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THE EFFECTS OF WATER SUPPLY AND SANITATION ON CHILDHOOD MORTALITY IN URBAN ERITREA

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Summary. Child mortality differentials according to water supply and sanitation in many urban areas of developing countries suggest that access to piped water and toilet facilities can improve the survival chances of children. The central question in this study is whether access to piped water and a flush toilet affects the survival chance of children under five in urban areas of Eritrea. The study uses data collected by the Demographic and Health Survey (DHS) project in Eritrea in 1995. The results show that while the unadjusted effect of household environment (water supply and toilet facility) is large and statistically significant during the post-neonatal and child periods, it is relatively small and statistically insignificant during the neonatal period. The effect of household environment remains substantial during the post-neonatal and child periods, even when other socioeconomic variables are held constant. However, the household environment effect totally disappears during the neonatal period when the socioeconomic factors are controlled for.

Introduction

Improvements in household environmental conditions, and especially in water supply and sanitation, seem to have played a major role in the decline in mortality in the cities of the United States (e.g. Gaspari & Woolf, 1985) and Europe (e.g. Preston & van de Walle, 1978) in the nineteenth century. Several studies in urban areas of contemporary developing countries have also demonstrated that infant and child mortality is closely associated with water supply and sanitation facilities (e.g. Gubhaju, Streatfield & Majumder, 1991; Timaeus & Lush, 1995; Merrick, 1985; Tekce & Shorter, 1984).

Despite the literature on the effect of water supply and sanitation on child health in many other developing countries, no research on this subject exists in Eritrea at present. There is almost nothing known about the basic demography of Eritrea, so of course this area is also under-researched. This is mainly due to the political instability and severe war of the last three decades. As a consequence of the country's long liberation war, no censuses have been conducted in the country, nor have national coverage surveys provided adequate sources of data before 1995. Two recent developments have enhanced the prospects for an examination of the effects of water supply, toilet facilities and other socioeconomic factors on child mortality in Eritrea. First, new data have recently become available: the Eritrea Demographic and Health Survey (EDHS), conducted in 1995. Since the EDHS survey collected detailed information on birth histories and other socioeconomic and health variables, it provides a unique opportunity to investigate the effect of water supply and sanitation on early childhood mortality and the nature of the inter-relationship with other variables. Second, because large-scale efforts have been directed in recent years towards primary health care and the reduction of mortality, especially among infants and young children, at both national and sub-national levels, the understanding of mortality differentials has taken on increased importance. Another recent innovation is that the Ministry of Health and the Water Resource Department have decided to improve the provision of water supply and sanitation facilities, and hence to reduce mortality, especially among infants and children, and have established policy guidelines for this purpose (Water Resources Department and UNICEF, 1996). To implement such health programmes so that they will have the greatest possible effect, it is vital to have at least an approximate idea of the severity of the problem in the urban population. It is with this background that this study has been planned.

The main focus of this paper is on the influence of water supply and sanitation on child mortality, and on the socioeconomic factors that affect the water supply and sanitation advantage in child survival. Urban areas have been focused on, mainly because preliminary analysis indicated that rural households do not have such facilities.

A review of the effects of the selected variables

Variables that influence infant and child mortality and that could explain mortality differentials among different groups include those with direct as well as indirect effects on the survival chances of children. Relevant direct causal variables include the quality of the household environment (water supply and sanitation) and the maternal and child health care to which people have access (Mosley & Chen, 1984). Background (or indirect) variables, such as education, household economic conditions and place of residence, may influence mortality by affecting or conditioning the directly causal variables.

Two of the most important causes of poor health among people of developing countries are inadequate provision for sewage disposal and contamination of drinking water (Johnson, 1964). An improvement in the quality of water and the provision of sanitation facilities for safe disposal of human excreta is particularly important for the health of children. Access to piped water in the household is likely to be of direct benefit in lowering child mortality by reducing exposure to water-related diseases, particularly diarrhoeal diseases (Merrick, 1985). Improved water supply can influence the survival chance of children in several ways (Poppel & Heijden, 1997): clean water may prevent the spread of water-related diseases, like cholera and typhoid, which are directly transmitted when water contaminated by faeces or urine is drunk or used in the preparation of food; access to safe water may also reduce the impact of diseases that are transmitted by the faecal–oral route by leading to better hygiene through washing hands and cooking utensils and cleaning floors (Esrey & Habicht, 1986). Moreover, the benefit of improved water supply occurs not only by a reduction in diseases, such as diarrhoea, but also by increased time spent in food procurement and feeding activities when water collection times are reduced (UNICEF, 1997).

Because so many of the major infectious agents of disease are spread through faeces and urine, hygienic disposal of waste is vitally important. Thus, improvements in water quality alone, without improvements in hygiene and sanitary conditions, might not lead to better health (Poppel & Heijden, 1997). Excreta disposal probably plays a more important role in determining children's health in developing countries than does water quality, especially where the prevalence of diarrhoea is high (Esrey & Habicht, 1986).

The role of improved water supply and sanitation facilities in increasing people's chances of survival is clear, both in the pre-industrialized nations of the eighteenth and nineteenth centuries and the developing countries of today. For instance, Preston & van de Walle (1978), in their study of mortality in three French departments during the nineteenth century, showed that water and sewage improvements played a major role in urban mortality decline. Moreover, the rate of decline was much more rapid in the two cities that introduced a vigorous sewage and pure water programme than in the one that did not. Likewise, in the late nineteenth century, infant mortality was found to be high in parts of the Swedish city of Linköping where water and drainage systems were poor in scope or non-existent (Nilsson, 1994), but it declined fastest in those areas which were first connected to the network.

