Risks, Amenities, and Child Mortality in Rural South Africa

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Abstract

Using a dataset from rural South Africa, this paper examines the effects of many established factors associated with child mortality at different ages and introduces some less explored issues, such as cause of death. Derived from a community census, the dataset captures many vulnerable people who are usually excluded, like children whose mothers have died or who are often away from home. The study revealed that the most significant predictors of child mortality are characteristics of the mother, especially her birth history, marital status and education. Factors specific to the individual child, such as being a twin, are important determinants of survival, but only during the first few months of life. Characteristics of the household, including economic and sanitation resources like source of drinking water and electricity, are ambiguously related to child survival, but regional characteristics underlie some of these relationships. The study presents some evidence that AIDS mortality follows a different distribution from overall mortality and may be changing the distribution of deaths among households.

Background

Several decades of research on child mortality have yielded many hypotheses and extensive empirical findings about the causes of infant and child deaths. Many studies have found the circumstances of birth and child characteristics to be important to survival. It is well established, for example, that twins and triplets have lower survival than singletons, and they are in fact often left out of analyses of child mortality (Guo and Rodriguez, 1992; Curtis *et al*. 1993). Gender is often a significant factor, with boys doing better in settings where they are preferred (see, for example, Das Gupta, 1990), and girls doing better otherwise.

The age of the mother at the birth of the child and the number of children she has already had are often considered important. Both variables have often been found to follow a J-shaped relationship for infant mortality

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(Curtis *et al*., 1993; Sastry, 1997). However, Gubhaju (1985) reports that, in Nepal, the risk of infant deaths generally decreases with the age of the mother. Reichman and Pagnini (1997) found that the relationship differs by race in the United States, with whites having a U-shaped relationship between the age of the mother and child mortality, and African Americans having a continuously increasing risk of child mortality at increasing maternal ages. Also focusing on heterogeneity within populations, Zaba and David (1996), using census data from Kenya, found that, among women at unusually high parities for their age, the "fast reproducers", there is increasing variability in risk. Das Gupta (1990), on the other hand, found both mother's age and parity to be dispensable. Many studies have focused on the intervals surrounding the birth. For example, Sastry (1997), Curtis *et al*. (1993) and Das Gupta (1990) found that being born after a short birth interval is detrimental to an infant's chances of survival, and several explanations have been offered for why this would be the case (Arulampalam, 2003).

A woman's socio-economic status has long been believed to affect her children's survival chances. One of the most frequent explanatory variables in the literature has been mother's education. Studies have consistently found that the children of women with some education do better, though the thresholds of the effect vary between study populations. For example, Sastry (1997) reports that in Brazil, mothers with at least three years of schooling experience 32% lower mortality risk among their children than less educated mothers. In a study of several African countries, Madise *et al*. (1999) found higher levels of education, secondary and beyond, to be important to child health. Magadi (1997) reported that father's, not mother's, education is significantly associated with child health in Kenyan communities where the status of women is low. Maternal education is usually included not only for its face value, but also as a proxy for other characteristics of the mother, the household, and the community. For example, Curtis *et al*. (1993: 36-37) explain that they use mother's education "as a general control for socio-economic status and for knowledge of health-related matters".

Other maternal characteristics, like marital status and migration, have been less explored, in part because of lack of variation within developing-country study populations or lack of adequate data. However, there is reason to believe that these factors play an important role in child outcomes. For example, a study from rural KwaZulu-Natal that did consider migration found that, in 1992, HIV was "three times more likely among those who have recently changed their place of residence" (Abdool Karim *et al*., 1992 in Lurie *et al*., 1997: 18).

Many studies have included household socio-economic characteristics, most often sanitation facilities, sources of drinking water, and sometimes income. The influence of socio-economic factors on child mortality is often considered within the Mosley-Chen (1984) framework, with socio-economic determinants affecting child health through maternal factors, environmental

contamination, nutritional inputs, and injury. However, socio-economic measures have often proved to be surprisingly weak in explaining child mortality. Casterline *et al*. (1989), using Egyptian data, found only weak and insignificant effects of household water source, toilet facilities, and income on infant and child mortality. In India, Das Gupta (1990) found that variables such as land ownership, per-capita income, toilet hygiene and source of drinking water were not significantly associated with child mortality. However, Guo's 1993 study reports that household socio-economic status explains much of the distribution of child mortality in Guatemala, leaving little unexplained variation. Also, Madise *et al*. (1999) found that having any sort of toilet facilities and owning household items were positively associated with child development in several African countries. Alderman *et al*. (2003) found significant positive effects of sanitation facilities and good water supplies on child health even when controlling for income, though these are weak when the household's urban location is included in the model. Using data from Brazil, Thomas (1990) presents evidence that child health is affected by who controls income within the household, with mothers devoting more resources to child health than fathers. Other household characteristics that have been shown to be relevant include the number of siblings and their survival (for example, Arulampalam and Bhalotra, 2003; Gubhaju, 1985; Curtis *et al*., 1993; and Das Gupta, 1990) and the presence of grandmothers (Voland and Beise, 2002).

