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Rebecca Sear, Fiona Steele, Ian A. McGregor and Ruth Mace

THE EFFECTS OF KIN ON CHILD MORTALITY IN RURAL GAMBIA*

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We analyzed data that were collected continuously between 1950 and 1974 from a rural area of the Gambia to determine the effects of kin on child mortality. Multilevel event-history models were used to demonstrate that having a living mother, maternal grandmother, or elder sisters had a significant positive effect on the survival probabilities of children, whereas having a living father, paternal grandmother, grandfather, or elder brothers had no effect. The mother's remarriage to a new husband had a detrimental effect on child survival, but there was little difference in the mortality rates of children who were born to monogamous or polygynous fathers. The implications of these results for understanding the evolution of human life-history are discussed.

The determinants of child mortality have received considerable attention in the demographic literature, but little has been written on the effects of family members on child survival. The lack of a mother, father, or other relatives to provide child care or economic support is likely to affect the child's probability of surviving to adulthood. However, retrospective information on whether various relatives were alive and present during childhood is often difficult to collect in large-scale quantitative surveys. Evolutionary anthropologists have shown more interest in this area because the effects of kin on demographic phenomena, such as child mortality and fertility, can shed light on the evolution of human social organization and life history (for discussions of evolutionary theory applied to demographic phenomena, see, for example, Hill and Hurtado 1996; Hill and Kaplan 1999; Low, Clarke, and Lockridge 1992; Mace 2000; Turke 1989).

Children require a considerable amount of investment from adults if they are to survive the dangers of childhood and grow up to be successful members of the community. Humans are a social species, and evolutionary anthropologists have suggested that a characteristic of human reproductive patterns is helping behavior from other members of the social group that aids mothers in raising children. This assistance has been used to explain the evolution of a number of unusual life-history characteristics of women, such as short interbirth intervals relative to the other hominoids (a taxonomic category that includes humans and apes) and menopause (e.g., Hawkes et al. 1998). Which individuals give the most assistance to mothers is a matter of debate, but evolutionary theory predicts that the most likely candidates are close relatives of the child (Hamilton 1964). Related individuals will be able to increase their inclusive fitness (i.e., their genetic representation in future generations) by helping to raise children, provided that the benefits of helping the child (B) outweigh the costs to themselves of helping (C), weighted by the coefficient of relatedness (r). This is Hamilton's rule ($rB > C$; Hamilton 1964), in which r measures the probability that any gene found in the actor is shared by the recipient by common descent: for example, the coefficient of relatedness between a parent and a child or between siblings is .5, between a grandparent and a grandchild is .25, and so on. This study used a long-term demographic database, together with genealogical information,

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from four villages in the Gambia (Jali, Kanton Kunda, Keneba, and Manduar) to identify those kin who significantly influence child survival.

Studies that have been able to collect sufficient data to determine the effect of the mother's death on a child's survival have demonstrated that the loss of a mother is severely detrimental to the child. Brittain (1992) used a historical data set from the Caribbean to demonstrate that one of the strongest determinants of mortality during the first year of life was whether the child's mother had died before the child reached age 1. This increased mortality is expected, because infants who are not breast-fed or are breast-fed for only a short period are known to be at a high risk of death in the developing world (Wang and Murphy 1998). A detailed study of the Ache hunter-gatherers in Paraguay, which investigated the effects of kin on both child mortality and fertility, found that the mother was important long after infancy: children without mothers suffered higher mortality rates up to age 10, although the effect after age 5 was small (Hill and Hurtado 1996).

Although mothers tend to be the primary caregivers of young infants, fathers may provide other services that are indispensable to children. Indeed, some anthropologists have argued that paternal provisioning of children is the unique human characteristic that has led to the evolution of human female life-history patterns (Hill 1993). Some investigations have found that children are disadvantaged without fathers. These studies tend to show that fathers are beneficial to children because of either the economic support they provide (Bhuiya and Chowdhury 1997; Bledsoe 1995) or the protection they afford children from unrelated males (Hill and Hurtado 1996). Fatherless children also may suffer reduced investment from their mothers, either because women who are unencumbered by offspring fare better in the marriage market (Voland 1988), or because the mother's new partner is reluctant to take responsibility for another man's children (Daly and Wilson 1988). Although some studies have found a beneficial effect of fathers, investment by men is generally found to be lower than that of mothers. Men are able to increase their reproductive success by seeking additional mates and creating a number of families in ways that are impossible for women. They may then fare better in terms of fitness by directing their resources toward acquiring new wives, rather than investing in their existing children. Uncertainty about paternity is also predicted to affect the degree to which men are willing to invest in their putative children. Mothers always know their exact relatedness to their children, whereas some degree of paternity uncertainty (which varies among populations) always exists for men.

Some authors have argued that it is not paternal investment, but investment by matrilineal kin, that has driven the evolution of human life history (Hawkes et al. 1998). In many societies, raising a child is not the sole responsibility of the parents. Older siblings, particularly sisters, are often responsible for caring for younger children while their mothers are engaged in subsistence or domestic work (Weisner and Gallimore 1977). Older women, who may have fewer economic and child care demands on their time than women of reproductive age, may also help out (Gryboski 1996; LeVine et al. 1996). "Helpers at the nest" in nonhuman species are frequently older offspring who increase their inclusive fitness by remaining in their natal home and helping their parents raise their younger siblings, rather than moving away to establish their own breeding territories (Emlen 1995). Analyses of the effects of siblings on child mortality in human communities have largely focused on the detrimental consequences of competition between siblings. Children with closely spaced siblings tend to suffer high mortality (e.g., Alam 1995; Cleland and Sathar 1984), and girls with older sisters have been found to die at particularly high rates in societies with pronounced preferences for sons (Muhuri and Preston 1991). Beneficial effects of caretaking by older siblings on the social development of young children have been suggested (Sigman et al. 1988), but whether the availability of elder siblings for child care has any impact on child mortality has not been well studied.

Grandparental care is of particular interest to evolutionary anthropologists because of menopause, a virtually unique feature of human female reproductive patterns. The "grandmother hypothesis" for the evolution of menopause (Hamilton 1966; Williams 1957) was first proposed in the 1950s. This hypothesis suggests that women terminate their reproduction long before the end of their potential lifespan because as the risks of maternal mortality increase with age, it benefits women more to divert their investment toward their grandchildren than to produce more children of their own. Although this hypothesis is controversial (e.g., Packer, Tatar, and Collins 1998), evidence that grandmothers do invest in their grandchildren is mounting. Hadza children in East Africa are better nourished in the presence of older matrilineal kin (Hawkes, O'Connell, and Blurton Jones 1997), and this effect is particularly strong around the time that their mothers' attention is diverted by the arrival of another baby. This anthropological study is supported by a number of studies in the psychological and sociological literature that have indicated that welfare and psychological well-being are improved in children whose grandmothers are involved in their upbringing, both in contemporary American (Pope et al. 1993; Wilson 1986) and urban African societies (Alawad and Sonugabarke 1992). No other study has found a significant impact of grandparents on child mortality; the only study that investigated this issue previously found that child mortality was not influenced by the presence of grandparents (Hill and Hurtado 1996).

DATA

The data we used came from a farming population in the West Kiang District of the Gambia and were collected by Sir Ian McGregor as part of a long-term study funded by the UK Medical Research Council (MRC). (For a full description of the study, see McGregor 1991; for a report on the demography of these villages, see Billewicz and McGregor 1981.) Between 1950 and 1980, McGregor spent several months each year in the area to carry out medical surveys in which information on the heights, weights, and health status of individuals was collected. A system was also set up in 1950 to collect demographic information, whereby the dates of all births and deaths in the four villages noted earlier were recorded by literate village recorders. These data were supplemented by information on marriages, migration, and residence that was collected during the surveys. This information has since been transcribed into a computer database. The unique identification number given to each individual in the data set allows us to link individuals with their parents, grandparents, siblings, and other relatives and to trace each individual's marriage and birth history. Attempts to reconstruct demographic events and family history before 1950 were also made. Some information on individuals who had died before 1950 but who were known to be related to individuals in the survey was recorded, as were births to women in the survey that occurred before 1950. The combination of demographic, anthropometric, and genealogical data make this a uniquely detailed record of an African population. The continual recording of vital events as they happened in the village and McGregor's efforts each year to trace individuals who were previously seen in the surveys also make this an unusually accurate record of an African community. Especially important is that this population was experiencing natural fertility and mortality during this period. The one limitation of the database for our purposes is that it contains no socioeconomic information.