Gaspari & Woolf (1985)'s study on the association between crude death rates and the availability of filtered water supply and the length of the sewer systems in 122 United States cities in 1910, revealed that cities that invested in sewer systems experienced significant decreases in mortality. However, although filtration of water systems had some disease-specific benefits, the decline in crude mortality could not be attributed to them. Filtered water was found to be important only in the decline of typhoid mortality in cities, but typhoid mortality was usually a small proportion of the total urban mortality.

During the past decades, several studies have also been made on the influence of water and sanitation interventions on childhood mortality in contemporary developing countries. For instance, infant mortality and household environment were found to be strongly associated in urban Nepal (Gubhaju *et al.*, 1991). After controlling for other socioeconomic and demographic factors, the risk of death was found to be 44% higher among infants born to households which used drinking water from a river or a lake than among infants born to households using piped water. The same study also indicated that the risk of death was 64% higher among infants born to households which did not have their own toilet facility than among their counterparts born to households which had such facility.

Child mortality and morbidity have been strongly associated with household environmental conditions in urban areas of Ghana, Egypt, Brazil and Thailand (Timaeus & Lush, 1995). Even after socioeconomic status (e.g. parental education and occupation) was controlled for, environmental conditions of households were strongly related to mortality in Egypt and Brazil, and to diarrhoea prevalence in Brazil, Thailand and Ghana. The importance of access to piped water for reducing child mortality was also shown in urban Brazil between 1970 and 1976, but the role of toilet facilities was found to be relatively minor (Merrick, 1985). Other studies, for example Butz, Habicht & Da Vanzo (1984) using data from Malaysia, found that infants born to households with piped water experienced significantly lower mortality than infants in houses using other water sources.

Despite the foregoing evidence, other studies have found that water supply and toilet facilities have no effect on mortality after socioeconomic variables are controlled for (e.g. UN, 1985). One possible reason for such conflicting findings is the lack of understanding of certain behavioural characteristics that have important effects on health (Blum & Feachem, 1983). It seems that the effect of household environment on health is complex, and is conditioned by several other characteristics and behaviours of the household and the community. For instance, the effect of water supply and toilet facilities on child mortality may vary between individuals or localities depending on the education of the parents (Esrey & Habicht, 1986), household income (Timaeus & Lush, 1995), child-feeding practices (Butz *et al.*, 1984), or cultural beliefs and practices (Tagoe, 1995). In urban Ethiopia, for instance, the impact of water supply and toilet facilities on child mortality was found to be negligible when socioeconomic variables, such as mother's schooling, economic status, religion and ethnicity were controlled for (Habtemariam, 1994). In Sri Lanka, Patel (1980) found a strong association between use of well water and low risk of death among infants, contrary to the expectation that piped water has important effects in reducing infant mortality.

It is also likely that methodological problems involved in both longitudinal and cross-sectional investigations could explain some of the contradicting findings of different studies (Blum & Feachem, 1983).

The socioeconomic variables included in this analysis are maternal education, household economic conditions, place of residence and birth year of child. These distant variables are thought to influence child mortality directly or indirectly through other intermediate variables (water supply and sanitation, for example).

The negative association between mother's education and child mortality has been demonstrated by several studies (Caldwell, 1979; Hobcraft, McDonald & Rutstein, 1984; Cleland & van Ginneken, 1988; Haines & Avery, 1982; Farah & Preston, 1982). These authors suggest a number of reasons for such links: first, more educated mothers tend to be less fatalistic about illness and disease and therefore more prone to seek medical assistance from outside the household for an ill child; second, educated mothers are more likely to adopt improved childcare practices, such as boiling water used in the preparation of infant formula; and third, education of women may change intra-family relationships, leading to a more child-centred approach that would have a positive impact on children's health. In addition, better educated mothers are more likely to earn higher incomes and to marry better educated men, consequently enabling their children to have better living conditions, better food and better health services (Schultz, 1984). It is suggested that the strength of the association between mother's education and child mortality becomes greater at higher ages of the child than during the infancy period (Cleland & van Ginneken, 1988), because biological factors rather than childcare practices play an important role in determining mortality among newborn children.

It has also been shown that variations in place of residence are related to variations in mortality (Hobcraft *et al.*, 1984; Rutstein, 1984; Sullivan, Bicego & Rutstein, 1994). Whether a mother resides in a city or in a small town may affect her exposure to education as well as the extent to which proper sanitation, clean water and health care facilities are available (Tagoe, 1995). One may therefore expect children from cities, where good water supply and sewerage systems and other health facilities are available, to have lower levels of mortality. If the inequalities in the provision of basic public health services between the two types of setting are less, the effect of residence on mortality may not be important.

Economic conditions of the household should also help explain variation in infant and child mortality. This is mainly because household economic status conditions the nature of housing, diet, access to and availability of water and sanitary facility, as well as medical attention, and therefore it usually has an inverse relationship with infant and child mortality. For instance, poor families may reside in crowded, unhygienic housing and thus suffer from infectious diseases associated with inadequate and contaminated water supplies and with poor sanitation (Esrey & Habicht, 1986). Several studies (e.g. Timaeus & Lush, 1995) have shown that the effect of poor housing environment on child mortality is greater for children of the poor socioeconomic groups than those of the better-off, suggesting that this latter group have the resources to protect their children from infectious diseases that lead to death.