Some recent papers also consider how community characteristics might influence child mortality. Using data from several communities in Brazil, Sastry (1996, 1997) found that community characteristics like sanitation services and drinking water are more important than family effects. Kanaiaupuni and Donato (1999) report that paved roads and female labour force participation are also important. Alderman *et a*l. (2003) also found evidence of important neighbourhood externalities for child health: the education level of other women in the vicinity is positively correlated with child height in Peru, even when controlling for own mother's education.

Age and cause of death offer important clues about the pathways of influence between the circumstances and characteristics discussed above and child mortality. Boerma (1996: 17) pointed out that "the relative importance of proximate determinants will vary considerably with age". He goes on to explain that maternal factors are most important to neonates, water quality becomes important at weaning, and vaccinations are protective after the ages at which they are administered. Among causes of death, Becker and Black (1996) emphasize the importance of considering AIDS specifically in studies of mortality trends, as does Clark (2002).

Conceptual Framework

Child health and survival are shaped by the intersection of bio-demographic and socio-economic circumstances. Each child is born with a number of personal characteristics, most of which are shaped, changed, and constrained by the circumstances and choices of the mother before as well as

after the birth of the child. The mother is simultaneously embedded within a household, whether it be that of her parents, her husband, or her own. The characteristics and health of the child are also formed and affected by the resources of that household, its priorities, choices, and position within the community. Finally, the resources, networks, and culture of the community affects the young child primarily through its household and its mother. We thus have a myriad of characteristics, circumstances and interactions that are of great importance to child health, only some of which are observable. Using a detailed longitudinal survey of a rural South African population, this paper examines the relationships of child, maternal and household characteristics with child mortality.

Among the characteristics specific to the child, we have selected the child's sex, birth order, the age of its mother at the time of the birth, and whether it was a singleton or a multiple birth. In this population, as in many African settings, young girls tend to have slightly better outcomes than young boys. Multiple births are usually excluded from studies of child mortality because they are expected to have much higher mortality than singletons, but this high twinning population offers a good setting to determine how and when twins and triplets are at a disadvantage. It may be that the disadvantages they face are only found early in life, so that those who survive the neonatal period have outcomes similar to those of singletons. As in other populations, birth order and mother's age at birth are expected to have a non-linear, J-shaped relationship with child mortality.

Turning to maternal characteristics, we consider education, marital status, circular migration, reproductive history, and survival. Many of these characteristics of the mother are shaped by household resources and decisions, which themselves affect child health. However, they can be expected to influence child health independently as well, for example through maternal health or through childcare. Though marriage is often a criterion for inclusion in studies such as this and non-marital births are excluded, this population is particularly well suited for studying the effects of marital and partnership relations because, unlike many study populations in developing countries, marriage is not universal, and the majority of the children studied here have unmarried mothers. This population also offers an interesting setting in terms of education, because, while many of the women of childbearing age have no education at all, many do reach high school and even post-secondary education. Finally, South Africa is known for migrant labour, and many of the women in this area spend time away from home regularly, a practice that can be expected to affect child health negatively or positively, depending on the balance of child care arrangements, possible contact with diseases, and the additional income generated.

The circumstances of households which can have an impact on child health are economic resources, hygiene, crowding, and proximity to public amenities and hazards. The indicators selected here are electricity, main source of drinking water, toilet facilities, and the survival of other children

in the household. Electricity is a measure of both household income, that is, ability to pay electric bills on a regular basis, and of community characteristics, in that households in the more urbanized neighbourhoods are more likely to be on the electricity grid. Source of water also serves as a dual proxy. On one hand, a household's location in part determines the water source, for example whether there is easy access to a borehole or a public tap. On the other hand, even though water is supposed to be free for all by law, in reality households often have to pay for access to clean water. For example, if they can afford it, they can secure an internal water tap, or pay for water from a fee tap, or, if they are destitute, fetch water from a river. Type of toilet is the most household-specific variable, with those who can afford it having the possibility to build a ventilation-improved pit latrine or even a flush toilet, while others must settle for the cheaper open pit latrines or even go in the bush. We include a variable indicating whether another child born since 1995 had died. This serves as an attempt to assess the distribution of deaths among households and to capture unobserved risks. A large relative hazard would indicate that households that have one child death are more likely to have another[2].

We can expect that some of these variables would be more important at different ages. For example, a newborn might not be as affected by the quality of drinking water as an older child, because it would be breastfed and so would not usually drink contaminated water. A twin that has survived through the first few months of life might have already survived many of the dangers of twinning and therefore may be as likely to survive as singletons. Other characteristics, like the mother's survival, are likely to be important for children at all ages. The age groups were split based on empirically grounded expectations for causes of death in the study population: neonates, 1 to 6 months, 6 to 12 months, 1 to 2 years, and over 2 years. Based on findings from verbal autopsies, we know that most of the neonates die from perinatal causes, like pre-maturity and birth trauma, often compounded by communicable infections. Most children in this area are largely breastfed up to the age of 6 months, and so are protected by the mother's immune system (Thairu, personal communication). Nonetheless, the majority of children who die at these ages die due to communicable diseases, particularly respiratory and diarrhoeal infections, as well as AIDS. Most child AIDS deaths occur between the ages of 6 and 24 months, and the majority of deaths at these ages are attributed to AIDS. After the age of 24 months, children become mobile and accidents become the most important cause of death. The majority of deaths occur before the age of 6 months, and few deaths occur after 24 months.