The population of West Kiang was patrilineal, patrilocal, and largely Muslim during this period. Women were responsible for farming rice, the main subsistence crop, while men farmed groundnuts, a cash crop, and a few grains. It was a seasonal environment: morbidity and mortality were much higher during the rainy season, when food was scarce, workloads were heavy, and disease was widespread. Polygyny was common, and age differences between spouses may have been considerable. Women married at menarche, but divorce and remarriage were not unusual. Women, as well as men, may have had a number of spouses during their lifetimes. Although residence was predominantly patrilocal, women tended to remain in their natal homes for some time after marriage and transferred to their husbands' compounds only after the birth of a child or two. The majority of women married within their own village or into a village nearby, so their own families were readily available during their marriages. None of the women and few of the men in these villages would have been educated because the government of the Gambia did not provide educational facilities in the region until the mid-1970s (McGregor 1991).

We restricted our analysis to births and deaths between 1950 and 1974 because in 1974 the MRC Dunn Nutrition Unit began research in the area and set up a permanent medical clinic in one of the survey villages (Keneba). This clinic has considerably altered the demography of the survey villages by dramatically reducing mortality and making contraception available (Lamb et al. 1984; Weaver and Beckerleg 1993). We confined our analysis to the period when the villages were representative of natural fertility and mortality Gambian farming communities. Between 1950 and 1974, villagers were given medical treatment as required, when McGregor was present in the villages, but with the exception of some short-term trials aimed at eradicating various parasitic diseases during the early years of the study, little other medical treatment was provided. Overall, neither the actions of the MRC nor any regional development appear to have influenced child mortality rates until the permanent clinic was set up in 1974 (see Figure 1 for mortality rates in childhood over the 25 years of this study).

METHODS

We used multilevel discrete-time event-history models to analyze the determinants of child mortality in this population. Event-history analysis was used to accommodate two common features of longitudinal event histories: right-censored observations and time-varying variables (see, for example, Allison 1984). In our study, children who were still alive at the end of the observation period or who had moved from the study area were right censored. It was also important to allow for time-varying covariates, since the key variables of interest in our study were indicators of the presence of various kin during childhood, which clearly can change over time.

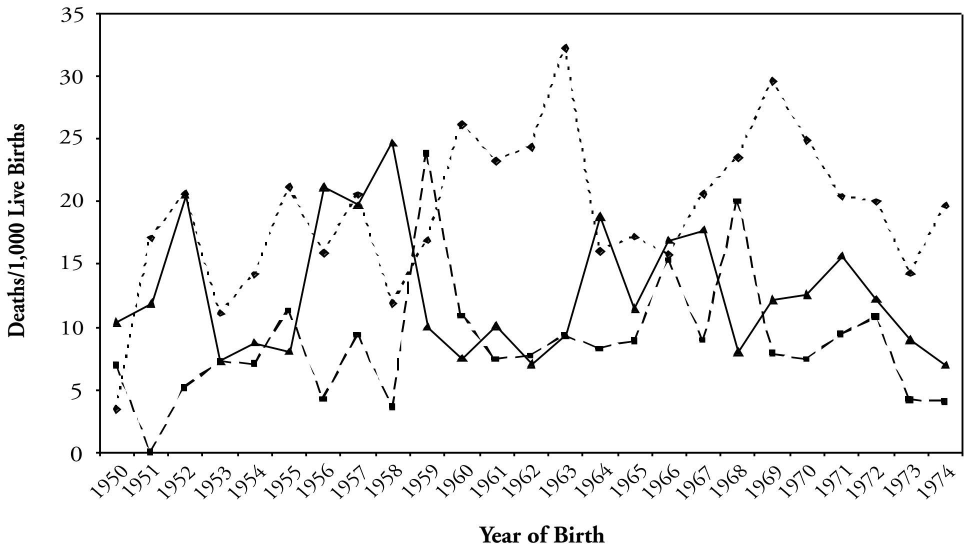
Another characteristic of our data that needed to be considered was the hierarchical structure of the population. Most women had more than one child over the 25-year observation period, and there is likely to be some correlation in mortality risks for children in the same family. In recent years, a number of studies have found evidence of familial association in mortality risks that may be due to genetic, behavioral, or socioeconomic factors that are shared by children of the same mother (Curtis, Diamond, and McDonald 1993; Das Gupta 1990; Guo 1993). If there is a correlation between the survival probabilities of children with the same mother, then observations are not independent. The multilevel approach allows for correlation in mortality risks between siblings by including a family-specific random effect in the model.

Define y_{tij} as the child survival indicator, where $y_{tij} = 1$ if child i in family j dies at time t and $y_{tij} = 0$ if the child survives beyond time t. We used a random-effects discrete-time logit model that takes the form

$$\log(h_{tij}/(1 - h_{tij})) = \alpha_t + \beta' \mathbf{x}_{tij} + u_j,$$

where $h_{tij} = \Pr(Y_{tij} = 1 \mid Y_{t-1,ij} = 0)$ is the hazard that child i in family j dies at time t; α_t is a function of time; $\mathbf{x}_{tij}$ is a vector of covariates (which may be constant over time or time-varying) with associated parameters β; and u_j is the family-level random effect that is assumed to follow a normal distribution with a mean of zero and variance σ_u^2. Here, the effect of age on mortality risks (represented by α_t) is modeled by including a set of dummy variables, one for each time point t.

Figure 1. Mortality Rates by Year of Birth: 1950–1974



Note: The dotted line indicates infant deaths (0–11 months); the dashed line indicates toddler deaths (12–23 months); and the solid line indicates later childhood deaths (24–59 months).

A useful measure that may be used to evaluate the extent of family-level variation that is due to unobserved factors is the intrafamily correlation. For the binary logit model, this measure may be defined as

$$\rho = \frac{\sigma_u^2}{\sigma_u^2 + \frac{\pi^2}{3}},$$

where $\pi^2 / 3$ is the variance of a standard logistic distribution. The intrafamily correlation may be interpreted as the correlation between latent mortality risks for a pair of children from the same family (see Pebley, Goldman, and Rodríguez 1996 for an explanation of how this expression for the intraclass correlation is derived).

The MLwiN software (Goldstein et al. 1998) was used to estimate the models. Two approximate estimation procedures are available in MLwiN to fit multilevel models to discrete response data: marginal quasi-likelihood (MQL) and penalized quasi-likelihood (PQL). In the case of binary response data, MQL may underestimate the parameters of the model (Rodríguez and Goldman 1995). We therefore used the PQL procedure, which has been found to reduce these biases (Goldstein and Rasbash 1996).[1]

There is considerable evidence to suggest that the factors that affect child mortality do not have equal importance over the entire period of childhood. Thus, separate models

1. In a simulation study designed to evaluate the performance of the PQL procedure for binary data, Breslow and Clayton (1993) found that PQL led to some downward bias in the estimates of both variance components and regression coefficients, but found little discrepancy between the simulated and estimated standard errors. Their overall conclusion, however, was that the PQL results were "sufficiently accurate for many practical purposes." Nevertheless, in the case of downward bias in the estimated regression coefficients and correct standard error estimates, we would expect hypothesis tests based on regression coefficients carried using PQL estimates to be conservative.

Table 1. Number of Children Who Died, Survived, or Were Censored During Each Period of Childhood

	Infancy (0–11 months)	Toddlerhood (12–23 months)	Later Childhood (24–59 months)
Died	435	203	245
Censored	195	120	221
Survived	1,664	1,341	875
Total	2,294	1,664	1,341

are fitted for 0–11 months (infancy), 12–23 months (toddler period), and 24–59 months (later childhood). It is common to split up the infant period into neonatal (first month) and postneonatal (1–11 months) intervals and to analyze these periods separately. Neonatal mortality tends to be high relative to mortality in the later months of childhood, and its etiology may differ; for example, deaths that are due to congenital defects and birth trauma are particularly common in the first month of life. However, we are particularly interested in the effects of kin on child mortality. In preliminary analyses (results not shown), we considered separate models for the neonatal and postneonatal periods. These analyses revealed a strong and highly significant effect of the death of the mother on child mortality in both periods but no effects of any other kin variables. We therefore combined the neonatal and postneonatal periods for the purposes of this study.