Eritrea today

Eritrea is situated in the horn of Africa. It is bordered by the Sudan on the north and west, the Red Sea on the east, Ethiopia on the south, and the Republic of Djibouti on the south-east. With an area of 124,330 square kilometres and a population of about 3 million, Eritrea is a land of contrasts with land rising from below sea level to more than 2500 metres above sea level. Over 80% of Eritrea's population live in rural areas, as small-scale farmers.

Located on an important sea route between Europe and Asia, Eritrea has suffered invasion, occupation and plunder through much of its history. Because of its strategic significance, Eritrea attracted many expansionists and colonizers, among which are the Ottomans (16th century), the Egyptians (19th century), the Italians (1882–1941), the British (1942–1950) and the Ethiopians (1952–1990). Of these, the Italian occupation had a distinct impact on the formation and development of the nation's identity. It was during the Italian occupation that Eritreans, regardless of their ethnic, religious and cultural histories, began to feel that they were one nation who belonged to one land. Indeed, the roots of the war for freedom, and its present boundaries, can be traced to the creation of the Italian colony of Eritrea. After 30 years of long and bitter armed struggle against Ethiopian occupation, from 1961 to 1991, Eritrea was liberated in May 1991.

As a consequence of the three decades of war and occupation, as well as of a recurrent drought, Eritrea today is one of the world's poorest countries. Its gross domestic product (GDP) *per capita* is estimated to be about US$ 150, which is much below the US$ 350 average for the Sub-Saharan African countries (Water Resources Department and UNICEF, 1996). The gross primary school enrolment rate, though it has increased since the war's end, is still only 52%. The adult literacy rate is only 15%. Its under-five mortality and maternal mortality rates are 136 and 10 respectively, per 1000 live births. Access to safe drinking water and adequate sanitation is very low, and non-existent in rural areas (UNICEF, 1996).

Data, methods and variables

Data

Source of data. Data for this study came from the 1995 Eritrea Demographic and Health Survey (EDHS). This survey was the first large-scale nationally representative survey to be conducted in Eritrea. It collected birth histories and other information on health characteristics from 5054 women aged 15–49 years. There are a total of 14,268 live births reported in the survey. Of these, about 8283 were born within the 10-year period prior to interview (of which about 3121 were from urban areas – cities or towns).

This study of the effect of water supply and sanitation on infant and child mortality centred on births that occurred within the 10 years preceding the survey in urban Eritrea. This allowed as many births as possible to be examined while minimizing mis-reporting due to recall errors. Omission and mis-reporting of key variables, such as date of birth or age at death for deceased children, are more likely to occur for longer recall periods (Sullivan, Bicego & Rutstein, 1990). Focusing on births that occurred no longer than 10 years before the survey may also reduce the time differential between the birth of the child and the survey date when access to water supply and sanitation was observed. In the past 10 years, however, no major improvements in household environmental conditions have been made in Eritrea.

Accuracy of the age at death data. While DHS surveys are conducted to high standards, several potential problems need to be taken into account when analysing the data. Perhaps the most important is the issue of data accuracy related to reporting or measurement errors. Events further back in a woman's life are particularly likely to suffer from omission of births, especially of those not surviving or not residing at home at the time of the interview (Chidambaram, McDonald & Bracher, 1987). In addition, rounding of ages at death is one of the most important forms of inaccurate reporting that leads to distortion of the age pattern of mortality in many developing countries (e.g. Sullivan *et al.*, 1990; Curtis, 1995; Obungu, Kizito & Bicego, 1994).

Since this study relies on the accuracy of retrospective reports of birth and death, evidence of mis-reporting or omission of events, and of heaping of ages at death were looked for. To detect omission or mis-dating of births, standard internal checks include calculating the average number of children ever born and average number of dead children by age of women, sex ratios at birth, cumulative fertility by period and cohort, and checking for the 'heaping' of reported ages of children (e.g. at 12 and 24 months). Except for rounding of ages at death, there was no evidence of omission, mis-dating of births or of differentials by sex in the reported births. However, heaping of children's ages at death remains a problem of concern, with strong heaping of ages at death at 12 and 24 months and small heaping at age 6 months. Moreover, the highest proportion of all ages at death was reported at 0 months. While most of this is undoubtedly real and refers to neonatal mortality, a portion is certainly due to rounding.

In this study, a non-standard age classification was used, namely age intervals of 0 months, 1–13 months and 14–59 months. Perhaps this age breakdown avoids biases in estimation due to heaping of reported ages at death at 6, 12 and 24 months, because these numbers fall between the age ranges used in this analysis. Some studies (e.g.

Sullivan *et al*., 1990) suggest that if heaping at certain ages is very high then these ages should not be used as cut-off points in analysing infant and early child mortality.

Statistical methods

The effect of water supply and sanitation on infant and child mortality was analysed by classifying the under-five children into three age segments. Such analyses of the determinants of child mortality pose two technical problems (Pebley & Stupp, 1987). The first relates to censored observations, that is, not all live births have the chance to survive to the oldest age under investigation by the time of the interview, and the second is concerned with the rapidly changing behaviour of mortality from one age to the next during the childhood period.

Use of hazard regression models permits inclusion of all births (censored and non-censored observations) for the analysis of age segments extending beyond the neonatal period (neonatal mortality analysis does not involve censoring because only births that occurred at least one month before the survey date are included) and to reflect the changing rates of mortality during the child period.