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[2] There are two approaches to this measure in the literature: some use a measure for whether any child other than the index child died, while others measure whether a child died previous to the index child. I have used both approaches. Since my purpose is general and is not intended to argue causality, I present results using the former method, but I also discuss results using the latter.

Cause of death, like timing of death, can provide information about the link between a death and the amenities and risks that led to its occurrence. For example, knowing that there was a cholera outbreak in a particular year strengthens the theoretical causal effect of drinking water quantity and quality. The dataset used here contains information from verbal autopsies for everyone who died since 2000[3]. In this paper, we focus specifically on AIDS, which is a major cause of death for children in the study population. We expect that AIDS deaths are associated with different socio-economic circumstances compared with other child deaths in the area, and furthermore that the increase in AIDS deaths is changing the distribution of child deaths among households. For example, it may be that wealthier households that are normally less vulnerable to child deaths are as vulnerable to HIV infection as other households.

Data

The study population comprises part of a district of KwaZulu-Natal, South Africa, a rural area with about 100,000 individuals who are members of over 11,000 households. This paper considers 7,045 households in which children were born between February 1995 and March 2002[4]. Table 1 provides some descriptive statistics. There were 13,682 births reported, of which 9% died by March 2002. These are the children of 9,974 mothers, with an average of 1.4 mothers in each household. The average mother was an unmarried woman in her mid-twenties with some education

A little less than half of the households had electricity. Whether a household has electricity depends both on whether its vicinity is wired for electricity and whether it can afford to purchase electricity. Most households have either no toilet or a pit latrine. The government has introduced a program to build toilets for those who cannot afford to build them themselves, but this provision had not reached many rural households by the time of the data collection rounds used here. Several sources of drinking water are common in the study area. The government has committed itself to providing piped water to poor rural people, but this service has also not reached many households. Currently, just over 40% of the study population drinks piped water. The other prevalent source is river water, which almost 23% of the population drinks, but which is known in the area to increase the risk of cholera[5].

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[3] Verbal autopsies are interviews used to determine causes of death in environments where many deaths are not supervised and recorded by health care providers. Diagnoses are reached through physician assessment of both disease algorithms and open-ended accounts of the circumstances of death.

[4] This includes most but not all households in which a child was born in the study area. The children of mothers who resided in a local household but were not members of a local household are excluded. Thus, child migrants in the area and abandoned children are generally excluded. Children whose mothers died before the beginning of data collection are also not generally captured in this dataset.

[5] For an example from a local paper, see Mawande (2002).

Table 1: Descriptive Statistics for the Sample Population

Variable	All Children	Child Deaths	Proportion of all with characteristic	Proportion of deceased with characteristic
Child-Specific Characteristics		**(N=13,682)**	**(N=1,196)**	
Gender				
Male	6,750	613	49.31%	51.25%
Female	6,743	547	49.28%	45.74%
Missing	189	36	1.40%	3.01%
Birth type				
Singleton	13,191	1,090	96.41%	91.14%
Twin or triplet	464	90	3.39%	7.53%
Missing	27	16	0.20%	1.34%
Birth order				
1st birth	4,967	417	36.30%	34.87%
2nd, 3rd, or 4th	5,852	553	42.77%	46.24%
5th or higher	2,863	226	20.93%	18.90%
Mother-Specific Characteristics				
Mother's age at the birth of this child				
Under 20	2,959	242	21.63%	20.23%
20 to 34	8,838	813	64.60%	67.98%
35 and over	1,885	141	13.78%	11.79%
Mother died between 2000 and 2002	271	103	1.98%	8.61%
Mother's education				
None	1,241	107	9.07%	8.95%
Lower primary	1,273	116	9.34%	9.70%
Higher primary	2,119	201	15.49%	16.81%
High school	6,357	481	46.46%	40.22%
Higher education	470	23	3.44%	1.92%
Missing	2,222	268	16.24%	22.41%
Mother's partnership status				
Married	2,931	181	21.42%	15.13%
Regular non-marital partner	8,674	809	63.40%	67.64%
Casual non-marital partner	456	47	3.33%	3.93%
No partner	1,295	132	9.46%	11.04%
Missing	326	27	2.38%	2.26%
Mother's presence in local household				
Is present most of the time	12,146	1,057	88.77%	88.38%
Spends time away regularly	1,197	104	8.75%	8.70%
Missing	339	35	2.48%	2.93%
Household-specific Characteristics				
Household electrification				
Is electrified	6,060	550	44.29%	45.99%
Is not electrified	6,436	527	47.04%	44.06%
Missing	1,186	119	8.67%	9.95%
Type of toilet facilities used				
No toilet or bucket only	5,027	435	36.74%	36.37%
Pit Latrine: open or ventilation-improved	6,641	586	48.54%	49.00%
Flush toilet	694	44	5.07%	3.68%

Unknown or uncommon facilities	1,320	131	9.65%	10.95%
Primary source of drinking water				
Flowing river	2,761	242	20.18%	20.23%
Piped water: internal or in yard	2,392	209	17.48%	17.47%
Public tap: free or paid	2,625	233	19.19%	19.48%
Wells and boreholes	2,565	217	18.75%	18.14%
Rainwater and stagnant water	1,146	105	8.38%	8.78%
Water carrier/tanker	276	25	2.02%	2.09%
Protected spring	614	40	4.49%	3.34%
Unknown or uncommon sources	1,303	125	9.52%	10.45%
Another child born since 1995 died	1,902	319	2.40%	1.90%

The source of the data used in this study is the Demographic Information System of the Africa Centre for Health and Population Studies in KwaZulu-Natal. Since January 2000, the Centre has collected demographic and socio-economic information on all individuals affiliated with the study area. It has an ongoing Demographic Surveillance Survey (DSS), a verbal autopsy program, and several associated sample surveys.

