea. In practice, however, such associations have been hard to demonstrate. Blum and Feachem[12] reviewed over 50 studies on the relationship between water supply and/or excreta disposal facilities and health, and concluded that while most studies claimed to show an improvement in one or more health indicators, a critical review of the papers raised serious doubts as to the validity of their conclusions. Most of the studies reviewed were either longitudinal or cross-sectional and none were case-control studies.

Esrey *et al*[1] estimated that improved water supply, excreta disposal and hygiene education might reduce diarrhoea mobidity rates by 35–50% and larger reductions might be expected in diarrhoea mortality in some circumstances. In the present study we found that those infants whose homes had piped water had a diarrhoea mortality rate that was 80% lower (95%

confidence interval(CI) 41%–93%) than those from homes with no easy access to piped water. Contrary to most studies on under-fives' mortality due to all causes,[1] we found no evidence that those in homes with flush toilets were at reduced risk of dying from diarrhoea, after adjusting for the effects of other variables. Furthermore, infants receiving untreated water were not at significantly higher risk than those receiving treated water. These findings suggest that the beneficial effects of piped water may relate to the easy availability of water rather than to its quality, which is in agreement with previous research on child mortality due to all causes.[1,2] It should be noted that we collected no data in this study on the degree of contamination of untreated water but in another study in Porto Alegre it was found that well water in shanty towns (where most of the cases lived) was likely to be highly contaminated (V Petrillo, personal communication).

Those living in a poorly constructed house were found to be at increased risk of death from diarrhoea but this was not quite statistically significant after adjusting for confounding variables. This effect may be due to residual confounding if our adjustment for socioeconomic or other factors was incomplete. On the other hand, we cannot rule out the possibility that poor housing may increase the risk of diarrhoea.

Residual confounding is also a possible explanation for the association with availability of piped water. For example, families which have a piped water supply may have easier access to health services (eg use oral rehydration solution more frequently to treat diarrhoea). It is never possible to rule out such explanations in observational studies but the increased risk associated with the lack of a piped water supply was not greatly affected by the adjustment for confounding variables, whereas that associated with poor toilet facilities was eliminated by such adjustment. If there was important residual confounding it might have been expected to affect the estimates of risk associated with toilet facilities in a similar way to those associated with water supplies. Furthermore, the relative risk associated with a poor water supply is high even after adjustment for confounding factors and this also argues against the possibility of confounding being the explanation for all of the association observed.

In summary, we have found an association between the availability of piped water and diarrhoea mortality of a greater magnitude than had been suggested by most earlier studies of overall infant mortality. After allowing for the piping of water, both the source of the water supply or the type of sanitation were no longer associated with mortality. These findings are in agreement with the idea that most life-threatening diarrhoea episodes in the study area are 'water-washed' rather than 'water-borne'.[13]

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