A total of 3,063 children aged 0–4 years lived in these villages during the period 1950–1974. Only singleton live births whose dates of birth and death (if applicable) were known to the nearest month were included in the analysis. Furthermore, a small number of children were excluded because the identity of their mother was unknown. These restrictions resulted in a total sample size of 2,294 children. Data records were available for children for each time unit from birth until they died, reached the age of 5 years, or were censored. Some children left the study before they died or reached 5 years either because they migrated out of the village or were lost to follow-up. These children were considered as censored at the age they were last known to be alive. Children who were born during the last five years of the study and who were still alive at the beginning of 1975 were treated as censored at the age they had reached on January 1, 1975 to exclude any effects of the medical center's treatment on child mortality patterns. Table 1 shows the sample sizes of children who died, survived, or were censored within each age group.

Variables Considered in the Analysis

Tables 2 and 3 show the categorizations of the variables used in the analysis and mortality rates for each period of childhood for the biodemographic and kin variables respectively. We treated all variables as categorical to include children for whom there were missing data for some variables. In initial models, we included dummy variables for each "missing" category. These dummy variables were dropped from the model if no statistically significant difference was found between the missing and reference categories. We also considered interactions between each variable and the age effects to test the assumption of proportional hazards, and tested two-way interactions between the kin variables and each of the other explanatory variables. Nonsignificant interactions were dropped from the model.

Age. A discrete-time event-history model requires that the data set be expanded from an individual-based data set, in which each individual contributes one record, to a time-based format, in which each record consists of a unit of time and each individual contributes a number of records. For the infant model, the database was expanded into one-

Table 2. Biodemographic Explanatory Variables Considered in the Multilevel Event-History Analysis, With Total Number of Children and Mortality Rates in Each Period Contributed by Each Variable

Variable	Total Sample Size	Infant Deaths per 1,000 Live Births	Toddler Deaths per 1,000 Live Births	Later Childhood Deaths per 1,000 Live Births
Village				
Keneba	1,257	182.2	124.3	188.3
Manduar	391	104.9	82.5	118.5
Kanton Kunda	189	158.7	84.7	147.4
Jali	457	295.4	172.4	256.8
Sex				
Male	1,128	201.2	103.5	188.5
Female	1,163	176.3	139.2	177.0
Birth Order				
1	432	233.8	125.0	155.1
2–3	800	182.5	122.0	194.8
4–6	748	177.8	129.3	190.3
7+	303	178.2	100.0	166.7
Mother's Age at Birth				
< 20 years	406	231.5	106.0	157.9
20–29 years	1,080	188.0	124.0	200.0
30–39 years	694	168.6	127.9	178.6
> 39 years	95	210.5	134.3	137.3
Length of Preceding Birth Interval				
< 24 months	342	213.5	127.1	188.5
24–47 months	1,139	188.8	134.5	204.7
> 47 months	162	135.8	132.8	200.0
Length of Succeeding Birth Interval[a]				
< 22 months	252	—	—	428.6
> 21 months	1,635	—	—	180.7
Last Born[a]				
No	1,984	—	—	173.4
Yes	309	—	—	184.2
Total	2,294	189.6	122.0	182.7

[a]This variable was included only in the later childhood model.

month periods because of the considerable variation in mortality rates over the first year of a child's life. Expanding the data into one-month periods, however, results in a large data set for the toddler and later childhood models. For these periods, when mortality fluctuates less by age, the data were expanded into three-month periods. For the infant model, dummy variables were created for each month; for the toddler and later childhood models, dummy variables were created for each three-month period.

Biodemographic variables. A number of biodemographic variables have consistently been shown to affect the probability of child death. They include the child's sex (e.g.,

Table 3. Kin Explanatory Variables Considered in the Multilevel Event-History Analysis With Total Number of Children and Mortality Rates in Each Period Contributed by Each Variable

Variable	Total Sample Size	Infant Deaths per 1,000 Live Births	Toddler Deaths per 1,000 Live Births	Later Childhood Deaths per 1,000 Live Births
Mother				
Died	36[a]	400.0	363.6	142.9
Alive	2,155[b]	189.0	122.1	184.8
Father				
Died	85[a]	100.0	47.6	142.9
Alive	2,045[b]	190.6	124.6	184.7
Maternal Grandmother				
Died	252[a]	188.1	157.0	138.2
Alive	899[b]	199.4	93.0	179.9
Paternal Grandmother				
Died	349[a]	145.3	121.8	146.1
Alive	569[b]	210.6	122.4	193.7
Maternal Grandfather				
Died	326[a]	177.9	116.5	148.9
Alive	676[b]	202.8	122.0	213.9
Paternal Grandfather				
Died	402[a]	182.8	101.5	156.8
Alive	216[b]	202.8	85.7	210.1
Living Sisters 10 or More Years Older				
Yes	300[c]	180.0	135.7	150.6
No	1,994[d]	191.1	119.9	187.2
Living Brothers 10 or More Years Older				
Yes	320[c]	187.5	119.8	159.0
No	1,974[d]	190.0	122.4	186.7
Subsequent Sibling Has Different Father[e]				
Yes	120	—	—	279.1
No	1,853	—	—	176.1
Father Has Other Wives				
Yes	603	197.0	142.2	194.6
No	1,599	191.8	109.2	180.0

[a]The number of children who lost this relative before age 5 and who were alive at their relative's death.

[b]The number of children whose relative survived until the child's death or the fifth birthday.

[c]The number of children who had one or more living siblings at least 10 years older than the child at the child's birth.

[d]The number of children who had no living siblings at least 10 years older than the child at the child's birth.

[e]This variable was included only in the later childhood model.

Aaby 1998; Clark et al. 1995; Muhuri and Preston 1991), birth order (e.g., Hobcraft, McDonald, and Rutstein 1985), maternal age at birth (e.g., Hobcraft et al. 1985; Rutstein

1984), and length of birth intervals (e.g., Alam 1995; Cleland and Sathar 1984; Gubhaju 1986; Muhuri and Menken 1997). We included variables for sex, birth order, maternal age at birth, and length of preceding and subsequent birth intervals to control for any effects these variables might have on child mortality. In addition, we included variables for the child's village of birth, because variation in child mortality among the villages in the study was observed in previous analyses of the demography of the study site (Billewicz and McGregor 1982). Finally, while building the models initially, we considered the survival status of the preceding child as a direct control for the potentially stronger correlation that may exist between the mortality risks of adjacent siblings, an approach adopted by several other authors (e.g., Curtis et al. 1993; Curtis and Steele 1996). However, there were no significant relationships between child mortality and the survival status of the child's immediately preceding sibling at any age. We removed this variable from the models because the assumption that all siblings have equally correlated mortality risks did not appear to be violated.

