DEMOGRAPHIC RESEARCH
A peer-reviewed, open-access journal of population sciences

DEMOGRAPHIC RESEARCH

VOLUME 49, ARTICLE 11, PAGES 249–294
PUBLISHED 17 AUGUST 2023
https://www.demographic-research.org/Volumes/Vol49/11/
DOI: 10.4054/DemRes.2023.49.11

Research Article

The dynamic role of household structure on under-5 mortality in southern and eastern sub-Saharan Africa

Ashira Menashe-Oren

Philippe Bocquier

Carren Ginsburg

Yacouba Compaore

Mark Collinson

Contents

Demographic Research: Volume 49, Article 11
Research Article

The dynamic role of household structure on under-5 mortality in southern and eastern sub-Saharan Africa

Ashira Menashe-Oren[1]

Philippe Bocquier [1,2]

Carren Ginsburg[2]

Yacouba Compaore[3]

Mark Collinson[2,4]

Abstract

BACKGROUND
Children are born and grow up in households, where they receive essential care, including time, socio-psychological support, and economic resources. Children's immediate environment, captured by household structure, changes over time.

OBJECTIVE
We evaluate the role of dynamic household structure in the risk of child death in southern and eastern Africa.

METHODS
We use longitudinal data from 15 Health and Demographic Surveillance Systems between 1990 and 2016, covering almost 282,000 under-5 year olds. We analyse under-5 mortality using semi-parametric Cox models accounting for time-varying household structure (household size and household typology) and controlling for maternal characteristics.

RESULTS
We find that children in smaller households have a higher risk of death than those in large households. In particular, children in households where they are the sole child with two adults of opposite sexes have the lowest chances of survival, reflecting a first-child effect.

[1] Université catholique de Louvain, Belgium. Email: ashira.menashe-oren@uclouvain.be.
[2] Medical Research Council/Wits Rural Public Health and Health Transitions Research Unit (Agincourt), School of Public Health, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa.
[3] Université Joseph KI-ZERBO, Burkina Faso.
[4] Department of Science and Innovation/ Medical Research Council, South African Population Research Infrastructure Network, South Africa.

By contrast, nuclear-type households with more than one child are the most protective, while children in extended households are more vulnerable.

CONTRIBUTION
Our findings suggest that the (in)stability of households is important in evaluating child survival, and that it is imperative to consider households as changing entities.

1. Introduction

Despite declines, infant and child mortality remain high in sub-Saharan Africa (SSA) compared to other regions of the world, with considerable variation within countries (Burstein et al. 2019; Masquelier, Reniers, and Pison 2014; You et al. 2015). Factors associated with these declines include increases in maternal education, improved sanitation, and better access to medical interventions (Akinyemi, Afolabi Bamgboye, and Ayeni 2012). However, other factors are also likely at play, especially when considering the within-country diversity in under-5 mortality rates. In this study, we consider the role of household structure on under-5 mortality in SSA.

Households are the backbone of societies. They are the centre of a myriad of processes, including childbearing and healthcare. They are considered as units of consumption and production in society at large, and they protect their members using psychological, social, and economic resources. It is not surprising, then, to consider them as important for children. Children are dependent on kin or the other adults they live with for essential care, economic support, and socialisation (Sear and Coall 2011). Usually parents provide the necessary resources, time and money, both of which are invaluable regarding child well-being (Thomson, Hanson, and Mc Lanahan 1994). Thus, considering the presence of parents and other household members in children's everyday life is essential. In SSA, even when children do not reside with their mothers, evidence suggests that they still maintain connections with the maternal household (Cotton and Beguy 2020).

In order to examine evidence on the relationship between household structure and composition, and child survival, it is essential to comprehensively address what the term 'household' means. A household broadly refers to people living within the same homestead, making common provision for essential living (Bongaarts 2001; Randall, Coast, and Leone 2011). A household often overlaps with a 'nuclear' family, but is not limited to kin. Moreover, production, consumption, and reproduction are not always limited to coresident boundaries: a household can have members that do not live in the same residence (Tillman and Nam 2008). Household membership can be, and is most often, defined as a status, where the members are those most motivated to help each other.

Household membership can also be defined as a network, where members transfer to their kin varying types, amounts, and quality of support (Clark, Madhavan, and Kabiru 2018).

Despite this fluidity in households and membership, in order to operationalize and compare households in demographic analysis we are limited to acknowledging households through a single definition, (Randall et al. 2015; Randall, Coast, and Leone 2011). Individuals are generally considered as members of only one household unit. In this study, we delimit households to individuals who live in the same residence and therefore have de facto membership, whether kin or not. This builds on the idea that coresidents are present in the day-to-day life of children. It does not mean, however, that non-household or de jure members do not affect child well-being.

2. Household composition and under-5 mortality

Previous research has mostly focused on the association between household composition and child survival as an ultimate indicator of health.[5] 'Composition' refers to the presence of specific individuals in the household, such as grandparents or siblings, whereas household structure refers to features of the household, such as sex of the household head, or whether the household is extended laterally or vertically. Considering the basic assumption that biological mothers are the primary caretakers of their own children, considerable research has addressed the presence of a mother in child survival. In all 32 studies across regions of the world, reviewed by Sear and Coall (2011), a mother's presence was found to have a positive effect on child survival, especially at youngest ages. By contrast, 60% of the studies showed that coresident fathers have no effect on child survival (Sear and Coall 2011). Fathers are mostly assumed to provide resources rather than be primary caretakers (Clark, Cotton, and Marteleto 2015; Gage 1997; Madhavan, Mee, and Collinson 2014; Sear 2008), though in rural South Africa, coresidence with fathers, associated with children's higher birth weight, indicates that their support is beneficial too (Cunningham et al. 2010). Fathers, even if not coresident, are expected to transfer finances and assist indirectly with childcare (through strong kin networks). Evidence from Kenya suggests that their indirect involvement is associated with better child health (Clark, Madhavan, and Kabiru 2018). By contrast, in a matrilineal society in Malawi, fathers appear to matter little for child survival, and when they are absent due to divorce (rather than migration) the risk of child death increases, likely because of the stress and disruption associated with divorce (Sear 2008).

The presence of grandparents in a household, particularly grandmothers, has also been found to have a mostly positive association with child health and survival in SSA

[5] Effects on mortality are the most extreme, while effects on health are likely more moderate.