A unique characteristic of these data is the approach to household identity and relationships. Membership in the household is determined by household members themselves, with only minimal rules set by the survey. Individuals are tied to households both by membership and by residence, so they can be members of more than one household, or members of one household but residents of another. This structure allows for the inclusion of individuals who are members of local households but spend some or much of their time away from home.

All socio-economic covariates have been measured since the beginning of data collection in 2000. This could be problematic in examining children born before 2000, because the information might not reflect a household's socio-economic status or resources at the time a child lived and died, particularly if improvements like sanitation projects are delivered first to households that need them most, i.e. if a household gets a piped water connection because one of its children died of cholera[6]. For this reason, we

[6] A few mothers are members of multiple households, in which case only the principle one is captured here – the one in which the mother was a member in January 2000 and generally the one in which she resided at the time. A few children therefore actually lived in a different household or spent time in the recorded household as well as in another. This complication concerns a small but not insignificant number of children and would affect the results by miss-stating the resources to which children had access.

also performed the same analyses exclusively for children born since 2000, for whom the data are collected prospectively and who have been followed with data collection since their birth. The results from these analyses were similar to those reported in this paper. Income is not included among the household-level characteristics because, with high levels of unemployment and widespread informal work in this district, income measures are not available, and resource variables are the best available approximation of income[7]. Therefore, electricity, water source, and type of sanitation facilities are used as proxies.

Methods

Taking advantage of the fact that most children in the dataset are linked to their mother and to their extended household, we use three levels of data: the individual child, the mother, and the household[8]. This structure makes it possible to include some children whose mothers have died[9] and to capture household-level shared risks and socio-economic amenities.

First, we use Cox proportional hazards models to track the survival patterns of the children. The method estimates non-parametrically the contribution of exposure time (months lived) to the likelihood of a child dying at time *t*. Additionally, covariates are then allowed to shift this baseline proportionally. We control for non-independence of children living in the same household with robust standard errors at the household level. Separate proportional hazard models are run to capture the compounding effects of individual, maternal, and household characteristics, as well as differences in the effects of these characteristics at different ages:

$$h(t) = h_0(t)\exp(\beta_i X_i) \qquad (1)$$

where $h_0(t)$ is the baseline hazard function and X_i is a vector of covariates.

The first model includes only information specific to the child, to pinpoint the individual-level sources of risk. The next model adds characteristics specific to mothers associated with mortality hazards among their children. We now include factors of reproductive history, education,

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[7] Less than 30% of women and 40% of men report that they are employed or earning money (Calculations were provided by Hosegood, 2002).

[8] A possible concern might be that there is confounding between the socio-economic variables. For example, it could be that education, a good measure of economic well-being, is absorbing the effect of the water variables. To determine whether this is the case, we estimated separate models, isolating the socio-economic variables in several combinations. The significance and magnitude of the coefficients is not affected by this, supporting the validity of the present model.

[9] The mother's survival status indicates whether the mother died since the beginning of data collection in early 2000. Those children whose mothers died before 2000 may still be omitted. Some of these are not captured at all; others were probably identified by other women as their children. For example, there are a few children whose mothers were well over 45 years old at the child's birth, and these are likely not actually mothers but grandmothers or other guardians.

partnership, and migration in the model. The third model includes household characteristics as well. Finally, we estimate the third model for different age groups to capture the effects of these characteristics at different ages.

To determine whether the distribution of AIDS mortality in this population is different from other causes of child mortality, we present an exploratory comparison of the one-year probability of dying of AIDS and the one-year probability of dying from all other causes. Verbal autopsy information is only available for children who died in 2000 at this time. We calculate a multinomial logistic regression model where the dependent variable has three possible outcomes for the children who were alive on January 1, 2000:

$$p(y=1) = \frac{1}{1+e^{\beta_1^{(2)}X_i+\beta_1^{(3)}X_i}} = 0$$

$$p(y=2) = \frac{e^{\beta^{(2)}X}}{1+e^{\beta_1^{(2)}X_i+\beta_1^{(3)}X_i}} \qquad (2)$$

$$p(y=3) = \frac{e^{\beta^{(3)}X}}{1+e^{\beta_1^{(2)}X_i+\beta_1^{(3)}X_i}}$$

Outcome 1, the reference category, is survival through 2000, outcome 2 is death in 2000 from causes other than AIDS, and outcome 3 is death in 2000 as a result of AIDS.

Results

The infant mortality rate for the cohorts included in the analyses fluctuates around 74 per 1,000, with the majority of child deaths taking place in the first 6 months of life. Of the 7,045 households with children, over 85% did not have any child deaths by March 2002 among children born since 1995. Among those that did have child deaths, almost 86% only had one death. About 2% of the households with children born since 1995 had more than one of the children die, and these multiple-death households had about 27% of total child deaths. This distribution is much more even than that reported in other study populations[10].