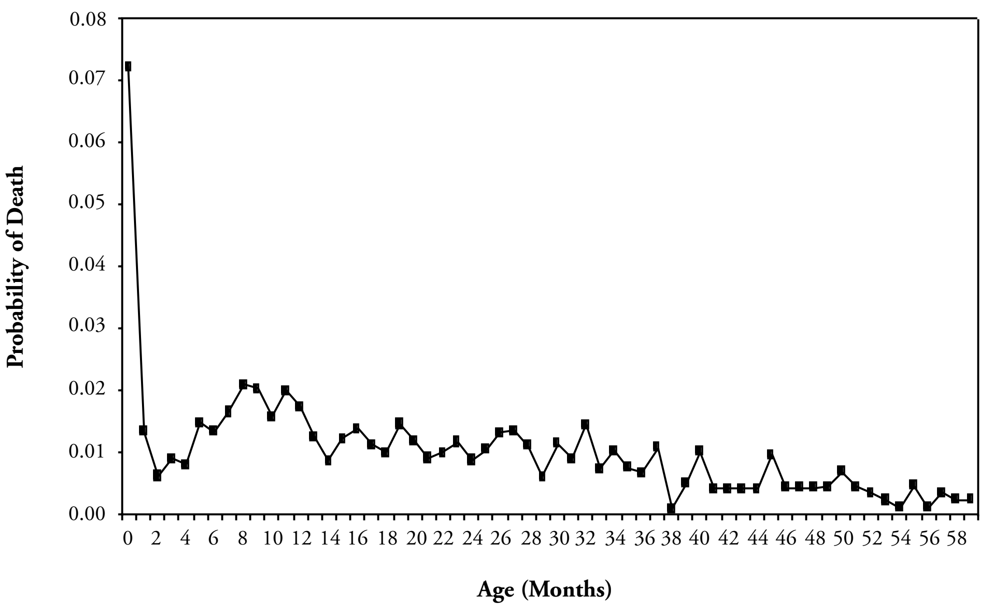
Kin. We created dummy variables to indicate the survivorship of six categories of biological kin: mother, father, maternal grandmother, paternal grandmother, maternal grandfather, and paternal grandfather. All kin variables were treated as time-dependent. A distinction was made between maternal and paternal grandparents because they may differ in their importance to their grandchildren, depending on differences in spousal age, residence patterns, or differential investment by the mother's or father's relatives. As with all other variables, we constructed a "missing-data" category for each kin variable and entered it into initial models to test the assumption that the sample of children with missing data was not biased. Because we have information only on individuals who were living in the study villages, the "missing" category for parents and grandparents included those relatives who were not living in one of the four study villages. We created two additional variables that indicated whether the child had any living sisters or brothers who were at least 10 years older than the child. We assumed that siblings who were at least 10 years older than the child were old enough to be available for child care and were not in direct competition with the child. These variables were also treated as time-dependent. In addition, we constructed indicators of the mother's and father's marital status. We could not directly determine when a woman had remarried after widowhood or divorce because we do not have dates of marriage. As a proxy variable for mother's remarriage, we created a variable coded 1 if the child's subsequent sibling had a different father and 0 if the subsequent sibling had the same father. We entered this variable only into the later childhood model because there were few birth intervals of less than two years during which the mother had remarried.

RESULTS

Of the 2,294 children in the database, 883 died before age 5 years. Figure 2 shows the distribution of mortality risk by age. Mortality in the first month of life was high, with 7% of live births dying in the neonatal period. Mortality then declined sharply and remained relatively low over the next few months while babies were still protected against disease by maternal antibodies and breast-feeding was virtually the only form of nourishment they received. After this time, the probability of death began to rise again as the effects of maternal antibodies wore off and supplementary foods, which may have been bacterially contaminated, were introduced. This increase resulted in a second minor peak of mortality around age 1 year. There was then a more or less continual decline in mortality until the end of the five-year period under study.

Figures 3, 4, and 5 display Kaplan-Meier survivor functions for children according to the survival status of their mothers, maternal grandmothers, and elder sisters. Although the number of children who lost their mothers during infancy was small, the effect of this loss is clear: all but one of these children died before age 5. Children without maternal

Figure 2. Distribution of Mortality Risk, by Age, Over the First Five Years of Life



grandmothers had lower survival rates than did those whose maternal grandmothers were still living, although this effect was seen only from around age 18 months. Children without elder sisters also had lower survival rates than did those with at least one sister 10 years or more older than they. This effect appears to be relatively small and was seen only after age 2.

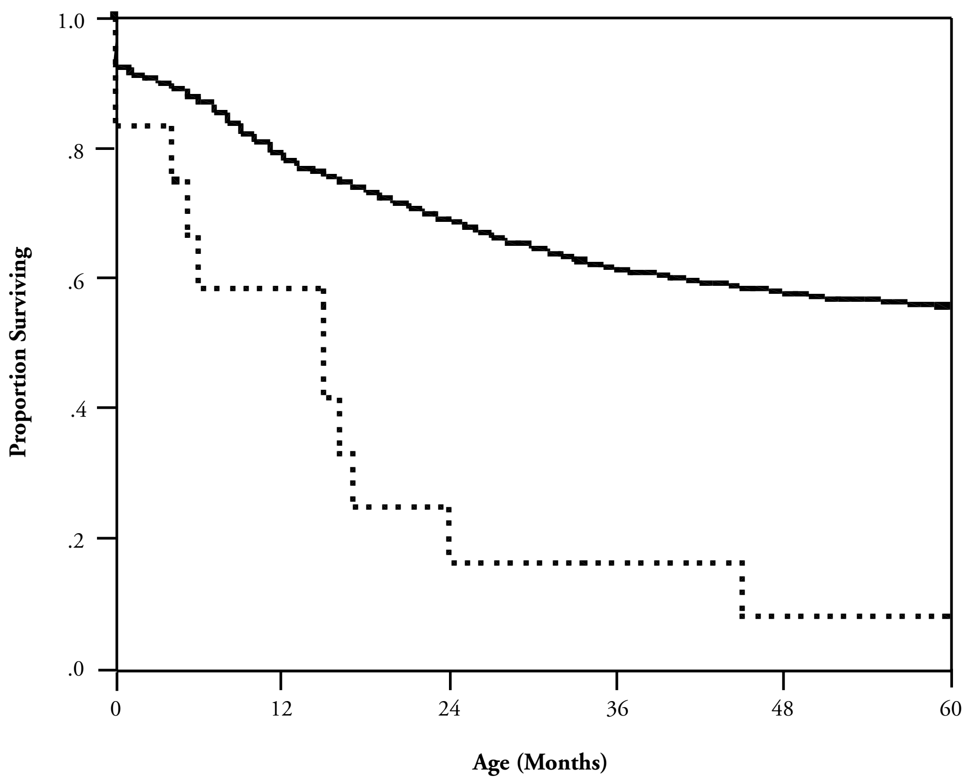
The parameter estimates and standard errors obtained from the multilevel event-history models for infant, toddler, and later childhood mortality are shown in Table 4. Odds ratios are also presented for all variables. There is a slight difference in the interpretation of an odds ratio estimated from a multilevel logistic regression compared with that obtained from a standard logistic regression model owing to the addition of the random family-level effect. Instead of being the odds of death for a child in a particular category compared with a reference category, these odds ratios can be interpreted as the median odds for a child in that category relative to the reference category (Madise 1996).

Biodemographic Effects

There were striking differences in child mortality rates among the four villages in the study, even though the villages are only a few kilometers apart. Manduar children had the lowest mortality rates at all ages, and Jali children had the highest. This difference may be due to variation in rates of malaria between the villages (McGregor et al. 1966). Manduar also had access to better-quality land than the other villages, so some of the differences may be related to nutritional status. There were no significant interactions between the village and kin variables, which indicates that the effects of kin were constant across all four villages.

Overall, roughly the same proportions of boys and girls survived the first five years of life, although the pattern of mortality over time differed between the sexes. Boys suffered

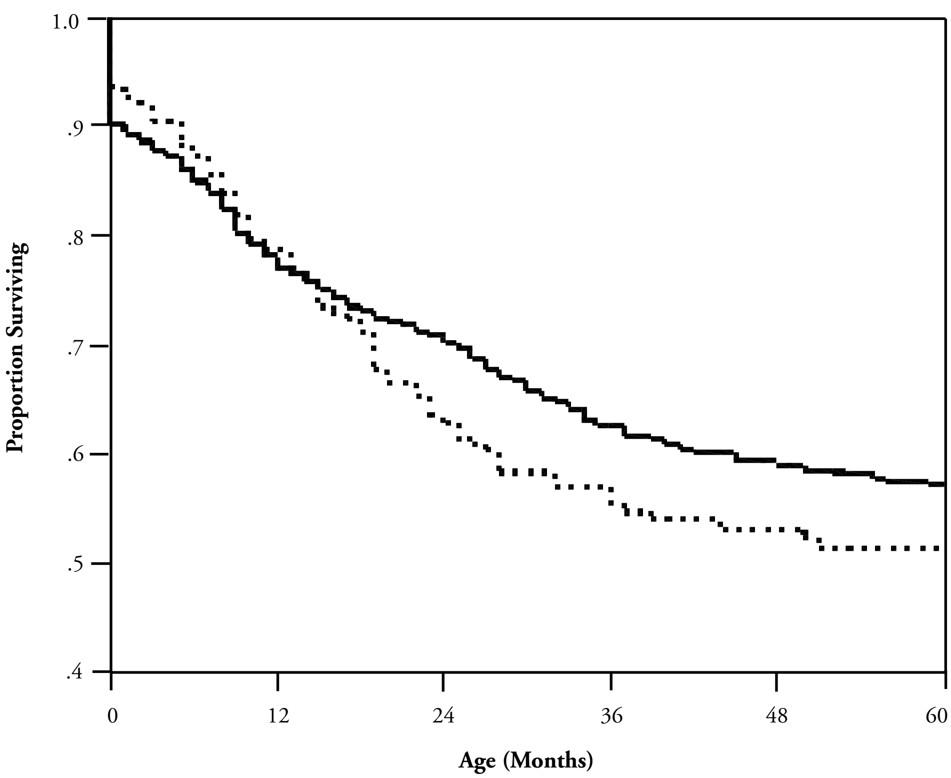
Figure 3. Kaplan-Meier Plot Showing Survival of Children Whose Mothers Died During Their First Year of Life (Dotted Line) and Those Whose Mothers Survived Throughout Their First Year (Solid Line)