(Clark, Madhavan, and Kabiru 2018; Cunningham et al. 2010; Duflo 2003; Sear 2008; Sear and Coall 2011; Sear, Mace, and McGregor 2000; Strassmann and Garrard 2011). Even if grandmothers are not coresident but live nearby, they may help directly with grandchild care, or relieve mothers of heavy domestic tasks, allowing mothers to spend time on childcare-related activities (Gibson and Mace 2005). Yet in high fertility settings where there are many grandchildren to care for, support could be spread thin. Maternal grandmothers are especially active in grandchild care since they are often younger than paternal grandmothers (since mothers have children at younger ages than fathers (Schoumaker 2019)) and their genetic relatedness to the child is more certain (Sear and Mace 2008), resulting in lower risk of child death (Compaoré 2021). Recent research suggests that there is a short ‘helping window’ during which grandmothers can provide care, when they are still active and healthy (Page et al. 2021). The evidence on grandfathers’ role in child survival is more limited, with some studies suggesting they are much less important (Sear and Mace 2008), but play a role when the father is absent (Sear and Coall 2011). The presence of paternal grandfathers in particular seems to be detrimental to child survival, likely because they are generally older than maternal grandfathers, and in poorer health, therefore requiring extensive care (Compaoré 2021).

Having older siblings who potentially helping with childcare and household chores could have a positive effect on child survival. Yet in places where fertility is low, children are less likely to have an older sibling with a wide enough age gap to assist with their care (Sear and Coall 2011). At the same time, siblings who are close in age may compete over resources and play a negative role in child survival (Bocquier et al. 2021). In addition to siblings, parents, and grandparents, other adults in the household may also affect child survival by providing greater access to financial resources and reliable childcare arrangements. This is noteworthy particularly in poor settings where resources are strained, and where care is needed for an ill household member (Houle et al. 2013). For instance, evidence from Nairobi indicates that children with single mothers do not receive care from aunts and uncles, even if coresident (Clark et al. 2017; Clark, Madhavan, and Kabiru 2018). By contrast, in rural Malawi transfer of resources from aunts and uncles is common (Weinreb 2002). Beyond the household, the involvement of extended female relatives with education and decision-making powers is positively linked with children’s healthcare utilization in rural Mali (Treleaven 2023).

3. Household structure and under-5 mortality

In contrast to household composition, the relationship between household structure and child health and mortality has been given less attention. One study in rural Mali finds that the odds of a child’s death are higher in large households (over 15 members) with multiple children, and in polygynous households. The study also indicates that children in households composed of multiple nuclear families (lateral households) fare better (Dasré, Samuel, and Hertrich 2019). Households that include lateral ties such as brothers living together or vertical multigenerational ties may provide different contexts for children, affecting their health and well-being. In some settings, such as Nigeria, children in 'nuclear' and three-generational households tend to be worse off than in laterally extended households, where children are vaccinated more effectively (Gage, Sommerfelt, and Piani 1997). By contrast, children in extended family households in rural SSA face a higher risk of death (though not in infancy) (Akinyemi, Chisumpa, and Odimegwu 2016). A higher risk of child mortality in multigenerational households has also been found in the United States, though this risk is attenuated when poor health and disability of other household members are controlled for (Rogers et al. 2020).

Evidence on differences between polygynous and monogamous households suggests that children living in polygynous households are less likely to survive (Gyimah 2009; Omariba and Boyle 2007). The reason for this could be resource dilution (Desai 1992; Omariba and Boyle 2007), co-wife rivalry (Lawson and Gibson 2018) or gender imbalance (Agadjanian and Ezeh 2000), particularly when co-wives live together. It is also possible that poorer or less healthy women are selected into polygynous marriages with well-off men. Conversely, polygynous households could be beneficial for child survival as they are often wealthier, pooling more economic activity, and there is greater birth spacing and time for breastfeeding (Lawson and Gibson 2018). Socioeconomic status could be a critical confounder in this relationship, though polygyny tends to reflect marriage markets more than socioeconomic characteristics (Timæus and Reynar 1998). The general social context in which children live could also be at play, as the survival disadvantage for infants is amplified in societies where polygyny is prevalent (Smith-Greenaway and Trinitapoli 2014). What may be detrimental to child survival may not be whether the household is polygynous or monogamous, but rather the instability caused by transition from one household structure to another when an additional wife moves in (Lawson and Gibson 2018).

Another aspect of household structure, the sex of the household head, may reflect the economic standing of the household and the child's share of resources. Female-headed households tend to direct more resources to children, though whether this is beneficial to child survival overall is debatable (Adhikari and Podhisita 2010; Akinyemi, Chisumpa, and Odimegwu 2016; Lloyd and Desai 1992). This unclear relationship may be due to compounding effects: a female household head could be the result of a migrant spouse, who may send remittances. Considering single mothers, who have considerable autonomy and full responsibility for their children, may be a better way of representing female decision-making and resource provision (Clark and Hamplová 2013). Alternatively, rather than being considered as married women or female heads, it may be more beneficial to consider whether women (namely mothers) benefit from their social networks or are socially isolated (Townsend et al. 2002).

In this study we consider household structure as the micro level of society and therefore propose examining structure based on the number of household members, by age and sex. This structure is essentially the sum of all the compositional effects, such as the number of siblings and the presence of grandparents, but it does not account for kin relations.[6] Rather, it indicates the presence of people – women and men, young and old – living with a child, reflecting the gender balance and the relative proportion of dependents, as compared to economically active individuals in the household. Moreover, we examine household structure as an elastic entity. Households are dynamic and vary over time – older siblings transition into adulthood and may leave the household, younger siblings are born, parents may divorce, relatives may stay for extended periods of time. With high rates of mobility of household members, and fluidity of residence, as seen in Mali, for example (Dasré, Samuel, and Hertrich 2019), it is important to account for dynamic households. As with 'doing family', whereby the configuration of family is practiced rather than fixed (Jurczyk 2014; Perlesz et al. 2006; Strasser et al. 2009), we contend that we can similarly 'do households'. By considering de facto interactions between members, we take a broad approach to this flexible social construct, the household. Moreover, the actual 'doing' of the household, the changes in household structure, can bring about instability and have important negative effects on child well-being (Lee and McLanahan 2015).

Yet little research considers household changes over time. Using longitudinal data, we can account for stability of the household, and examine de facto household structure at the time of a child's death and not at the time of data collection, which is often long after the event of interest (e.g., child death) took place, as in the Demographic and Health Surveys (DHS), for example. Longitudinal data can also reduce sample selectivity; for example, by including children whose mothers may have died (Lloyd and Desai 1992).