Multiple Levels of Risk

Table 2 shows the results of proportional hazards models estimating the effects of child, maternal and household characteristics on child mortality among those born between 1995 and 2002. Because child mortality was increasing, primarily due to AIDS, throughout the period, we control for year of birth.

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[10] This is based on a comparison of: Zaba and David (1996), Curtis et al. (1993), DasGupta (1990) and Sastry (1997).

As shown in Table 2, Model 1, the most important individual-level predictor of death is whether the child was a singleton or a multiple birth. Twin and triplets are more than 2.5 times more likely to die than singletons. Boys are 14% more likely to be deceased than girls. Birth order and mother's age at the time of the birth are significant only in some specifications, and their effects are somewhat unusual, with high parity children and those with young and old mothers having better survival chances. This is different from the J-shaped pattern reported in other populations. It may result from the spread of HIV among women of childbearing ages in this area, with younger and older women being less likely to have contracted or developed AIDS.

Maternal characteristics are introduced in Model 2. The most important maternal influence on child survival is the mother's own survival. Those children whose mothers died since the beginning of data collection are more than 4.5 times more likely to also be deceased than children whose mothers are alive[11]. Also important to child survival are mothers' partnerships. Among those whose mothers are unmarried, those whose mothers are involved in non-marital partnerships have higher survival chances than those whose mothers have no partner. We can distinguish between the types of non-marital partnerships in which mothers are involved. As shown in Model 2, the children of mothers in a committed non-marital relationship do even better than those of women who are in casual partnerships having a 20% lower hazard of dying than the children of mothers with no partner. Children whose mothers are currently married have significantly lower chances of dying, with the children of married women facing about half the hazard of dying faced by the children of unmarried mothers with no partner. This is a finding that has seldom been reported but is strong and significant across specifications. This could be because of access to resources or because of selection. The children of married couples are likely to have access to the pooled resources of both parents.

[11] These odds would have probably been even greater if *all* children whose mothers died could have been identified.

Table 2: Hazard Ratios from Proportional Hazards Models of Child Mortality

Variable	(1) Child only	(2) Mother and child	(3) Household, mother and child
Child-specific Characteristics			
Child is male	1.144*	1.144*	1.136*
Twin or triplet	2.521**	2.423**	2.233**
Birth order (omitted category is "1st birth")			
2nd, 3rd, or 4th	1.088	1.060	0.999
5th or higher	0.884	1.002	0.923
Mother-specific Characteristics			
Mother's age at the birth of this child (omitted category is "Mother was 20 to 34 years old")			
Under 20		0.892	0.865
35 and over		0.849	0.893
Mother died between 2000 and 2002		4.485**	3.879**
Mother's education (omitted category is "No education")			
Lower primary school		1.080	1.086
Higher primary school		1.112	1.114
High school		0.877	0.890
Higher education		0.643+	0.669+
Partnership status (omitted category is "No partner")			
Married		0.553**	0.575**
Regular non-marital partner		0.810*	0.802*
Casual non-marital partner		0.988	0.960
Mother spends time away regularly		1.069	1.084
HOUSEHOLD-SPECIFIC CHARACTERISTICS			
Household is electrified			1.149+
Type of toilet facilities used (omitted category is "No toilet")			
Pit Latrine: open or ventilation-improved			0.974
Flush toilet			0.727+
Primary source of drinking water (omitted category is "Flowing river")			
Piped water: internal or in yard			1.043
Public tap: free or paid			1.010
Wells and boreholes			0.902
Rainwater and stagnant water			0.994
Water carrier/tanker			1.066
Protected spring			0.727+
Another child born since 1995 died			2.072**
Observations	13682	13682	13682
Log Likelihood	-11147	-11034	-10972
Robust z statistics used			
+ significant at 10%; * significant at 5%; ** significant at 1%			

Note: The Models Include Controls for Year of Birth. Odds Ratios for Categories with Missing Values on a Characteristic not Shown

Furthermore, marriage is likely a proxy for wealth, since only those who are fairly well off can afford to get married, especially in this setting, where men must pay a high bride wealth to marry[12]. The children of married women in general have an advantage in survival. If we distinguish between monogamous and polygamous marriages, it appears that children of

[12] The standard is 11 cows, which is to be paid up-front.

polygamous marriages are especially protected. This is further evidence that marriage might be correlated with unobserved wealth. When these models were estimated using fixed effects logistic regressions, we found that, even within the same household, the children of married women do better (not shown). This might be evidence that, within the same household, those women who are married or have a partner have access to more of the household resources or are towards the top of the household hierarchy, and therefore command more benefits for their children.

The educational level of the mother is only marginally significant at the highest levels of education, as shown in Table 2. Women with primary schooling had similar child mortality outcomes to women with no schooling. The advantage of education appears at the high school level. Mothers with high school education had better child outcomes, and those with postsecondary education had even better chances of not losing a child: about 40% lower hazard. Other studies of child mortality have found a much lower threshold for education effects. For example, Sastry (1997) divides women into those with and without three years of schooling; Bishai *et al*. (2003) divide women into those with and without any education; and Casterline *et al*. (1989) begin the highest educational group at 7 years of schooling. The present results are from a population with a relatively high level and wide range of educational attainment among women. They offer support for the hypothesis that measures of education do not only measure literacy and communication skills, as has often been suggested, but may be more importantly a proxy for other wealth and geographic advantages.