higher rates of mortality during the first few months of life; girls died at higher rates during the toddler period. Mortality rates were similar for both sexes during later childhood. A pattern of higher male mortality in infancy is commonly observed and has been attributed to the greater frailty of boys, which leads to high mortality in the dangerous period shortly after birth. Many researchers think that because of their greater frailty, males should suffer higher mortality rates than females throughout their lifespans and that any populations that exhibit higher female mortality in childhood actively discriminate against girls. Because the villages in the study are patrilineal, girls may have been somewhat discriminated against, which resulted in higher mortality among female toddlers. Aaby (1998), however, has challenged the traditional assumption that the risk of mortality should be higher for males at all ages and suggested that different patterns of disease transmission between the sexes may be one explanation for differential mortality by sex.

As has been commonly observed in other studies (e.g., Cantrelle and Leridon 1971; Hobcraft et al. 1985; Manda 1999, but see Gubhaju 1986), firstborn children suffered higher rates of mortality in early life than did those born later, although this effect was significant only during the toddler period. Children who were born before or after short birth intervals also died at high rates, which is consistent with several other studies (Alam

Figure 4. Kaplan-Meier Plot Showing Survival of Children Whose Maternal Grandmothers Died Before Their Birth (Dotted Line) and Those Whose Maternal Grandmothers Were Alive at Their Birth (Solid Line)

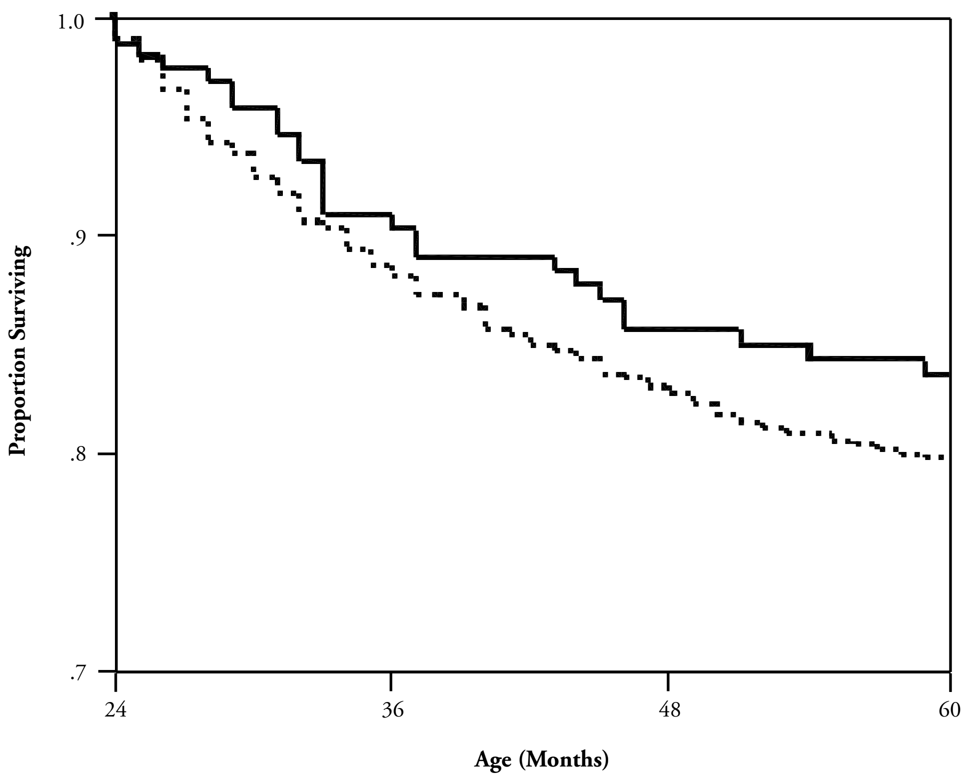


1995; Cleland and Sathar 1984; Gubhaju 1986; Muhuri and Menken 1997). Neither crude mortality rates nor estimates obtained from the multilevel models indicate any consistent or significant differences in child mortality by maternal age over the entire period of childhood. The crude mortality rates suggest a U-shaped pattern of mortality with maternal age in infancy, a finding that has been observed elsewhere (e.g., Rutstein 1984).

Between-Family Variance

This analysis supports the numerous other studies that have found that the children of any one mother have correlated probabilities of survival (Curtis et al. 1993; Das Gupta 1990; Guo 1993). The mother-level variance, which represents variance that is due to unobserved factors operating at the family level, is significant in both infancy and later childhood, though not in the toddler period. The intrafamily correlation is approximately .10 for all periods, indicating that 10% of the variation in mortality risks is the result of unobserved family-level factors. The significant effect during the first year of life may be due to physiological factors that lead to the correlation of survival probabilities for children with the same mother. Some women tend to have low-birth-weight babies and difficult

Figure 5. Kaplan-Meier Plot Showing Survival of Children Who Had One or More Sisters at Least 10 Years Older at Birth (Solid Line) and Those Who Had no Sisters 10 or More Years Older At Birth (Dotted Line): Data Shown for Late Childhood Period Only



labors, and their children are at a high risk of mortality during the first year of life. When this effect is seen in later childhood, it may be an indication that environmental variables, such as socioeconomic status or child care, are the basis of differential child mortality among women (Das Gupta 1990).

Kin

The death of the mother was a strong predictor of child mortality during the first two years of life. During infancy and toddlerhood, children without mothers had odds of death that were 5–6 times greater than those of children whose mothers were still alive. Despite this strong effect on infants and toddlers, losing a mother after the second year of life did not significantly affect the probability of a child dying.

The death of the father appeared to have no influence on child mortality at any age. This result should be interpreted with caution, however, given the relatively small sample sizes involved. Although the death of the father did not affect child mortality directly, the mother's remarriage negatively affected the survival of her children in later childhood. This finding suggests that it was the changes associated with the mother's remarriage,

Table 4. Parameter Estimates and Standard Errors From the Multilevel Discrete-Time Event-History Models of Infant, Toddler, and Later Childhood Mortality

	Infancy			Toddlerhood			Later Childhood		
Variable	Estimate	*SE*	Odds Ratio	Estimate	*SE*	Odds Ratio	Estimate	*SE*	Odds Ratio
Constant	–3.35**	0.35		–5.02**	0.58		–3.52**	0.47	
Keneba	0		1.0	0		1.0	0		1.0
Manduar	–0.60**	0.18	0.6	–0.36	0.23	0.7	–0.53*	0.21	0.6
Kanton	–0.01	0.21	1.0	–0.55	0.35	0.6	–0.12	0.31	0.9
Jali	0.61**	0.12	1.8	0.14	0.19	1.1	0.41*	0.18	1.5
Male[a]	0.50**	0.15	1.6	–0.31*	0.15	0.7	0.16	0.14	1.2
Female	0		1.0	0		1.0	0		1.0
Birth Order									
1	0.61	0.32	1.8	1.19*	0.47	3.3	–0.43	0.41	0.6
2–3	0.02	0.23	1.0	0.40	0.34	1.5	–0.33	0.30	0.7
4–6	–0.06	0.20	0.9	0.29	0.29	1.3	–0.28	0.26	0.7
7+	0		1.0	0		1.0	0		1.0
Mother's Age at Birth									
< 20 years	0		1.0	0		1.0	0		1.0
20–29 years	–0.12	0.17	0.9	0.31	0.27	1.4	0.09	0.25	1.1
30–39 years	–0.24	0.22	0.8	0.51	0.34	1.7	0.06	0.31	1.1
> 39 years	0.07	0.33	1.1	0.67	0.51	1.9	0.04	0.53	1.0
Preceding Birth Interval									
< 24 months	0.58**	0.20	1.8	0.59*	0.29	1.8	0.19	0.25	1.2
24–47 months	0.46**	0.17	1.6	0.65**	0.24	1.9	0.29	0.20	1.3
> 47 months	0		1.0	0		1.0	0		1.0
Succeeding[b] Birth Interval									
< 22 months	—	—		—	—		1.11**	0.48	3.0
> 21 months	—	—		—	—		0		1.0
Last Born[b]									
No	—	—		—	—		0		1.0
Yes	—	—		—	—		0.18	0.24	1.2
Mother									
Died	1.82**	0.51	6.2	1.66**	0.61	5.2	0.35	0.56	1.4
Alive	0		1.0	0		1.0	0		1.0
Father									
Died	0.13	0.61	1.1	–0.73	0.73	0.5	–0.33	0.39	0.7
Alive	0		1.0	0		1.0	0		1.0
Maternal Grandmother									
Died	0.13	0.19	1.1	0.55*	0.27	1.7	–0.09	0.26	0.9
Alive	0		1.0	0		1.0	0		1.0