We aim to examine the role of household structure in child survival in southern and eastern Africa where the meaning of a household is relatively consistent.[7] Our focus is on these regions because households tend to be larger (Bongaarts 2001). Moreover, in recent decades, HIV/AIDS has triggered shifts in living arrangements and raised concern for children's well-being (Heymann et al. 2007; Hosegood 2009; Hosegood et al. 2007; Zimmer and Treleaven 2020). While the spread of antiretroviral therapy (ART) appears to have attenuated this relationship (Houle et al. 2023), the effect of HIV/AIDS mortality on social support for orphans is expected to extend beyond peak years of the epidemic

[6] Kinship patterns require more detailed data than those we use here. Moreover, using household structure accounts for the combined effects of individuals.
[7] In West Africa, 'household' is often interchangeable with 'compound', that is, homesteads with a cluster of households.

(Zagheni 2011). In southern Africa in particular, the HIV/AIDS epidemic has increased the number of orphans, and reliance on fostering (Beegle et al. 2010; Cotton 2021). Households caring for orphans often have few financial resources (Heymann et al. 2007; Madhavan 2004), with detrimental consequences for child well-being.

By using longitudinal data available from Health and Demographic Surveillance Systems (HDSS) we capture the (in)stability of households, and consider them as complex and fluid. We demonstrate an approach to measuring household structure that may be applied to other longitudinal datasets and present, in particular, a standardised and adaptable method for deriving household structure measures using relatively limited data. By accounting for time-varying living arrangements, we emphasise the importance of the timing of events. Household structure may be influenced by the death of a child (for example, parents may separate because of the death), and by establishing the sequence of events it is possible account for the correct temporal order of events.

The household typology we employ, presented in Table 1, does not rely on kin relationships between the members. It is rather a means of classifying the different types of household structure in which children live. For example, the term 'nuclear' is used only as a proxy for a couple, referring to the presence of one man aged 15–64 and one women aged 15–64. Nuclear-type households thus comprise working-age adults of opposite sexes, reflecting the gendered division of labour observed across many societies. It refers to the physical, de facto, presence of individuals who may contribute in different ways to the health and welfare of a child, whether they are related (parents), or not. The household types in Table 1 are not exhaustive, and the residual is grouped in an 'other' category.

Table 1: Potential effects of household structure on under-5 mortality

Household Type	Increased risk of child death	Lower risk of child death
'Nuclear' (1 man, 1 woman), only 1 child under 5 years old	Higher mortality among first-borns (First child effect) Previous child death (death clustering) Older mother with large birth spacing	Exclusive care of child, no competition, no dependents
One woman only	Unstable relationship (e.g. divorced mother) Inexperience (e.g., young single mother) Fewer resources	Positive selection of autonomous, responsible women
'Nuclear' (1 man, 1 woman), 2+ children aged 0–14 years old	Sibling competition and short birth intervals (less than 24 months) Greater division of resources for dependents	Selection effect, of a healthy and stable family where children survive (as opposed to death clustering) Older children can help look after younger children or assist with other household chores (freeing up adults' time)
Multiple adults of both sexes	Resource dilution Diffusion of responsibility	Working-age adults provide resources (pooled economic activity) and extra care
Old-age dependents	Dependent age group may need care themselves (competition for resources) Traditional or out-dated care practices	Older adults (including grandmothers) can actively assist in childcare

We aim to identify the association between the risk of children dying and type of household as defined around the time of the child's death. For each household type outlined in Table 1, it is possible to consider a positive or negative effect on under-5 mortality, based on the literature discussed above. Rather than testing hypotheses, we take an exploratory approach by assessing the direction of effects. Since there is somewhat limited and contradictory evidence on the direction of the effects of household structures in particular, we prefer to be open to different options (either positive of negative effects).

4. Data and methodology

4.1 Health and Demographic Surveillance Systems

We examine the effect of household structure on infant and child mortality between 1990 and 2016 in five countries in southern and eastern SSA where mortality remains highest and households are relatively large. We use readily available data from 15 Health and Demographic Surveillance Systems (HDSS) accessible through the INDEPTH network's iShare repository (INDEPTH 2017).[8] The HDSS cover entire populations in delineated areas, and follow demographic events of these populations including births, deaths, and migrations. Each site is visited at least once a year after an initial baseline census, and all events are recorded. Although each HDSS is not representative at the country level, taken together the HDSS offer a broad overview of population changes over time at a large geographical level. The HDSS vary in size of population covered and in overall level of under-5 mortality over the entire period covered by each site (ranging from a low probability of 14 out of 1000 children dying in Harar Urban, to 104 out of 1000 in Kersa), and are broadly rural, with the exceptions of Harar Urban in Ethiopia, and Nairobi in Kenya (Table 2). We pool the data from all sites to create a dataset that includes 281,964 under-5 year olds with information about their mothers, in 48,358 households. The pooled probability of dying from birth to age 5, ${}_5q_0$, a mortality estimate of 66.4 per 1000 (95% CI: 65.4–67.4), is in line with the average ${}_5q_0$ based on DHS data from the same countries we analyse (65.0 per 1000, 95% CI: 57.6–72.6).[9] This comparison suggests that

[8] We exclude the HDSS in Uganda (Iganga/Mayuge) because the household identifier is not comparable with the other sites. The file we use is accessible through this link: https://www.indepth-ishare.org/index.php/catalog/181

[9] The DHS estimates were based on data from Statcompiler (www.statcompiler.com), using only one survey per country, and the most recent one between 2010 and 2018. The average urban ${}_5q_0$ based on the DHS is 63.2 per 1000 (95% CI: 49–77) and the average rural ${}_5q_0$ is 65.8 per 1000 (95% CI: 57.2–74.8).

the pooled data are generally representative of mortality trends in southern and eastern Africa.

On average, children under 5 in eastern and southern Africa live in households of 6.3 members, including themselves (Table 2). These households generally also have a relatively high number of under-15-year-old children, averaging 4.2 across sites.[10] The larger average household size in southern African sites could be a reflection of cultural practices related to living arrangements (for example, where couples reside after marriage), differential fertility norms, and possibly also better child survival over this period (You et al. 2015). These findings are not surprising, considering the sites are mostly rural, where fertility is higher (Garenne 2017; Shapiro and Tambashe 1999), and that we explicitly examine households with resident under-5 year olds.