The measures of circular migration are usually not significant. In general, the results suggest that spending time away from the household is positively correlated with child mortality. It is possible to distinguish between mothers who are seldom in the household and those who work close enough to sleep in the household regularly, but no significant differences can be detected. The effects of these variables are likely determined by the characteristics of the location where the mother spends her time away and by the childcare arrangements she has during that time.

The individual and maternal characteristics discussed above - whether the child was a singleton, mother's education and marital status, and mother's survival - are robust to the addition of household-level variables. The most important household-level predictor of child survival is the survival of other household children, as shown in Model 3. Controlling for the survival of the mother, those children living in households where another child died are at more than twice the risk of also dying[13]. When using a more conservative measure, whether another child died previously, the indicator becomes weaker. This suggests that mortality clustering may not be as strong in this area as has been reported in other study populations.

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[13] The survival of other household children is an endogenous variable. Its inclusion, however, does not affect the magnitude and significance of the other variables.

Electricity, source of drinking water, and type of toilet do not contribute much. As would be expected, flush toilets are associated with higher survival than having no toilet facilities. Unexpectedly, river water is not shown to be a significantly more detrimental source of drinking water than other sources. In fact, households that use piped water taps, both at home and communal, as their principal source of drinking water are at least as likely to experience child deaths. It is the children living in households that use protected springs who have significantly better survival chances. Having electricity is positively associated with child mortality. Other South African datasets have also shown positive associations between amenities like electricity and child mortality (Simelane, personal communication). One explanation for this result is policy endogeneity – that is, programs aimed at improving living conditions may be placed among those who need them most – people living in areas where mortality rates are high. Another possibility is that household investments are being confounded with location characteristics. As discussed earlier, type of toilet used in a household is the only amenity included here that is specific to the household and is not directly affected by surrounding community resources. Electricity and piped water, which show some unexpected relationships with child mortality, reflect both household investments and location within the study area. Unobserved location characteristics may be affecting the observed characteristics. For example, households on the electricity grid may be in areas that are more susceptible to child deaths – close to highways or in dense, polluted areas. Preliminary results from the inclusion of community characteristics suggest that some of the household relationships discussed above are actually the result of community characteristics.

Effects by Age Group

Since certain amenities and hazards can only be expected to affect child health at certain ages, it is important to ask how these individual, maternal, and household characteristics might affect child survival at different stages of childhood. Table 3 shows the importance of the characteristics discussed in the previous section at each age group.

Bio-demographic characteristics, especially whether the child was a multiple birth, are most important at the youngest ages. Mother's survival is important to child survival at all ages observed. Babies are more than twice as likely to die if their mother died. The risk of the child's dying as well increases with age, reaching a 7-fold relative hazard above the age of 1. This is rather unexpected, since children are normally most dependent on their mother during the first few months of life. It is probably the effect of AIDS, with orphaned children dying not only because of neglect but succumbing to the infection that killed their mothers. As stated above, most child AIDS deaths occur around the age of 2, and over 60% of child deaths between ages 1 and 5 in 2000 are attributed to AIDS.

Table 3: Hazard Ratios from Proportional Hazards Models of Child Mortality, by age group

Variable	(1) Neonates	(2) 1 to 6 months	(3) 6 to 12 months	(4) Age 1	(5) Over 2 years
CHILD-SPECIFIC CHARACTERISTICS					
Child is male	1.159	1.154	1.137	1.011	1.107
Twin or triplet	3.760**	1.762*	1.571	1.145	1.671
Birth order (omitted category is "1st birth")					
2nd, 3rd, or 4th	1.040	1.028	0.984	1.207	0.636
5th or higher	1.010	0.710+	1.240	1.488	0.510
Year of birth	1.019	1.079**	0.975	1.114*	1.051
MOTHER-SPECIFIC CHARACTERISTICS					
Mother's age at the birth of this child (omitted category is "Mother was 20 to 34 years old")					
Under 20	1.186	0.686*	0.839	0.967	0.876
35 and over	1.129	0.925	0.769	0.591+	1.046
Mother died between 2000 and 2002	2.306**	4.891**	2.364**	6.606**	7.987**
Mother's education (omitted category is "No education")					
Lower primary school	1.276	0.814	1.089	1.868	0.908
Higher primary school	1.199	0.865	1.338	1.778	0.950
High school or college	1.114	0.649*	1.147	1.172	0.547
Partnership status (omitted category is "No partner")					
Married	0.689+	0.709+	0.708	0.128**	0.584
Regular non-marital partner	0.787	0.924	1.034	0.670	0.968
Casual non-marital partner	0.588	0.964	1.158	1.451	1.774
Mother spends time away regularly	0.989	1.216	0.712	0.731	1.779
HOUSEHOLD-SPECIFIC CHARACTERISTICS					
Household is electrified	0.982	1.339*	1.193	1.190	0.797
Type of toilet facilities used (omitted category is "No toilet"					
Pit Latrine: open or ventilation-improved	0.996	1.050	0.858	1.042	0.688
Flush toilet	1.097	0.665	0.450+	0.797	0.584
Primary source of drinking water (omitted category is "Flowing river")					
Piped water: internal or in yard	0.825	0.947	0.932	1.444	2.665*
Public tab: free or paid	0.825	1.002	0.909	1.749+	1.298
Wells and boreholes	0.862	0.750+	0.685+	1.726+	2.383*
Rainwater and stagnant water	0.636+	0.820	1.155	1.878+	2.292+
Water carrier/tanker	1.276	0.900	0.687	0.560	2.811
Protected spring	0.540+	0.716	0.633	1.519	1.532
Another household child born since 1995 died	2.384**	2.311**	1.758**	1.647*	0.794
Subjects	13682	13357	12550	11445	9306
Log Likelihood	-2983	-3705	-2415	-1282	-536
Robust standard errors used					
+ Significant at 10%; * significant at 5%; ** significant at 1%					