More specifically, for the neonatal period, the logistic regression model was used. This model can be expressed as

$$\ln(q_i/1-q_i)=\beta_0+\beta_i x_i,$$

where q_i is the probability of neonatal mortality for the i^{th} individual, β_0 is the baseline constant, and β_i is a series of unknown coefficients estimated via the Maximum Likelihood procedure (Hosmer & Lemeshow, 1989) using the SPSS Logistic program, and x_i is an array of independent variables. The estimated coefficients (β_i), when exponentiated, are interpreted as the odds of mortality ($q/1-q$) for individuals with certain characteristics relative to the odds of mortality in a reference (or baseline) group of individuals: that is, as relative odds or odds ratios. In the present study where q is fairly small, the odds ratio nearly translates to a relative risk.

The Cox proportional hazard model was used to estimate the effects of covariates on the death rates of the post-neonatal (1–13 months) and the child (14–59 months) ages. The basic form of this model is

$$\lambda_i(t)=\lambda_0(t)\exp(\beta_i x_i),$$

where $\lambda_i(t)$ is the force of mortality at age (months) t for an individual, $\lambda_0(t)$ is the baseline hazard at age t, β_i is the regression coefficient estimated by the Partial–Likelihood method of Cox (1972), and x_i is an array of independent variables.

The baseline function, $\lambda_0(t)$, is defined when all independent variables in the model take the value of zero. It is roughly analogous to the constant term in a standard regression, with the major exception that $\lambda_0(t)$ denotes values that change over time rather than a single value. The dependent variable, $\lambda_i(t)$, is the hazard rate (death rate) at any given age t. This rate is modelled by modifying the baseline hazard function, $\lambda_0(t)$. The estimated coefficients of the hazard model, when exponentiated, are interpreted as relative risks of dying. The estimate of relative risk should be viewed as a scalar quantity that raises or lowers (depending on the sign of β) the underlying baseline hazard proportionally within each of the post-neonatal and child age segments.

Analytical strategy

Access to water supply and sanitation was observed at the time of the interview, while data on the survival of children relate to a period of years before the interview. This causes two analytical problems. First, some births, especially the first or second births of older women, may have been exposed to a different environment from that at the time of interview, because peoples' access to water and sanitation may have changed, especially after independence.

However, no major changes have been made in either water- or sanitation-system constructions after independence. Because of the war, there were no constructions or maintenance of water and sanitation facilities before independence either. Underscoring the problems of water supply, a report by UNICEF (1996) pointed out that 'while urban Eritreans may have access to piped water, the systems are old and lose as much as half their water through leaks and breaks. Rural Eritreans collected water from springs, rivers, wells or reservoirs.' With regards to sanitation, the report stressed that only 40% of the capital city's houses are connected with piped sewerage, but the system is still in poor repair and in several cases it empties into peri-urban neighbourhoods, posing serious health risks. Thus, since there has been no significant change in water supply and sanitation during the past 10 years, it is unlikely that older children were exposed to a different household environment at the time of their birth from that during the survey time.

Secondly, even if the water supply and sanitation are unlikely to have changed in specific locations, people themselves may have changed their environments by changing their place of residence. To circumvent this, births were excluded that occurred before their mothers moved to the current place of residence. In general, however, measurement of factors at the time of birth of the child would further enhance the study of infant and child mortality in developing countries, including Eritrea.

A further complication is that it is possible that the availability of piped water and sanitation facilities are correlated with a number of other factors, a correlation which could neutralize the effect of water supply or sanitation. For example, households with high economic status are more often connected to piped water supply and flush toilet facilities; educated mothers are more aware of the advantage of using clean water for cooking food for the child, etc. Such an association between piped water supply and sanitation and other controlling and mediating factors on mortality could result in the disappearance of the pure effect of water supply and flush toilet on mortality. In such a case, the true benefit of water or sanitation cannot be estimated without controlling for confounding variables (Esrey & Habicht, 1986). By inclusion of socioeconomic factors in the analysis, the bias of some of these factors may be eliminated.

Many studies of early childhood mortality in developing countries do not analyse mortality by age of the child. This can be a serious problem as the impact of environmental factors are unevenly distributed among various age groups (Blum & Feachem, 1983; Esrey & Habicht, 1986). Available evidence indicates that water supply and other environmental factors affect mortality at relatively higher child ages rather than immediately after the birth of the child (Poppel & Heijden, 1997). In this study, the models were estimated separately for three different age segments of the child's life: (1) neonatal – the first month after birth, (2) post-neonatal – from 1 to 13 months, and

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(3) child – from 14 months up to 5 years of age. This breakdown allows the examination of the effect of household environment on different age periods of the under-five mortality.

Finally, there are numerous factors that may influence the effects of water supply and sanitation on early childhood survival which we are not able to take into account. These include factors that reflect cultural beliefs and practices of the people. The cultural pattern of different ethnic or religious groups can be varied and may enhance or inhibit hygiene change. Beliefs and practices about childcare and causes of childhood diseases and their treatment are of special interest. Even though information on ethnicity and religion was collected in the EDHS survey, this information could not be assessed. Other factors that could not be considered, and which most probably confound the results of this analysis, are the extent of overcrowding, patterns of infections (e.g. malaria and other diseases causing poor nutritional status) and breast-feeding. Overcrowding, for example, enhances the spread of pathogens directly from one person to another and this will mask the true effects of improved water. The length of breast-feeding has a crucial role in child survival, especially when sanitary conditions are poor (Pebley & Stupp, 1987), but there are several potential problems with the breast-feeding data in the EDHS survey. First, the distribution of the length of breast-feeding shows that the data are heavily heaped on popular durations: 12, 18 and 24 months. These results are problematic because they may bias the true effect of breast-feeding, resulting in inaccurate estimates of infant and childhood mortality. Another problem is that it is not possible to distinguish periods in which the child was being exclusively breast-fed from those in which the child was in the process of being weaned. The introduction of supplementation with other liquids or foods (i.e. other than breast milk) marks the beginning of a child's exposure to possibly contaminated food, or liquids. Moreover, since the data on breast-feeding and other health care variables were collected in the EDHS only for children born about 3 years prior to the survey, they are too thin for meaningful analysis, especially when only data for urban areas are considered. Most of the variables indicated here are more direct or proximate determinants of child mortality. Presumably, the distant variables (mother's education, household economic status, and urban residence) considered in this analysis may also act as proxies for many of these proximate determinants.