Table 2: Characteristics of 15 HDSS sites in eastern and southern Africa

Country	HDSS	Start and end dates of surveillance	Number of children under 5	Median household size [and inter-quartile range]	Probability of dying $_5q_0$	In-migration rate (per 1000)	Out-migration rate (per 1000)
Ethiopia	Gilgel Gibe	2006–2015	18,079	6 [3]	0.0897	38.6	58.1
Ethiopia	Kilite Awlaelo	2010–2014	7,371	6 [4]	0.0345	24.7	73.9
Ethiopia	Kersa	2008–2016	20,148	6 [3]	0.1038	10.2	29.6
Ethiopia	Harar Urban	2012–2016	3,033	5 [2]	0.0136	58.3	116.9
Ethiopia	Dabat	2009–2015	7,830	6 [3]	0.0274	32.5	62.9
Ethiopia	Arba Minch	2010–2015	11,235	6 [2]	0.0383	43.0	59.4
Kenya	Nairobi	2003–2015	22,975	4 [2]	0.0692	199.4	270.2
Kenya	Kombewa	2011–2015	7,783	5 [3]	0.0510	76.1	93.8
Mozambique	Chokwe	2010–2015	13,952	6 [4]	0.0580	66.8	123.6
Tanzania	Ifakara Rural	1997–2014	46,909	5 [3]	0.0974	102.5	158.8
Tanzania	Rufiji	1999–2014	33,975	6 [4]	0.0881	74.6	115.2
Tanzania	Magu	1994–2013	13,639	7 [4]	0.0977	167.2	211.7
South Africa	Agincourt	1993–2016	43,066	8 [6]	0.0454	61.2	90.3
South Africa	Dimamo	1996–2016	6,429	8 [4]	0.0187	31.0	40.1
South Africa	AHRI	2000–2016	25,540	8 [5]	0.0547	84.8	122.4

Note: Household size refers only to households in HDSS with an under-5-year-old child; number of under-5-year-old children only includes children who we were able to match to mothers. AHRI is short for Africa Health Research Institute (located in the uMkhanyakude district).

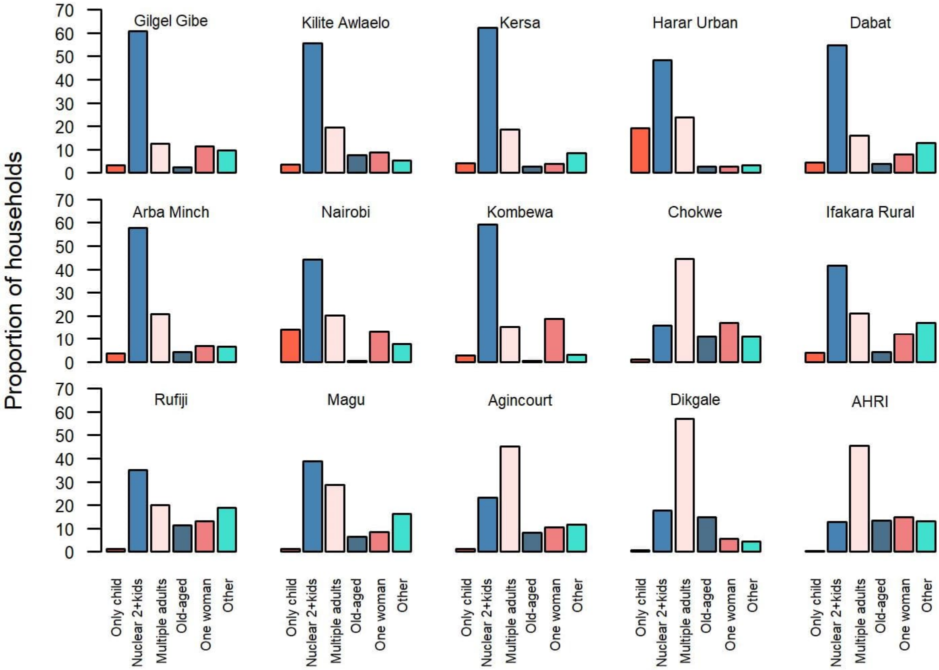
There is also considerable diversity between the different HDSS, with households being smaller in the two urban sites – a mean of 3.6 and median of 4.0 in Nairobi and a mean of 4.6 and median of 5.0 in Harar Urban. By contrast, in South Africa rural

[10] By definition the households examined are those with at least one under-5-year-old child. When including all households on site, the mean number of household members is 4.8, and the mean number of under-15 year olds is 3.1.

households with under-5 year olds are especially large, with a mean and median of 8.0 members, reflecting a high proportion of children. While Table 2 demonstrates the heterogeneity in household structure between sites, it is also important to note that the means hide considerable ranges of household structure within the sites. For example, considering the inter-quartile ranges of household size (Table 2), households in the urban sites are mostly distributed within a narrow range, while in the South African sites the range of household size is wider and households with over ten members are common. Household structure is also likely to fluctuate in response to migration in and out of the HDSS sites, and, like household sizes, the migration rates across sites are heterogenous (Table 2).

The prevalence of household typologies differs by HDSS site (Figure 1), reflecting the heterogeneity of populations covered in our analysis, despite these sites covering small sub-district-level areas. By grouping the sites, we are able to provide a broad perspective on children's living arrangements in southern and eastern Africa. Urban sites Nairobi and Harar Urban are characterised by higher proportions of households with only one child. By contrast, in the HDSS sites in South Africa, a country acutely affected by shifts in household structure due to HIV (van Blerk and Ansell 2006; Monasch and Boerma 2004), and where around a quarter of mothers have fostered children (Cotton 2021), children tend to live frequently in households with multiple adults aged 15–64 of both sexes. Such households are also common in Chokwe, Magu, Rufiji, and Ifakara Rural; that is, in the Tanzanian and Mozambican sites. All of the Ethiopian sites have a high prevalence of nuclear-type households with at least two children. These children mostly live with their parents, as fostering prevalence is relatively low in Ethiopia (Cotton 2021). Households with only one adult woman are relatively common in Nairobi, Kombewa, Chikwe, Rufiji, and the AHRI. Households with adults over age 65 are most prominent in the South African sites.