Note: The Models Include Controls for Year of Birth. Odds Ratios for Categories with Missing Values on a Characteristic not Shown

The mother's marital status is important for both neonates and older children. It is especially strong for children aged one to two years. This might be related to the fact that most children infected with AIDS die at these ages. Non-marital partners are not particularly important to child

survival at any one age. The hazard ratios associated with mother's circular migration fluctuate from age to age, but are significantly and positively associated with child mortality between 1 and 6 months in some specifications. Perhaps mothers who have work in another region leave home a few weeks after giving birth and terminate breastfeeding early.

In estimating the effects of mother's education, we combine high school and college-educated women because very few college-educated women lost a child, and in fact none lost a child above the age of 2. The two educational groups are not significantly different from each other with respect to child mortality. The children of women with at least high school education had better survival chances during the first year of life, but this is only significant in some specifications. The children of women with some education may have even worse outcomes during the second year of life than the children of women with no education. This is

unexpected and, since this is the interval with the most AIDS deaths, it may be related to the presence of the disease. To find out whether this is the case, we will explore the relationship between education and AIDS further in the next section.

The survival of children residing in the same household is consistently very important up to age 2, with infants living in households where other children died being more than twice as likely to also die. This correlation gets weaker with age, and, for children over age 2, the survival of other household children does not inform us about the survival of the index child.

Of the household variables, no type of toilet is consistently associated with child survival when age groups are segmented, though children from households with flush toilets and pit latrines tend to do better than those from households with no toilet. Electricity is positively associated with mortality in some age groups. Though drinking water was not significantly related to survival in the overall model, it shows significance in certain age groups. Children of families that use river water seem to do quite well, and in fact most water sources, including piped water, are associated with lower survival than river water. There are several possible explanations. While cholera is an important concern in the area, and there was a cholera outbreak in KwaZulu-Natal in 2000 which killed 32 people across the province,[14] the direct effects of the disease were still quite small – only one child death from cholera was recorded in the study population. Furthermore, unobserved location characteristics could be affecting the results for these observed socio-economic variables. If, for example, the households with piped water are clustered in one area, the water variables could be capturing the effects of other characteristics specific to that area. In fact, the inclusion of some community-averaged socio-economic characteristics eliminates most of the negative associations between piped water and electricity and child mortality (not shown). Alternatively, as discussed above, this may well be

[14] Provincial estimate is from Ka-Min (2000).

the result of policy endogeneity. Another explanation is that, due to the heterogeneous distribution of frailty across children in any population, the frailest are usually selected out of the population first. If the most vulnerable children living in high-risk environments are first to die, those who survive to older ages are the ones who are less susceptible to the dangers of the high-risk environment. As Sastry (1997:256) explains, "unobserved heterogeneity … induces a spurious duration dependence between socio-economic covariates and mortality risks".

As mentioned above, child mortality has been increasing in recent years. By separating out the age groups, as shown in Table 3, it becomes clear that the significant increases in mortality have been in post-neonatal infancy and at age 1, with yearly increase in the hazard of death at these ages of about 10%.

These results demonstrate that the impact of many bio-demographic and socio-economic variables is not the same at all ages. Because most deaths occur during the first 6 months of life, the overall results are weighted towards the youngest age group. Running separate but identical regressions on the age groups allows us to identify the correlates of child mortality at older ages as well. If instead we had only controlled for age group, the estimates of the explanatory variables would have been assumed to be the same, obscuring these relationships.

AIDS-Related Mortality

A substantial proportion of child deaths in the study area are attributed to AIDS. In 2000, there were 226 deaths among children under the age of 5, 41% of which were diagnosed as AIDS deaths. Are there certain characteristics that are associated with the probability of a child AIDS death? We conducted an exploratory comparison of the probability of dying in the year 2000, conditional on having survived to January 2000. Only cause of death information for children who died in 2000 was used, because they are the only ones available at this time. We calculated a multinomial logistic regression on three possible outcomes: survival through 2000, death of AIDS in 2000, and death of a cause other than AIDS in 2000. Table 4 shows the results from this model.

Separating out the causes of death, we can see the sources of some of the ambiguities reported in the more general models. The survival of the mother is important for all children, but the death of the mother, as would be expected, is extremely predictive of a child dying of AIDS, presumably both mother and child having died of the disease[15].

[15] We should note, however, that the mother's death from AIDS is taken into account in verbal autopsy diagnoses, so a child death is more likely to be diagnosed as AIDS if the mother is reported to have died of AIDS. Therefore, the actual effect is likely smaller.