Variables

Several environmental and socioeconomic variables that influence infant and child survival are available in the Eritrea Demographic and Health Survey (EDHS). For the purpose of this study, the key covariates were water supply and sanitary facilities. Control variables included mother's education, place of residence, household economic status and year of childbirth. All the covariates were represented as a series of dummy variables. A list together with descriptive statistics of all the covariates used in the present analysis is given in Table 1. A brief description of each of these covariates is given below.

Household environmental factor. The information about household environmental conditions collected in the EDHS survey covers sources of drinking water and toilet facilities. In terms of water supply, respondents were asked whether the source of water was piped or non-piped. The latter group comprised wells, springs, rivers, lakes, tanker trucks, etc. Respondents were also asked whether the dwelling had flush or non-flush toilet facilities (the latter group included households using traditional pit, pit latrine, open field or other). Since the number of households that had a flush toilet but not piped water was very small, it was considered that the collective effect of these two environmental measures may be more important than the individual effect of each of the two. Thus, a new 'household-environment' variable was produced by collapsing these two factors. Originally, three levels of the household-environment variable were defined: (1) neither piped water nor flush toilet = poor household environment; (2) either piped water or flush toilet = medium household environment, and (3) both piped water and flush toilet = good household environment. However, no difference was found in the relative risks of the preliminary models between poor environment and medium environment. Thus, these two levels were collapsed into one level (= poor household environment).

Socioeconomic factors. Four socioeconomic factors were considered in this analysis: education of mother, household economic status, type of place of residence and birth year of child. Education was measured in terms of the highest level of education completed. Four categories of education were given in the EDHS: no education, primary, secondary and higher. These four categories were recoded into two: no education and primary or higher. A further split of the primary education or higher group, though analytically desirable, was not feasible because of the small number of women, and hence births, in the secondary and post-secondary groups.

Like most DHS surveys, the EDHS did not attempt to collect information about income directly. Instead, respondents were asked about the consumer durables owned by the household, such as radio, television, car, bicycle, farming animal and the like. In this study, the first three items were best regarded as proxy for general household wealth in urban areas. These variables (i.e. radio, television and car) were used to construct a new household-wealth variable with three levels, and was defined as low if the household possessed none of these items, medium if the household owned only a radio, and high if the household possessed a television, car or both.

Type of place of residence indicates the current residence of the respondent at the time of the interview and is coded as city, town or rural. Rural refers to all localities with fewer than 2000 people, while city and town refer to localities with 2000 people or more and with some major municipal facilities or social services. As indicated earlier, this study was restricted to urban areas (cities and towns). In the EDHS, no clear definition is given for 'city' and 'town', except that a town is a lower urban administrative level, and a city is a higher urban administrative level.

Year of birth of the child is an important factor in indicating trends in the risk of child mortality because children can be exposed to different time hazards in different periods. The period prior to mid 1991 represents a time of political disruption, displacement and war, and fighting was especially intensive during the last phase of the war, in 1989–1991. The 4 years immediately before the survey (i.e. 1992–1995) instead represent a period of political stability, peace, reconstruction and rehabilitation of socioeconomic and other networks in Eritrea. Including this variable in the analysis may therefore be of particular interest for many Eritreans concerned with the health

Table 1. Variables included in the models of child mortality, urban Eritrea, 1995

Variable	Percentage of births
Household environmental factor	
Poor environment	74·7
Good environment	25·3
Socioeconomic factors	
Maternal education	
No education	49·0
Primary or higher	51·0
Urban residence	
Town	42·8
City	57·2
Household economic status	
Low	24·3
Medium	54·0
High	21.7
Birth year of child	
1985–88	33·9
1989–91	26·7
1992–95	39·4

conditions of children because it will indicate the direct or indirect effects of the war and the benefits of peace after the war. Birth year is defined here as 1985–88, 1989–91 and 1992–95.

Results

Figure 1 shows estimates of the proportions of children who had survived up to a specific age during the first 5 years of life, according to availability of a good household environment (access to both piped water and flush toilet facility).

The data show that during the whole childhood life span, the proportion of surviving children is much higher for those born in households which had a good environment (i.e. both piped water and flush toilet) than for those born in households for which that was not the case. The probability that a child will die before age 5 is about 7% if the child is from a household that had a good environment, while it is as much as 15% if the child is from a household that did not have access to such facilities. It is also evident from Fig. 1 that differentials are smaller in the early infancy period, but widen with increasing age up to the fourth year of life; thereafter the differences remain constant.