Figure 1: Distribution of household types with under-5-year-old children by HDSS site



4.2 Longitudinal framework: time-varying household structure

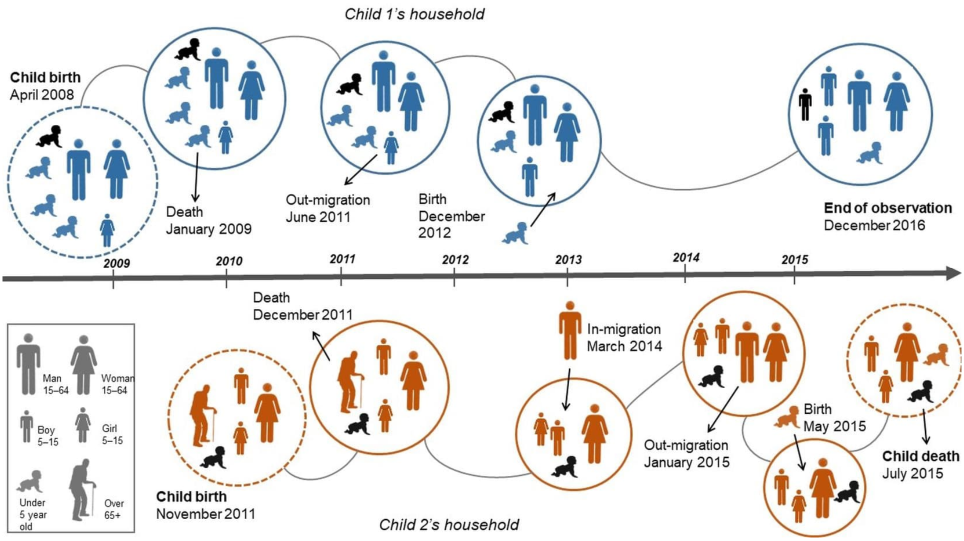
Households are often defined as a group of people who live in the same property and eat together (Randall et al. 2015). This definition is similar to that used by the DHS, which defines households as a person or group of people, whether related or not, who live together in the same dwelling, acknowledge one adult as the household head, and share the same housekeeping arrangements (including collective eating) (ICF International 2012). The HDSS data use a similar definition of household – a local residential unit, with shared resources (though this varies slightly from site to site). In Agincourt, Rufiji, and Nairobi, HDSS households are defined as a group of individuals who eat from the same pot of food (Beguy et al. 2015; Kahn et al. 2012; Mrema et al. 2015), while in Magu the criterion of living together in the same compound is added to this definition (Kishamawe et al. 2015). Our definition of household membership is not limited to family ties. We employ a de facto definition of household, whereby any individual, migrant or not, is considered a member of the household if they reside more than six months in the household, with the exception of babies born in the household who are resident and members from the time of their birth. In order to construct time-varying household structure measures we rely on the population equation (see Appendix A-1 for a detailed example of the construction of household measures):

$$HS = \sum ENU_{m,f|a} + BTH_{m,f|a} + IMG_{m,f|a} + ENT_{m,f|a} - DTH_{m,f|a} - OMG_{m,f|a} - EXT_{m,f|a}$$

where *m* denotes male, *f* female, and *a* age group. *HS* indicates household size, *ENU* enumeration, *BTH* births, *IMG* in-migration into the household from out of the HDSS site, and *ENT* indicates entry of an individual into the household, moving within the site. *DTH* indicates death, *OMG* out-migration from the household and HDSS site, and *EXT* indicates an individual leaving the household but moving within the site. Based on the balance of events we can calculate the household size, as well as the number of members by age and sex at any point in time. Households that were particularly large, with over twenty members (equivalent to three standard deviations above the median) were excluded from the analysis to prevent outlier bias. This led to 1% of households being excluded from the analysis, 80% of which were in three sites (Ifakara, Agincourt, and AHRI). When we ran a sensitivity test including these households our results did not change. Moreover, some households at some point in the surveillance were estimated to have a negative number of members. Such households likely reflect errors in recording the timing of events or household identifiers, and they were also removed from analysis (see Appendix A-2 for details). They accounted for only 0.1% of the sample, and were most common in two sites (Chokwe and Nairobi).

In Figure 2 we present two examples of children in Kersa, to illustrate how dramatically a household structure can shift for a child. Child 1 in Figure 2 was born into a household of six individuals, three of whom were under age 5. A year later, an under-5 year old in Child 1's household died, possibly meaning this child lost a sibling. A girl who was in the household and may have taken care of Child 1 migrated out of the household during the third year of the child's life, and then a (most likely) sibling was born four years later. For the next four years the child lived with the same five individuals. Child 2 was born into a household with four individuals, but the eldest household member died a month later. Nearly three years later, an adult man moved into the household, possibly a partner to the woman member. However, this man left the household a year later, a few months before the birth of another child in the household. Child 2 then died before reaching age 4, when there was only one adult in the household (and four under-15 year olds, including Child 2). These children's living arrangements at time of birth differ considerably to their living arrangements at end of observation (or death). Examining their household structure at only one point in time, as is often the case in surveys, does not capture the multiple changes in the social environment of these children.

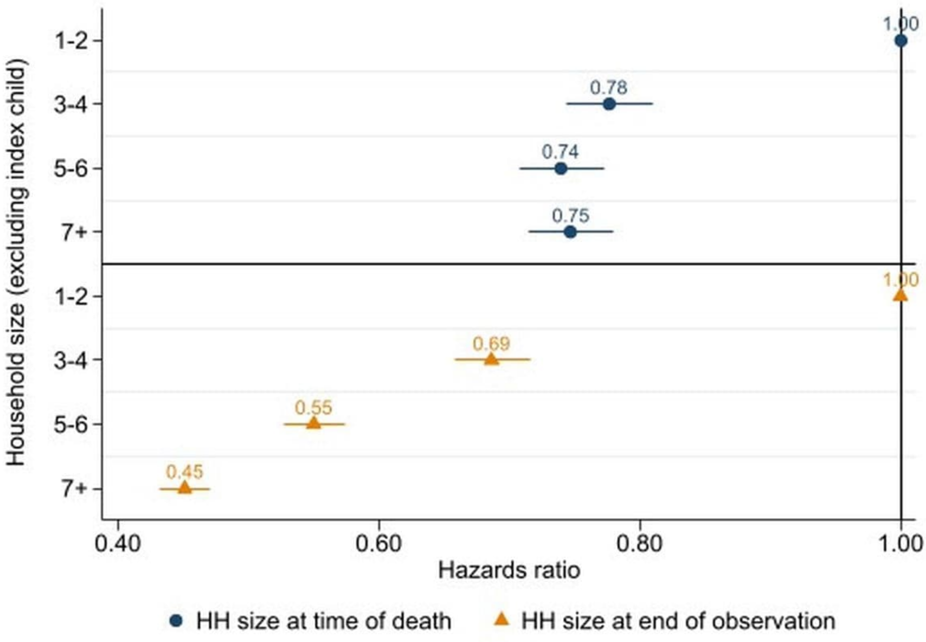
Figure 2: Examples of household structure churning, two children in Kersa HDSS