(continued)

(Table 4, continued)

	Infancy			Toddlerhood			Later Childhood		
Variable	Estimate	*SE*	Odds Ratio	Estimate	*SE*	Odds Ratio	Estimate	*SE*	Odds Ratio
Paternal Grandmother									
Died	–0.25	0.19	0.8	–0.17	0.24	0.8	–0.05	0.23	0.9
Alive	0		1.0	0		1.0	0		1.0
Maternal Grandfather									
Died	0.07	0.18	1.1	0.28	0.26	1.3	0.01	0.24	1.0
Alive	0		1.0	0		1.0	0		1.0
Paternal Grandfather									
Died	0.28	0.16	1.3	–0.05	0.38	0.9	–0.29	0.21	0.7
Alive	0		1.0	0		1.0	0		1.0
Living Sisters 10+ Years Older									
Yes	–0.03	0.18	1.0	–0.07	0.25	0.9	–0.48*	0.24	0.6
No	0		1.0	0		1.0	0		1.0
Living Brothers 10+ Years Older									
Yes	0.06	0.19	1.1	–0.22	0.26	0.8	–0.30	0.24	0.7
No	0		1.0	0		1.0	0		1.0
Subsequent Sibling Has[b]									
Same father	—	—		—	—		0		1.0
Different father	—	—		—	—		0.65*	0.27	1.9
Father									
Monogamous	0		1.0	0		1.0	0		1.0
Polygynous	–0.02	0.12	1.0	0.18	0.16	1.2	0.03	0.16	1.0
Month									
0	0		1.0	—	—		—	—	
1	–1.67**	0.21	0.2	—	—		—	—	
2	–2.38**	0.30	0.1	—	—		—	—	
3	–1.98**	0.26	0.1	—	—		—	—	
4	–2.06**	0.28	0.1	—	—		—	—	
5	–1.41**	0.22	0.2	—	—		—	—	
6	–1.46**	0.24	0.2	—	—		—	—	
7	–1.21**	0.23	0.3	—	—		—	—	
8	–0.93**	0.22	0.4	—	—		—	—	
9	–0.92**	0.22	0.4	—	—		—	—	
10	–1.14**	0.25	0.3	—	—		—	—	
11	–0.87**	0.24	0.4	—	—		—	—	
12–14	—	—		0		1.0	—	—	
15–17	—	—		–0.01	0.19	1.0	—	—	

(continued)

(Table 4, continued)

Variable	Infancy Estimate	Infancy SE	Infancy Odds Ratio	Toddlerhood Estimate	Toddlerhood SE	Toddlerhood Odds Ratio	Later Childhood Estimate	Later Childhood SE	Later Childhood Odds Ratio
Month (*cont.*)									
18–20	—	—		–0.00	0.20	1.0	—	—	
21–23	—	—		–0.16	0.21	0.8	—	—	
24–26	—	—		—	—		0		1.0
27–29	—	—		—	—		–0.03	0.23	1.0
30–32	—	—		—	—		0.12	0.23	1.1
33–35	—	—		—	—		–0.19	0.25	0.8
36–38	—	—		—	—		–0.49	0.28	0.6
39–41	—	—		—	—		–0.44	0.28	0.6
42–44	—	—		—	—		–0.86**	0.33	0.4
45–47	—	—		—	—		–0.46	0.29	0.6
48–50	—	—		—	—		–0.60	0.31	0.5
51–53	—	—		—	—		–1.01**	0.37	0.4
54–56	—	—		—	—		–1.39**	0.44	0.4
57–59	—	—		—	—		–1.22**	0.41	0.3
Between-Family Variance	0.39*	0.16		0.36	0.28		0.44*	0.12	
Intrafamily Correlation	0.10	—		0.10	—		0.12	—	

[a]There was a significant interaction between sex of child and month for infants (estimate = –0.066, *SE* = 0.025, $p < .01$), indicating that boys die at high rates relative to girls in early infancy, but the difference between the sexes decreases throughout the first year of life).

[b]This variable was included only in the later childhood model.

*$p < .05$; **$p < .01$

either being left in the father's compound without the mother or moving into an unrelated man's household, that were harmful to the child.

The father's marital status appeared to have little effect on child survival: children who were born to polygynous fathers did not have significantly different mortality risks from those who were born to monogamous fathers. Polygyny is correlated with other variables, such as wealth, that may have an impact on child survival. We do not have data on the socioeconomic statuses of the households in this study, so we may not have conducted a properly controlled analysis of the effects of polygyny on child survival.

Children with living maternal grandmothers had significantly lower mortality during the toddler period, but not during infancy or later childhood. Neither paternal grandmothers, maternal grandfathers, nor paternal grandfathers had any effect on child mortality at any age. The lack of any relationship between child survival and the survival of any of the grandparents except the maternal grandmother suggests that this finding is not merely the result of inherited effects, such as socioeconomic status or genetic propensity to long life, but is a function of a factor unique to the maternal grandmother, such as child care.

Children without older sisters suffered significantly higher mortality during the later childhood period, though not in earlier childhood. There was no significant interaction between this variable and the sex of the child in this model, indicating that the beneficial effects of elder sisters were felt by boys and girls alike. The presence of elder brothers did not affect mortality at any age.

We also ran each model in a reduced form with only kin variables and no control variables (results not shown). In all models and for all kin variables, the results were similar to those obtained from the full models, except that the effect of elder sisters on the mortality of children aged 24–59 months was no longer significant. This finding suggests that the effects of mothers and maternal grandmothers are robust results that are not influenced by other variables in the model, but may indicate that the influence of elder sisters is a smaller effect.

DISCUSSION

We have shown that having a living mother, maternal grandmother, or elder sisters significantly improved the probability of surviving through certain periods of childhood. The strong correlation between the death of the mother and the death of her child during the first two years of life was expected, given the lack of alternatives to breast milk for feeding infants in this community. It is perhaps surprising that the negative effects of the death of the mother are confined to the child's first two years. However, women had heavy subsistence duties in this community, and from about the age of six months, children would have been left behind in the villages when their mothers went to farm their rice fields (Thompson and Rahman 1967). During the second year of life, the care of young children may have been further delegated to other individuals as weaning began, and during the third year of life, most mothers would have become preoccupied with their new babies. Our analysis suggests that other matrilineal kin, such as maternal grandmothers and elder sisters, became important around the time that mothers were reducing their investment in their young children and turning their attention to their next pregnancies, a particularly dangerous time for young children (Cassidy 1980). Both maternal grandmothers and elder sisters may have assisted mothers with child care and with subsistence and domestic duties. If maternal grandmothers were still working their own fields, they may have provided an additional source of food for the mothers and their children.

In addition to analyzing the effects of kin on child mortality, we also have investigated the effects of kin on the nutritional status of children (Sear, Mace, and McGregor 2000). When we compared the heights and weights of children with and without each category of kin, we found that the results mirrored those of the mortality analysis exactly. Mothers, maternal grandmothers, and elder sisters had significant positive effects on the nutritional status of children, whereas fathers, paternal grandmothers, grandfathers, and elder brothers had negligible effects. This finding supports our argument that matrilineal kin provided assistance to mothers of young children that was substantial enough to be demonstrated in both improved nutritional status and survival rates.