The estimated relative risks from different models for the three age groups, namely the neonatal, post-neonatal and child ages, are presented in Tables 2, 3 and 4, respectively. Each table contains three models. Model 1 includes only the household variable. Model 2 contains only socioeconomic variables, namely maternal education,

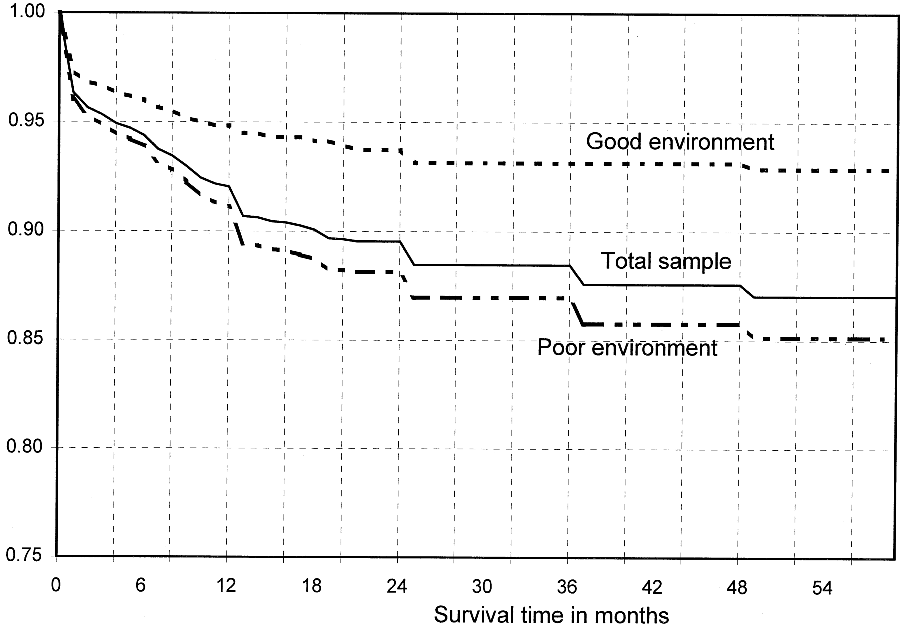

Fig. 1. Probability of survival during the first 5 years of life according to availability of a good environment in the household, urban Eritrea.

household economic status, place of residence and birth year of child. Finally, Model 3 combines all variables of Models 1 and 2, in order to assess the conditioning effect of the distant socioeconomic variables on the association between household environment and mortality. At the bottom of each table, degrees of freedom of each model and associated changes in model statistics (change in χ^2 statistics, from the initial model) are displayed. The results of the estimated models for each age group are presented below.

The neonatal period

Nearly half (47%) of infant deaths and about one-quarter (24%) of all under-five deaths in Eritrea occur during the neonatal period (i.e. during the first month after birth). Table 2 presents the estimated relative risks of neonatal death according to the environmental and socioeconomic factors described earlier. Examination of the results reveals that the unadjusted effect of household environment is substantial, but not statistically significant (Model 1). Urban children are 33% less likely to die if they live in households with access to a good environment (i.e. both piped water and flush toilet) than if they live in households with a poor environment. However, after controlling for the effect of maternal education, household economic status, urban residence and birth of child, the advantage that can be gained from living in houses with a good environment almost totally disappears (Model 3). This suggests that most of the association between household environment and neonatal mortality is due to other factors associated with socioeconomic status rather than to disease transmitted directly by water and faeces.

Table 2. Relative risk of neonatal mortality associated with model variables

Variable	Model 1	Model 2	Model 3
Household environmental factor			
Poor environment	1	—	1
Good environment	0·67	—	0·90
Socioeconomic factors			
Maternal education			
No education	—	1	1
Primary or above	—	1·21	1·22
Urban residence			
Town	—	1	1
City	—	0·83	0·84
Household economic status			
Low	—	1	1
Medium	—	0·93	0·93
High	—	0·38**	0·39**
Birth year of child			
1985–88	—	1	1
1989–91	—	1·37	1·38
1992–95	—	1·03	1·03
Degrees of freedom	1	6	7
χ^2 statistic (change in model X)[a]	3·35	12·23	12·35

*Factor level significant at <10%, **significant at <5%, ***significant at <1%.
[a]α^2 against model with constant only.

Of the socioeconomic variables entered in Models 2 and 3 of Table 2, only household economic status showed a strong and significant influence on neonatal mortality. Even though household economic status is important in determining mortality during the neonatal period, it is important to note that it is only the highest economic level that tends to reduce neonatal mortality. Children born in the most advantaged households are about 60% less likely to die than children born in households of the lowest or medium economic levels. It may be that mothers from the most wealthy households were more likely to have access to adequate nutrition and health care services during the time of pregnancy or delivery. Socioeconomic status may partly act as a proxy for these proximate variables.

The results of Models 2 and 3 show no significant association between education and mortality during the neonatal period. The effects of city/town residence and year of birth on neonatal mortality are also not significant (Models 2 and 3). However, the risk of mortality is elevated during the period of the last phase of the war.

The post-neonatal period

Model 1 of Table 3 shows that when the other variables are not controlled, access to piped water and sanitation has a large and significant effect on post-neonatal

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Table 3. Relative risk of post-neonatal mortality associated with model variables

Variable	Model 1	Model 2	Model 3
Household environmental factor			
Poor environment	1	—	1
Good environment	0·42***	—	0·60*
Socioeconomic factors			
Maternal education			
No education	—	1	1
Primary or above	—	0·81	0.87
Urban residence			
Town	—	1	1
City	—	0·91	0·97
Household economic status			
Low	—	1	1
Medium	—	0·68*	0·70*
High	—	0·32***	0·40***
Birth year of child			
1985–88	—	1	1
1989–91	—	1·18	1·18
1992–95	—	0·85	0·82
Degrees of freedom	1	6	7
χ^2 statistic (change in model *X*)[a]	29·58	25·60	44·00

*Factor level significant at $<10\%$, **significant at $<5\%$, ***significant at $<1\%$.
[a]χ^2 against model with constant only.

mortality. The risk of mortality is 58% lower among children born in households with a good environment than among those born in households with a poor environment. Even after controlling for socioeconomic variables, the effect of household environment still remains substantial and statistically significant (Model 3), though it is weaker than the unadjusted effect. This decrease in the net effect of environmental conditions is in line with other studies (e.g. Hobcraft *et al.*, 1984) that found little or no significant effect of water supply and sanitation on mortality after socioeconomic factors were controlled for. In this case, however, a strong effect still remains even after the socioeconomic variables are held constant.