The changes in households, due to new members joining (through birth or migration) or leaving (through death or migration), alter the environment in which a child lives. We find that on average across the HDSS sites a child experiences changes in household structure mostly through migration in/out of the HDSS site. On average, a child sees 3.4 in-migrants and 2.8 out-migrants from its household over the first five years of its life, and this excludes short-distance moves in/out of the household within the HDSS. However, births also contribute considerably to increases in the household size, with a child experiencing on average 2.3 births in the household before reaching age 5. A change in household structure due to death is less common, with a fifth of children experiencing a death in their household before age 5. Multiple changes in a child's household environment have similarly been documented in Mali (Dasré, Samuel, and Hertrich 2019).

The importance of capturing the household size at the time of the event of interest – in our case, at time of death – is demonstrated in Figure 3. We compare the use of household size at the time of child's death in comparison to at the time of end of observation period (mimicking time of survey) in a simple model, predicting death among under-5 year olds according to categories of household size and controlling for site and period effects.[11] It is clear from Figure 3 that the results are quite different, emphasizing the need to consider time-varying household structure. When using time-varying household size, the odds of a child's death in large households does not change with additional members. However, if we were to use a static measure of household size based on the size at end of observation, we would find that the more individuals in the household, the lower the likelihood of child death. This gradient reflects a bias that necessarily emerges from cross-sectional analysis whereby survivors increase household size (and deaths reduce household size).

Figure 3: Example model results comparing use of household size at time of child death as opposed to at time of survey



Note: HH= household.

[11] When we model household structure as described further below, including maternal covariates, the results are consistent.

4.3 Measures of household structure

We use two distinct measures of household structure: the simple household size and a household typology. Household size is used to capture the number of people living with a child. In addition to total household size, we initially examined the number of household members in specific age groups and by sex. We expected that these different characteristics would have different effects on child survival. However, when these age- and sex-specific categories were separately included in the model we observed some collinearity and could not clearly interpret the results. For example, for every additional woman of reproductive age in the household, the model indicated a 20% increase in the risk of child death. At the same time, for every additional child aged 0–4 the model suggested a 10% reduction in risk of child death. Yet an additional woman aged 15–49 in the household could often mean that she also brings children into the household, and these opposing effects were contrary to expectations. We therefore found that this strategy of examining the presence of age- and sex-specific members independent of the presence of other members of the household was not valuable. Indeed, the presence of some household members is dependent on the presence of others, and each member's presence cannot independently impact child survival. For example, a grandmother's effect on under-5 mortality may differ according to whether her spouse is also alive and living in the household.

This led us to cluster the household members by age and sex according to a meaningful typology (see Table 1). As noted above, the presence of one man and one woman in the household does not necessarily mean that the household consists of a nuclear family, but it does represent the presence of both a male and female working-age adult, where it is possible that at least one of them is the parent of the child. The typology provides a measure of micro-level population structure (by age and sex), rather than a measure of relationships. The distribution of person-years (PYARs) of under-5 year olds according to this typology is presented in Table 3. We use five mutually exclusive categories: 'nuclear' (presence of one man aged 15–64 and one women aged 15–64) with only one child, 'nuclear' with two or more children, multiple adults between ages 15–64 in the household (and any number of children), only one woman aged 15–64 in the household (and any number of children), and households with at least one member over age 65 (typically no longer economically productive and more likely to have health issues) and any number of children. We also include in the analysis an 'other' household type that may be indicative of uncommon living arrangements, including no adults present, though it most likely captures errors in the data. We refrain from interpreting this residual category.

Table 3: Person-years at risk of death according to type of household with at least one under-5-year-old child

Household type	*PYAR*	*% of PYAR (0–5 year olds)*
'Nuclear' (1 man, 1 woman), only one child	30,159	3.14
One woman only	109,456	11.38
'Nuclear' (1 man, 1 woman), 2+ children aged 0–14	363,747	37.81
Multiple adults of both sexes	271,862	28.26
Old-age adults (includes 65 year olds)	66,262	6.89
Other, errors	120,467	12.52

Note: PYAR=Person-years at risk.

4.4 Modelling strategy

We limit our analysis to children under age 5 who were born within an HDSS site at any time during surveillance. It is possible that some children born on site out-migrated and then returned to the site. Following this in-migration, we only include these children in our analysis if they are resident for six months or more (to avoid including temporary visitors). Essentially, we only consider under-5 mortality among children who are exposed to the HDSS environment. This reduces selection of children who in-migrated and necessarily survived to move to the site. As such, our results are likely conservative. Moreover, we examine only children who can be matched to a mother's event history. This limits the sample to 281,964 children, since mothers can only be matched to their children if the child was born in the HDSS site, but it still allows us to account for the presence of the mother in the household. Previous work has demonstrated how critical a mother is to a young child's survival (Bocquier et al. 2021; Chikhungu, Newell, and Rollins 2017; Yaya et al. 2018). Thus, we build on this and model the relationship between household structure and under-5 mortality conditional on a mother's death, migration, or coresidence.

Maternal covariates included in our models are mother's age at birth in discrete categories, typically U-shaped in relation to child death (Finlay, Özaltin, and Canning 2011; Gibbs et al. 2012); maternal survival status, including the period around her death (six months before or after) (Houle et al. 2015); and mother's migration status (whether she out-migrated and is non-resident in the HDSS, in-migrated to the site recently, or in-migrated 2–5 years ago). Child covariates included in our models are the child's sex and whether a twin. Our Cox proportional hazard models also control for site and period effects (also time-varying), which captures the variation in mortality level and trends between the HDSS. We also run a model to check for robustness by only including one child per household. This removes any potential correlation between children within the same household.[12] Although frequent transitions from one household type to another could be detrimental to children's health and survival (Lee and McLanahan 2015), we do not include in our Cox models a measure of the number of changes, since this would be quasi-collinear with age. We tested the assumption of proportional hazards using a log-log plot of the household typology, and found that we do not violate the assumption (and can use Cox Models). All code for the analysis is available on Github.[13]