Table 4: Odds Ratios from a Multinomial Logit Model Comparing Odds of Dying from AIDS and Dying from other Causes

Variable	(1) Died in 2000 of cause other than AIDS	(2) Died in 2000 of AIDS
Child-specific Characteristics		
Child is male	0.917	1.741+
Age in months on 1 January 2000	0.897**	0.917**
Mother-specific Characteristics		
Mother's age at the birth of this child (omitted category is "Mother was 20 to 34 years old")		
Under 20	0.599	1.034
35 and over	1.004	0.327
Mother died between 2000 and 2002	6.621*	19.238**
Mother's education (omitted category is "No education")		
Lower primary school	0.575	2.447
Higher primary school	0.576	2.951
High school	0.616	0.859
Higher education	0.367	1.723
Partnership status (omitted category is "No partner")		
Married	0.167**	0.231+
Non-marital partner	0.329**	0.988
Mother spends time away regularly	1.140	0.700
Household-specific Characteristics		
Household is electrified	1.232	1.727
Household has toilet facilities	0.384**	0.601
Household has piped drinking water	1.917+	0.838
Observations	7,387	
Log Likelihood	-412	
+ significant at 10%; * significant at 5%; ** significant at 1%		

Outcome 'Did not die in 2000' is the comparison group

Note: Odds Ratios for Categories with Missing Values on a Characteristic not Shown

The education variables are particularly interesting. The children of women with any education have higher odds of surviving deaths other than AIDS. This relationship is particularly strong for the children of high school educated women, who have 40% the odds of dying compared with the children of mothers with no education. The protective effects of education on child mortality disappear and are in fact reversed when we consider the odds of dying of AIDS. The relationship is insignificant but large compared with the omitted category, especially for women with primary education. This suggests that AIDS may affect the distribution of deaths among households, reducing the advantage of those with education. Perhaps mothers with some education are exposed to a larger number of potential sexual partners because education affords more opportunities for employment. It may also be that education is capturing other unobserved factors.

Results relating to mother's relationships are also quite informative. The children of married women are much less likely to die of any cause,

including AIDS, than are the children of unmarried mothers. This relationship is smaller and barely reaches statistical significance for AIDS, perhaps due to the small number of observations. Among the children of unmarried mothers, those whose mothers have a partner are about 30% more likely to have survived than to have died of causes other than AIDS. However, they are as likely to die of AIDS as the children of women with no partner. Non-marital partnerships often provide additional resources and care which are beneficial to children, but are less stable and may increase the chance of contracting AIDS. The mother travelling away from home to work is not significantly related with child mortality from any cause, though this variable seems to pull in opposite directions for AIDS and other causes.

Households with toilets, either flush toilets or pit latrines, have significantly lower odds of child deaths from any cause. Children living in households with any kind of toilet are about 60% less likely to die of causes other than AIDS and 40% less likely to die of AIDS than to survive compared with children living in households with no toilet facilities. Having electricity and piped water are, however, positively associated with child mortality from other causes and possibly AIDS.

Conclusion

This study set out to examine the distribution of child deaths among households in a rural South African population. An in-depth analysis was undertaken to determine which demographic and socio-economic characteristics tend to place children at higher risk of death.

We found that individual, maternal, and household characteristics are important factors of child survival. Most of the variation comes from the maternal level[16]. The child's personal circumstances at birth and the survival of his or her mother are very important. The mother's birth history, education, and marital status are also important. Mothers with high school and higher education are somewhat less likely to lose a child than mothers with no education, but mothers with primary education may be more likely to lose a child to AIDS than are women with no education. In this population where most births occur outside of marriage, women who are married or at least have a regular partner experience significantly fewer child deaths. In fact, the mother's partnership status is the most robust predictive characteristic in these analyses.

Some household resources matter, but the relationships between these resources and child survival are ambiguous. Most consistent among them is the household's investment in toilet facilities. Flush toilets are consistently associated with better child survival. Other resources that are related both to household investments and to the location of the household with respect to

[16] This is supported by estimates of variance at maternal, household and community levels in multilevel models (not shown).

community amenities are more ambiguous. For example, piped water usually thought to be the best source of drinking water, actually correlates with higher child mortality. It is households using protected springs and some uncommon sources of drinking water like quarries that have the best child survival outcomes. Electricity also has a weak but negative relationship with child survival. This ambiguity has been observed in studies from other populations (for example, Sastry 1997). It may be the result of policy endogeneity or location-specific unobserved characteristics and warrants careful study. Controlling for community characteristics captures some of the unobserved location characteristics that may be at the root of these ambiguities.

Finally, we have presented some evidence that AIDS may be affecting the distribution of child deaths across households in this community. Using information from verbal autopsies, we found that the protective effects of mother's education are not operating against child death from AIDS as they are against other causes of death. Having a married mother is protective from all deaths. Children whose unmarried mothers have non-marital partners are less likely to die of most causes, but are not similarly protected from AIDS. This signals that some of the relationships between amenities and child mortality may be obscured by the presence of AIDS. AIDS mortality appears to be differently distributed across households in this community compared with the distribution of other causes of death. As AIDS becomes an increasingly predominant cause of child deaths, we will likely see more changes in the relationships of some predictive characteristics and circumstances with child mortality.

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