As in the case of the neonatal period, education of mothers has no important effect on mortality during the post-neonatal period (Models 2 and 3). The effect of place of residence also remains insignificant during this age period. Household economic status differentials are, however, large and significant: children from the most advantaged households enjoy the lowest mortality, the middle have fairly low mortality and poor children have highest mortality. Although post-neonatal mortality is lowest during the post-war period, the effect of birth year remains insignificant.

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Table 4. Relative risk of child mortality associated with model variables

Variable	Model 1	Model 2	Model 3
Household environmental factor			
Poor environment	1	—	1
Good environment	0·37***	—	0·68
Socioeconomic factors			
Maternal education			
No education	—	1	1
Primary or above	—	0·54**	0·58**
Urban residence			
Town	—	1	1
City	—	0·92	0·92
Household economic status			
Low	—	1	1
Medium	—	0·62*	0·62*
High	—	0·25***	0·30**
Birth year of child			
1985–88	—	1	1
1989–91	—	1·75**	1·69*
1992–95	—	1·07	1·07
Degrees of freedom	1	6	7
χ^2 statistic (change in model *X*)[a]	23·81	27·98	43·01

*Factor level significant at $<10\%$, **significant at $<5\%$, ***significant at $<1\%$.
[a]χ^2 against model with constant only.

The child period

During the child period, the unadjusted effect of household environment on mortality is highly significant (Model 1 of Table 4) and even stronger than during the post-neonatal period, but weakened when the control variables are included. The household environment differential in child mortality of 63% is reduced to 32% after the inclusion of the control variables.

Consistent with findings for most other developing countries (e.g. Cleland & van Ginneken, 1988; Obungu *et al.*, 1994), and with expectations, the risk of child death is inversely related to maternal education (Models 2 and 3). Children born to mothers with some education experience a significantly lower risk of mortality (42–46% lower) than children born to uneducated mothers.

As in the case of the neonatal and post-neonatal periods, the risk of death during the child period does not differ significantly between towns and cities. The association between household economic status and child mortality is negative and statistically significant. Children born to the most advantaged families are 70–75% less likely to die than children from the poorest families. Finally, mortality is found to be highest towards the end of the war. It is significantly higher than during both the post-war and

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early periods. Children born during the period 1989–91 were at about 70% higher risk of death than children born during 1985–88 and during the post-war period.

Before proceeding to discuss these findings, it should be noted that comparison of the model statistics for Models 2 and 3 of each table shows that the inclusion of the household-environment variable in Model 3 is associated with significant improvements in the fit of the model for the post-neonatal and child periods, but not for the neonatal period. Each possible interaction of household environment with the rest of the variables was also added to Model 3 (not shown) to check whether inclusion of the interaction yielded significantly better results. The results showed that they did not add significantly. It is concluded, therefore, that Model 3 describes the data most satisfactorily for the post-neonatal and child periods. For the neonatal model, the addition of household environment did not contribute to the improvement of the fit of the model.

Discussion and conclusion

While theory suggests that water supply and toilet facilities are important household environmental conditions in influencing child health, this has rarely been confirmed by rigorous experimental evidence. Some evidence is available, but because of the practical difficulties involved in conducting control trials of environmental interventions, their validity has been often questioned (Blum & Feachem, 1983). On the other hand, there are several studies based on single-round household surveys which have examined the relationship between child health and household environment, but the results from these surveys are not consistent. While some studies found the expected relationship between household environment and child health, others detected no such effect. These inconsistent findings may partly be due to methodological pitfalls in study design and inadequate controls, and partly due to lack of attention paid to control for various confounding socioeconomic factors (Blum & Feachem, 1983; Esrey & Habicht, 1986). Failure to analyse infant and child mortality by age of child is also one of the shortcomings that contributes to such confusing results (Blum & Feachem, 1983).

Household surveys of the EDHS type are not ideal devices for establishing definitive conclusions about the impact of water supply and sanitation on child health (Timaeus & Lush, 1995). Such surveys are also not capable of providing adequate information for distinguishing the important mechanisms that mediate between water supply and child survival. For an in-depth and rigorous analysis of the effects of water supply and sanitation on child survival, longitudinal surveys or case-control studies may be more appropriate than single-round surveys. Household surveys can nonetheless be used to improve our understanding of various aspects of the relationship between child mortality and household environment, which may be of relevance to urban health-development programmes.

First, the EDHS survey can be used to investigate the association between the household environment and child mortality in urban Eritrea for different age groups of children's lives. While it is known that the impact of environmental intervention on mortality is not the same at all ages (Blum & Feachem, 1983), many of the recent studies on environmental differentials in mortality do not adopt such an age-specific approach. This study, in contrast, has tried to investigate the effects of household environment on child mortality at different sub-periods of the first 5 years of life.