Why did maternal grandmothers but not paternal grandmothers improve children's health and survival? During a two-year stay in Keneba in the early 1960s, Thompson (1965), a sociologist, found that the majority of children were sent away to relatives to "forget the breast" at weaning, a practice also observed in other societies (LeVine et al. 1996; Pennington and Harpending 1993). Women preferred maternal relatives for this task, particularly their own mothers, and almost all the children whose maternal grandmothers were available for child care and were not living in the same compounds as the children were sent to their maternal grandmothers at weaning. This preference for maternal kin may explain why it was maternal, rather than paternal, grandmothers who significantly affected child mortality despite the patrilocal nature of this community, which means that children were more likely to live with their paternal grandmothers. But the question of why women prefer maternal relatives still remains. The relative ages of maternal and paternal grandmothers may be part of the explanation. As we noted earlier, husbands tended to be a decade or more older than their wives in this society, so paternal grandmothers would have been older (and more infirm) than were maternal grandmothers, and fewer paternal grandmothers would have been alive to care for their grandchildren. We entered the ages of all grandparents at the child's birth into initial models during this analysis to control for this factor, but we removed all the variables because they had no significant effect on the model results. Residential patterns also may influence the availability of grandmothers for child care. In this patrilocal society, however, children were more likely to live with their paternal than their maternal grandmothers. In addition, marital instability may have reduced the opportunities for paternal grandmothers to keep in contact with their grandchildren. About 30% of marriages ended in divorce, although more than half these marriages were childless, so divorce probably affected a relatively small proportion of children.

A final possibility is that maternal kin may be more caring than paternal kin if uncertainty about paternity is high. In this situation, women can be sure that their daughters' children are related to them, but are less certain of their sons' children. This uncertainty may lead to preferential investment in daughters' children over sons' children. One study of grandparental solicitude in Germany that distinguished between maternal and paternal grandparents found that adults rated maternal grandparents as more caring than paternal grandparents in childhood (Euler and Weitzel 1996). Paternity uncertainty was used to explain this finding, though the degree of paternity uncertainty in this population was not ascertained. Another study replicated this finding using a different German sample but found that a similar survey in Greece observed greater solicitude from paternal grandparents (Pashos 2000). The author suggested that the social system may also influence grandparental investment and lead to higher investment from paternal grandparents in patrilateral societies, such as Greece. (The social system also may affect the level of paternity uncertainty, but this possibility was not tested in Pashos's study.) Our study, however, used data from a patrilineal and patrilocal society and still found a preference for grandmothers to invest in their daughters', rather than their sons', children.

The lack of any relationship between the father's death and child survival can perhaps be explained by the economic and social systems in the society we studied. Households in these villages were made up of patrilineally related men and their wives and children. These extended families, together with the fact that women did much of the subsistence farming in this community, may have meant that the loss of a father did not imply economic ruin to the household. Investment by men in their children may be low in societies in which much of the responsibility for subsistence work is assumed by women. Thus men may be able to make better use of their resources by using them to acquire new wives, rather than by investing them in their existing children. Polygyny was the ideal in this society: 75% of the men who reached old age had more than one wife. As with all patrilineal relatives, paternity uncertainty also may affect a man's probability of investing directly in his children. Although we were unable to determine quantitatively the degree of paternity uncertainty in this community, the considerable age differences between spouses and the relative marital instability may suggest some degree of uncertainty.

This analysis provides support for the hypothesis that matrilineal kin were important in the evolution of human female life-history traits. The finding that matrilineal kin became particularly important around the time of weaning suggests that human mothers may be weaning their children relatively early compared with the closely related great apes, safe in the knowledge that their mothers and elder daughters will be able to take over some of the responsibility for the children's welfare. This assistance may result in shorter birth intervals than for other great apes, in which mothers are solely responsible for child care. The investment in grandchildren by older women is also predicted by the grandmother hypothesis for the evolution of menopause. This result does not constitute proof of this hypothesis because it is impossible to determine whether grandmothers' investment is a cause or a consequence of menopause. Our study does provide quantitative information on the magnitude of the beneficial effect of grandmothers, however, which may be used to model mathematically whether menopause could be an adaptation to increase inclusive fitness through grandmaternal care of children. Although previous models of menopause have suggested that it may not be an adaptive trait (e.g., Rogers 1993), more complex models of menopause that include both the costs of continued reproduction and the benefits of stopping reproduction early indicate that menopause may provide benefits through inclusive fitness (Shanley and Kirkwood 2001).

REFERENCES

Aaby, P. 1998 "Are Men Weaker or Do Their Sisters Talk Too Much? Sex Differences in Childhood Mortality and the Construction of 'Biological' Differences." Pp. 223–45 in *The Methods and Uses of Anthropological Demography,* edited by A.M. Basu and P. Aaby. Oxford: Clarendon Press.

Alam, N. 1995. "Birth Spacing and Infant and Early Childhood Mortality in a High Fertility Area of Bangladesh: Age-Dependent and Interactive Effects." *Journal of Biosocial Science* 27:393–404.

Alawad, A.M.E. and E.J.S. Sonugabarke. 1992. "Childhood Problems in a Sudanese City—A Comparison of Extended and Nuclear Families." *Child Development* 63:909–14.

Allison, P.D. 1984. *Event History Analysis: Regression for Longitudinal Event Data.* Newbury Park, CA: Sage.

Bhuiya, A. and M. Chowdhury. 1997. "The Effect of Divorce on Child Survival in a Rural Area of Bangladesh." *Population Studies* 51:57–62.

Billewicz, W.Z. and I.A. McGregor. 1981. "The Demography of Two West African (Gambian) Villages, 1951–75." *Journal of Biosocial Science* 13:219–40.

———. 1982. "A Birth-to-Maturity Study of Heights and Weights in Two West African (Gambian) Villages, 1951–75." *Annals of Human Biology* 9:309–20.

Bledsoe, C. 1995. "Marginal Members: Children of Previous Unions in Mende Households in Sierra Leone." Pp. 130–53 in *Situating Fertility,* edited by S. Greenhalgh. Cambridge, England: Cambridge University Press.

Breslow, N.E. and D.G. Clayton. 1993. "Approximate Inference in Generalized Linear Mixed Models." *Journal of the American Statistical Association* 88:9–25.

Brittain, A.W. 1992. "Birth Spacing and Child Mortality in a Caribbean Population." *Human Biology* 64:223–41.

Cantrelle, P. and H. Leridon. 1971. "Breast Feeding, Mortality in Childhood and Fertility in a Rural Zone of Senegal." *Population Studies* 25:505–33.

Cassidy, C.M. 1980. "Benign Neglect and Toddler Malnutrition." Pp. 109–39 in *Social and Biological Predictors of Nutritional Status, Physical Growth and Neurological Development,* edited by L.S. Greene and F.E. Johnston. New York: Academic Press.

Clark, S., E. Colson, J. Lee, and T. Scudder. 1995. "Ten Thousand Tonga: A Longitudinal Anthropological Study From Southern Zambia, 1956–1991." *Population Studies* 49:91–109.

Cleland, J.G. and Z.A. Sathar. 1984. "The Effect of Birth Spacing on Childhood Mortality in Pakistan." *Population Studies* 33:401–18.

Curtis, S.L, I. Diamond, and J.W. McDonald. 1993. "Birth Interval and Family Effects on Postneonatal Mortality in Brazil." *Demography* 30:33–43.

Curtis, S.L. and F. Steele. 1996. "Variations in Familial Neonatal Mortality Risks in Four Countries." *Journal of Biosocial Science* 28:141–59.

Daly, M. and M. Wilson. 1988. *Homicide*. New York: Aldine de Gruyter.

Das Gupta, M. 1990. "Death Clustering, Mothers' Education and Determinants of Child Mortality in Rural Punjab, India." *Population Studies* 44:489–505.

Emlen, S.T. 1995. "An Evolutionary Theory of the Family." *Proceedings of the National Academy of Science, USA* 92:8092–99.