4.5 Limitations of the data: Missing indicators of socioeconomic status

The HDSS data available from the INDEPTH iShare repository are limited in scope, and do not allow us to include socioeconomic indicators. This is an important limitation, since socioeconomic status could be associated with household structure (Thomson, Hanson, and Mc Lanahan 1994), and therefore confound the household structure–mortality relationship. However, we consider socioeconomic status as a distal determinant of child death (Mosley and Chen 1984), essentially acting through observed proximate determinants. All the same, we checked the relationship between socioeconomic status and household structure using DHS data for the same countries as in our analysis, and around the same period.[14] We examined whether larger households were wealthier or vice versa using the DHS wealth index.[15] Since household size may differ by rural or urban sector, driven by variation in fertility, mortality, and migration patterns, and similarly wealth may differ according to sector, we analysed the relationship by rural/urban sector. In the urban sector, wealthier households broadly seem to be larger (Figure 4), with an average difference of one member between poorer and richer households. By contrast, in the rural sector there is hardly any difference in household size according to the wealth index (with confidence intervals overlapping). Considering that the majority of the HDSS sites in our analysis are rural (only two are urban), we infer that the association between wealth and household size within the HDSS is negligible.

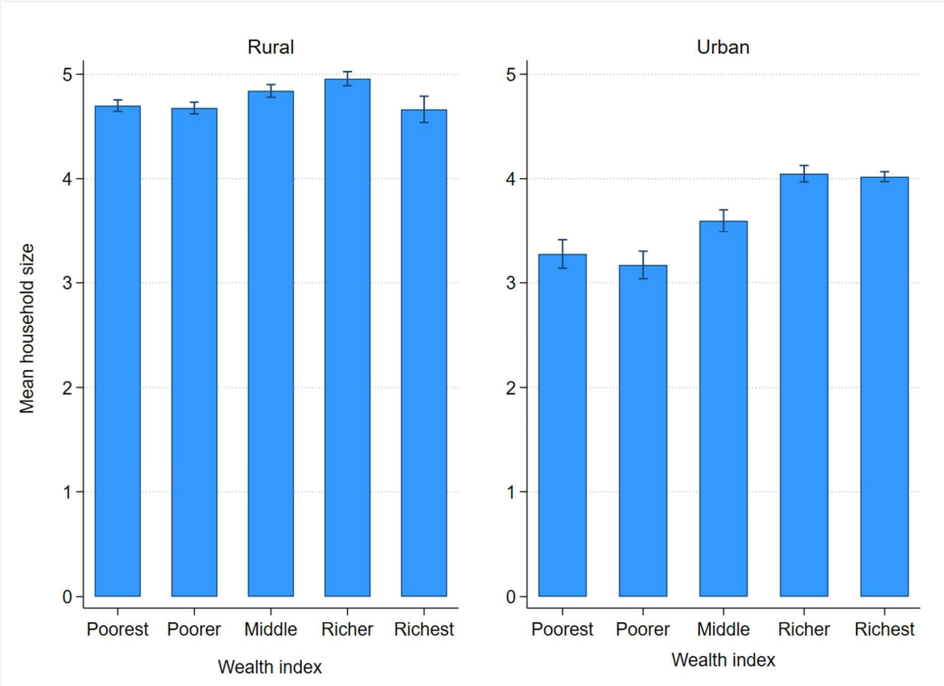
[12] We could not control for this through fixed effects since, to our knowledge, the number of households is too large for existing software to handle.

[13] https://github.com/ashira-mo/households.

[14] The DHS surveys are Ethiopia (2003), Kenya (2008–2009), Mozambique (2011), South Africa (2016), and Tanzania (2011–2012), available from https://dhsprogram.com/. Sub-regions within countries were selected according to the presence of HDSS sites in these regions.

[15] This composite measure is based on principal components analysis of indicators of household access to infrastructure like electricity, as well as ownership of assets like a bicycle.

Figure 4: Average household size according to wealth quintile, based on five DHS surveys from regions within countries where HDSS sites we use are located, with confidence intervals



Source: DHS surveys used are: Ethiopia (2003), Kenya (2008–2009), Mozambique (2011), South Africa (2016), Tanzania (2011–2012).

5. Results on the effect of household structure on child survival

In Table 4 we present hazard ratios from a set of Cox models examining the role of household structure on under-5 mortality. The first model accounts only for child's sex and maternal covariates. As expected, female children have a lower risk of death (Roth et al. 2018). Additionally, having a twin is known to be a strong risk factor for under-5 mortality (Becher et al. 2004; Justesen and Kunst 2000), and we find here that it increases the risk of the index child's death by between 2.4 to 2.8.[16] Children born to mothers under 20 years old or over 36 years old face higher risk of death. This U-shaped risk factor is similar to those found in previous studies (Bocquier et al. 2021; Finlay, Özaltin, and Canning 2011; Houle et al. 2015; Kravdal 2018). We further find, in line with other studies (Anderson et al. 2007; Chikhungu, Newell, and Rollins 2017; Houle et al. 2013), that the death of a mother has a particularly strong effect on a child's death, with highest risk around the month of her death. Moreover, the risk is high even up to six months before her death, with a minimum effect of 4.0, likely due to the mother's prolonged illness, during which time she is unable to fully care for her child (Garenne et al. 2013; Houle et al. 2015). Finally, in Model 1 we also account for maternal in-migration to the HDSS site, since this may affect child survival (Antai et al. 2010; Bocquier et al. 2011; Omariba and Boyle 2010; SSengonzi, De Jong, and Stokes 2002). We find a small effect of higher risk of child death when the mother is a recent migrant; that is, moved to the site 6–24 months earlier (HR = 1.10, 95% CI = 1.05–1.15).[17]

When we include household size in the model (Model 2 in Table 4) we note that the hazard ratios of the child and the maternal covariates hardly change. This implies that household size or type is independent of, and supplementary to, maternal and child effects. The relationship between household size and child death is curvilinear, where an increase in household size is associated with a lower risk of child death, with the relationship flattening out from around five household members (excluding the index child). This is in line with previous research that found on the one hand higher risk among single mothers, especially among never-married women (Clark and Hamplová 2013; Ntoimo and Odimegwu 2014), and on the other no evidence of children in extended households faring worse (Gage, Sommerfelt, and Piani 1997).