Table 5. Relative risks of death according to household environment, before and after adjustment for socioeconomic factors, by age of child

Age of child	Poor household environment	Good household environment
Neonatal		
Unadjusted	1	0·67
Adjusted	1	0·90
Post-neonatal		
Unadjusted	1	0·42
Adjusted	1	0·60
Child		
Unadjusted	1	0·37
Adjusted	1	0·68

Second, by comparing the unadjusted and adjusted risks of mortality, separation of the direct (or independent) effect of the household environment from the effect that comes from the confounding socioeconomic variables considered in this analysis has been attempted.

In general, these findings indicate that household environment differentials in urban mortality increase in size with increasing age of child. Specifically, absolute household environment differentials in survival are smallest in the early infancy period, but widen with increasing age up to the fourth year of life (Fig. 1). Findings from the univariate analysis (Model 1 in Tables 2–4) also indicate that the relative mortality differentials are much smaller during the neonatal period than during the post-neonatal and child periods. For clarity, a summary of the results associated with household environment are shown in Table 5.

When the socioeconomic variables were introduced into the neonatal analysis, the household environment differential in mortality almost disappeared. This suggests that it is not the degree of inequality in household environmental conditions that explains most of the differentials in neonatal mortality, but the socioeconomic differentials that are associated with household environment. These results are consistent with the general notion that the effect of household environment is less important during the first month of life, that is, during a period when all children are largely protected from water- and sanitary-related infections by exclusive breast-feeding (Obungu *et al.*, 1994). It is widely recognized that neonatal mortality is largely influenced by biological characteristics, such as maternal propensity to low birth weight and prematurity, and complications associated with pregnancy and delivery (Zenger, 1992; Pinnelli, 1993) rather than infections associated with unsafe water and inadequate sanitation. Effective use of health care services, especially prenatal care and place of delivery, may also have an important influence on infant and child mortality (Gaminiratne, 1991; Forste, 1994). It is therefore possible that the socioeconomic variables included in this model, especially household economic status and education, may be acting partly as proxies for such uncontrolled intermediate health factors. It is noteworthy that because of the limited information on health variables, including breast-feeding and birth weight, it was not possible to control for the effects of these variables.

It is suggested that water supply and sanitary facilities have the most pronounced effect on child mortality at the time when supplementary foods (weaning foods) are introduced (Trussell & Hammerslough, 1983; Obungu *et al.*, 1994). Poor household environment may be more important in affecting the health of weaning children, because weaning food introduces a number of pathogenic organisms which cause diarrhoeal diseases (Gaminiratne, 1991). For instance, if bottles for formula milk are not cleaned properly or if the water used for the preparation of the milk is not adequately boiled, the infant formula can be a source of bacteria. The present findings support this hypothesis: during the post-neonatal period, the presence of piped water and flush toilet exerts a strong negative effect on the risk of dying, even when other variables are controlled for. The effect of household environment is also substantial during the child period, although its significance is not retained when the influences of other variables are controlled for. These findings are consistent with Trussell & Hammerslough (1983)'s study, which showed the strongest association between toilet facility and mortality during the post-neonatal period. Other studies (e.g. Obungu *et al.*, 1994) also showed that flush toilet is considerably associated with lower mortality during the late post-neonatal period after controlling for mother's education and household economic status.

This study further indicates that education of the mother (after controlling for household environment, city/town residence, household economic status, and birth year of child) is not an important determinant of mortality during the neonatal period, when biological factors rather than childcare practices are most important in determining mortality. During the post-neonatal and child periods, the effect of education is in the expected direction, although it is only statistically significant for the latter period. Educated mothers are more likely to introduce weaning food earlier, which may affect the child's survival negatively. During the child period, most children are weaned and therefore the effect of education through feeding supplementary foods may be less important than before. During this period, the effect of mother's education may operate through other factors. The strong effect of maternal education during the child period also reaffirms the importance of education in reducing risks of mortality at relatively higher ages of the child's life span. It also confirms that the education effect cannot be explained by more favourable household economic status.

Household economic status inevitably play an important role in influencing human behaviour. Consistent with results from many other studies in developing countries, it was found that children from households that are socioeconomically advantaged appear to be at lower risk. The beneficial effects of belonging to the most advantageous group seem to be very important at all age periods. Economic status of households partially also conditions the possibility to construct and maintain adequate water supply and excreta disposal facilities.

The results show no significant survival advantage accrued to city residents after controlling for differences in household environmental and socioeconomic conditions. Perhaps it could be that inequalities in the provision of health services between the two types of locality are not important. Finally, the results show that the 1989–91 birth cohort appeared to be more vulnerable to mortality than either the preceding or subsequent birth cohorts. This effect is most pronounced during the child period.

In general, if the adjusted relative risks presented in Table 5 are taken as valid indications of the pure effect of household environment on mortality of children in urban Eritrea (after the removal of the influence of socioeconomic advantages enjoyed by the households with good environment), a very strong effect beyond the first month of life, and a more limited effect during the first month of life are found. During the first month after birth, socioeconomic factors (possibly acting as proxies for factors such as biological characteristics and health care services) account for most of the association between household environment and mortality.

Finally, even though it is difficult to conclude through what mechanisms the distant socioeconomic variables are conditioning the child mortality reductions, these findings suggest that improvements in the provision of water supply and toilet facilities are likely to reduce mortality, especially beyond the first month of life. The policy implication of these findings is that increased availability and use of piped water and flush toilets certainly would have some effect on mortality during the post-neonatal and child periods. Thus, interventions in water supply and sanitation should be given priority in Eritrea.

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