Euler, H.A. and B. Weitzel. 1996. "Discriminative Grandparental Solicitude as Reproductive Strat-

egy." *Human Nature* 7:39–60.
Goldstein, H. and J. Rasbash. 1996. "Improved Approximations for Multilevel Models With Binary Responses." *Journal of the Royal Statistical Society, A* 159:505–13.
Goldstein, H., J. Rasbash, I. Plewis, D. Draper, W. Browne, M. Yang, G. Woodhouse, and M. Healy. 1998. *A User's Guide to MlwiN*. London: Institute of Education.
Gryboski, K.L. 1996. "Maternal and Nonmaternal Time-Allocation to Infant Care and Care During Infant Illness in Rural Java, Indonesia." *Social Science and Medicine* 43:209–19.
Gubhaju, B.B. 1986. "Effect of Birth Spacing on Infant and Child Mortality in Rural Nepal." *Journal of Biosocial Science* 18:435–47.
Guo, G. 1993. "Use of Sibling Data to Estimate Family Mortality Effects in Guatemala." *Demography* 30:15–32.
Hamilton, W.D. 1964. "The Genetical Evolution of Social Behaviour I." *Journal of Theoretical Biology* 7:1–16.
———. 1966. "The Moulding of Senescence by Natural Selection." *Journal of Theoretical Biology* 12:12–45.
Hawkes, K., J.F. O'Connell, and N.G. Blurton Jones. 1997. "Hadza Women's Time Allocation, Offspring Provisioning and the Evolution of Long Postmenopausal Life Spans." *Current Anthropology* 38:551–78.
Hawkes, K., J.F. O'Connell, N.G. Blurton Jones, H. Alvarez, and E.L. Charnov. 1998. "Grandmothering, Menopause and the Evolution of Human Life Histories." *Proceedings of the National Academy of Science, USA* 95:1336–39.
Hill, K. 1993. "Life History Theory and Evolutionary Anthropology." *Evolutionary Anthropology* 2:78–88.
Hill, K. and A.M. Hurtado. 1996. *Ache Life History: The Ecology and Demography of a Foraging People.* New York: Aldine de Gruyter.
Hill, K. and H. Kaplan. 1999. "Life History Traits in Humans: Theory and Empirical Studies." *Annual Review of Anthropology* 28:397–430.
Hobcraft, J.N., J.W. McDonald, and S.O. Rutstein. 1985. "Demographic Determinants of Infant and Early Child Mortality—A Comparative Analysis." *Population Studies* 39:363–85.
Lamb, W.H., C.M.B. Lamb, F.A. Foord, and R.G. Whitehead. 1984. "Changes in Maternal and Child Mortality Rates in Three Isolated Gambian Villages Over Ten Years." *Lancet* 2(8408):912–14.
LeVine, R.A., S. Dixon, S. LeVine, A. Richman, P.H. Leiderman, C.H. Keefer, and T.B. Brazelton. 1996. *Childcare and Culture: Lessons From Africa.* Cambridge, England: Cambridge University Press.
Low, B.S., A.L. Clarke, and K.A. Lockridge. 1992. "Toward an Ecological Demography." *Population and Development Review* 18:1–31.
Mace, R. 2000. "The Evolutionary Ecology of Human Life History." *Animal Behaviour* 59:1–10.
Madise, N.J. 1996. "Child Mortality in Malawi: Further Evidence of Death Clustering Within Families." Pp. 27–35 in *Population Dynamics: Some Past and Emerging Issues,* edited by R.A. Powell, E.A. Mwageni, and A. Ankomah. Exeter, England: Institute of Population Studies, University of Exeter.
Manda, S.O.M. 1999. "Birth Intervals, Breastfeeding and Determinants of Childhood Mortality in Malawi." *Social Science and Medicine* 48:301–12.
McGregor, I.A. 1991. "Morbidity and Mortality at Keneba, the Gambia, 1950–75." Pp. 306–24 in *Disease and Mortality in Sub-Saharan Africa,* edited by R.G. Feacham and D.T. Jamison. Oxford: Oxford University Press.
McGregor, I.A., K. Williams, W.Z. Billewicz, and A.M. Thomson. 1966. "Haemoglobin Concentration and Anaemia in Young West African (Gambian) Children." *Transactions of the Royal Society of Tropical Medicine and Hygiene* 60:650–67.
Muhuri, P.K. and J. Menken. 1997. "Adverse Effects of Next Birth, Gender and Family Composition on Child Survival in Rural Bangladesh." *Population Studies* 41:279–94.

Muhuri, P.K. and S.H. Preston. 1991. "Effects of Family Composition on Mortality Differentials by Sex Among Children in Matlab, Bangladesh." *Population Development Review* 17:415–34.

Packer, C., M. Tatar, and A. Collins. 1998. "Reproductive Cessation in Female Mammals." *Nature* 392:807–11.

Pashos, A. 2000. "Does Paternal Uncertainty Explain Discriminative Grandparental Solicitude? A Cross-Cultural Study in Greece and Germany." *Evolution and Human Behavior* 21:97–109.

Pebley, A.R., N. Goldman, and G. Rodríguez. 1996. "Prenatal and Delivery Care and Childhood Immunization in Guatemala: Do Family and Community Matter?" *Demography* 33:231–47.

Pennington, R. and H. Harpending. 1993. *The Structure of an African Pastoralist Community: Demography, History and Ecology of the Ngamiland Herero.* Oxford, England: Clarendon Press.

Pope, S.K., L. Whiteside, J. Brooks-Gunn, K.J. Kelleher, V.I. Rickert, R.H. Bradley, and P.H. Casey. 1993. "Low-Birth-Weight Infants Born to Adolescent Mothers: Effects of Coresidency With Grandmother on Child Development." *Journal of the American Medical Association* 269:1396–400.

Rodríguez, G. and N. Goldman. 1995. "An Assessment of Estimation Procedures for Multilevel Models With Binary Response." *Journal of the Royal Statistical Society, Series A* 158:73–90.

Rogers, A.R. 1993. "Why Menopause?" *Evolutionary Ecology* 7:406–20.

Rutstein, S.O. 1984. *Infant and Child Mortality: Levels, Trends and Demographic Differentials.* Rev. ed. Voorburg, the Netherlands: International Statistical Institute.

Sear, R., R. Mace, and I.A. McGregor. 2000. "Maternal Grandmothers Improve the Nutritional Status and Survival of Children in Rural Gambia." *Proceedings of the Royal Society, Series B, Biological Sciences* 267:461–67.

Shanley, D.P. and T.B.L. Kirkwood. 2001. "Evolution of the Human Menopause." *Bioessays* 23:282–87.

Sigman, M., C. Neumann, E. Carter, D. Cattle, S. D'Souza, and N. Bwibo. 1988. "Home Interactions and the Development of Embu Toddlers in Kenya." *Child Development* 59:1251–61.

Thompson, B. and A.K. Rahman. 1967. "Infant Feeding and Child Care in a West African Village." *Journal of Tropical Pediatrics* 13:124–38.

Thompson, E.D.B. 1965. *Marriage, Childbirth and Early Childhood in a Gambian Village: A Socio-Medical Study*. Unpublished Ph.D. thesis, University of Aberdeen, Aberdeen, Scotland.

Turke, P.W. 1989. "Evolution and the Demand for Children." *Population and Development Review* 15:61–90.

Voland, E. 1988. "Differential Infant and Child Mortality in Evolutionary Perspective: Data From Late 17th to 19th Century Ostfriesland (Germany)." Pp. 253–76 in *Human Reproductive Behavior: A Darwinian Perspective,* edited by L. Betzig, M. Borgerhoff Mulder, and P. Turke. Cambridge: Cambridge University Press.

Wang, D.L. and M. Murphy. 1998. "Covariates of Infant Mortality in China: An Exploratory Approach." *Social Biology* 45:21–38.

Weaver, L.T. and S. Beckerleg. 1993. "Is Health Sustainable? A Village Study in the Gambia." *Lancet* 341:1327–30.

Weisner, T.S. and R. Gallimore. 1977. "My Brother's Keeper: Child and Sibling Caretaking." *Current Anthropology* 18:169–90.

Williams, G.C. 1957. "Pleiotropy, Natural Selection and the Evolution of Senescence." *Evolution* 11:398–411.

Wilson, M.N. 1986. "The Black Extended Family: An Analytical Consideration." *Developmental Psychology* 22:246–58.