Next, we turn to analysis of the effect of household structure through a typology of households (Model 3 in Table 4). Figure 5 summarises the household typology effects estimated in Model 3.[18] We find that an only child (the index child living with one man and one woman) faces a higher risk of death by a minimum of 32% (HR = 1.42, 95% CI = 1.32–1.53), in comparison to nuclear-type households with at least two children. This could be due to a first-child effect (Finlay, Özaltin, and Canning 2011; Kravdal 2018), or due to death clustering of children (van Dijk 2018). Children in households with multiple adults have a higher risk of death, by up to 20% (HR = 1.15, 95% CI = 1.01–1.20). Households with adults over age 65 (older-aged adults) are associated with

[16] We refer to the boundaries of the confidence intervals of the hazard ratios, within which we are confident the hazard ratio lies, rather than to an exact hazard ratio. The confidence intervals provide likely minimum and maximum effects.
[17] For a mother to be considered a migrant in our analysis, her move must have happened at least six months ago.
[18] Table A-3 in the Appendix replicates Model 3 using a randomly selected child per household. The effects of each household type remain in the same direction, though the confidence intervals are wider.

between 15% to 30% higher risk of child death (HR = 1.23). However, based on the results of this model, we cannot conclude that living with only one woman affects child survival.

Table 4: Cox model results of the relationship between household structure and under-5 mortality, across eastern and southern Africa, based on 15 HDSS

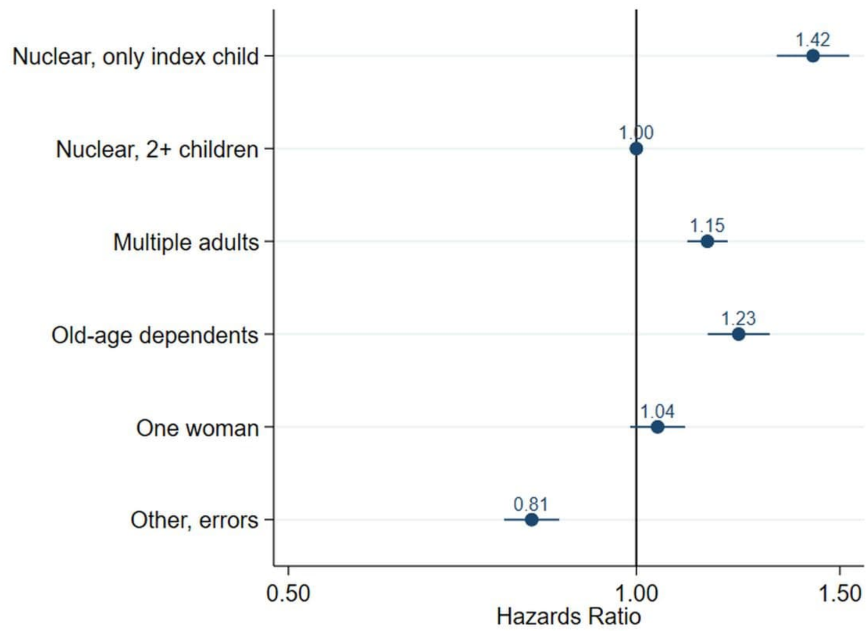
	Model 1: Maternal covariates only	Model 2: Household size	Model 3: Household type
	Hazard ratio & 95% Confidence Interval		
Female	0.889	0.890	0.888
	[0.862,0.917]	[0.863,0.918]	[0.862,0.916]
Twin	2.591	2.635	2.620
	[2.377,2.824]	[2.418,2.871]	[2.427,2.828]
Mother's age at birth (ref= 21–23)			
15–17	1.200	1.215	1.202
	[1.124,1.281]	[1.138,1.297]	[1.126,1.282]
18–20	1.052	1.055	1.038
	[0.995,1.112]	[0.997,1.115]	[0.982,1.097]
24–26	1.006	1.012	1.020
	[0.951,1.064]	[0.956,1.070]	[0.965,1.078]
27–29	1.015	1.029	1.035
	[0.957,1.076]	[0.970,1.091]	[0.977,1.096]
30–32	1.043	1.067	1.068
	[0.981,1.109]	[1.003,1.134]	[1.006,1.134]
33–35	0.988	1.017	1.017
	[0.923,1.058]	[0.949,1.088]	[0.951,1.088]
36–38	1.111	1.148	1.143
	[1.031,1.197]	[1.065,1.237]	[1.063,1.229]
39–41	1.067	1.108	1.098
	[0.975,1.169]	[1.011,1.213]	[1.004,1.201]
42+	1.239	1.289	1.265
	[1.123,1.366]	[1.169,1.422]	[1.148,1.394]
Mother survival status (ref=alive)			
3–6 months before mother's death	5.320	5.160	5.577
	[4.074,6.948]	[3.950,6.741]	[4.264,7.293]
15 days to 3 months before mother's death	6.731	6.549	7.133
	[5.260,8.612]	[5.116,8.384]	[5.589,9.102]
+/– 15 days around mother's death	24.52	23.87	26.03
	[20.83,28.87]	[20.27,28.11]	[22.15,30.58]
15 days to 3 months after mother's death	17.50	17.09	18.39
	[14.29,21.43]	[13.96,20.92]	[15.05,22.48]
3–6 months after mother's death	7.829	7.691	8.167
	[5.666,10.82]	[5.566,10.63]	[5.905,11.30]
6+ months after mother's death	4.044	3.995	4.195
	[3.206,5.101]	[3.168,5.038]	[3.343,5.265]

Table 4: (Continued)

	Model 1: Maternal covariates only	Model 2: Household size	Model 3: Household type
	Hazard ratio & 95% Confidence Interval		
Mother non-resident	1.590	1.530	1.661
	[1.482,1.707]	[1.425,1.643]	[1.550,1.780]
Mother migration status (ref=permanent resident)			
In-migrated 6–24 months before	1.100	1.077	1.054
	[1.048,1.154]	[1.026,1.130]	[1.005,1.104]
In-migrated 2–5 years before	1.082	1.064	1.058
	[1.030,1.138]	[1.012,1.119]	[1.008,1.111]
Household size (excluding index child)		0.948	
		[0.933,0.964]	
Squared household size		1.002	
		[1.001,1.003]	
Household typology (ref= ‘nuclear’ 2+ children)			
‘Nuclear’, only index child			1.422
			[1.323,1.529]
Multiple adults			1.152
			[1.107,1.199]
Older-aged adults			1.226
			[1.153,1.304]
One woman			1.043
			[0.988,1.102]
Other			0.812
			[0.768,0.858]
chi2	7045.0	7199.6	7471.4
Number of children	281,955	281,955	281,923
PYARs	963005.7	963005.7	961947.6
Number of deaths	16,666	16,666	16,665

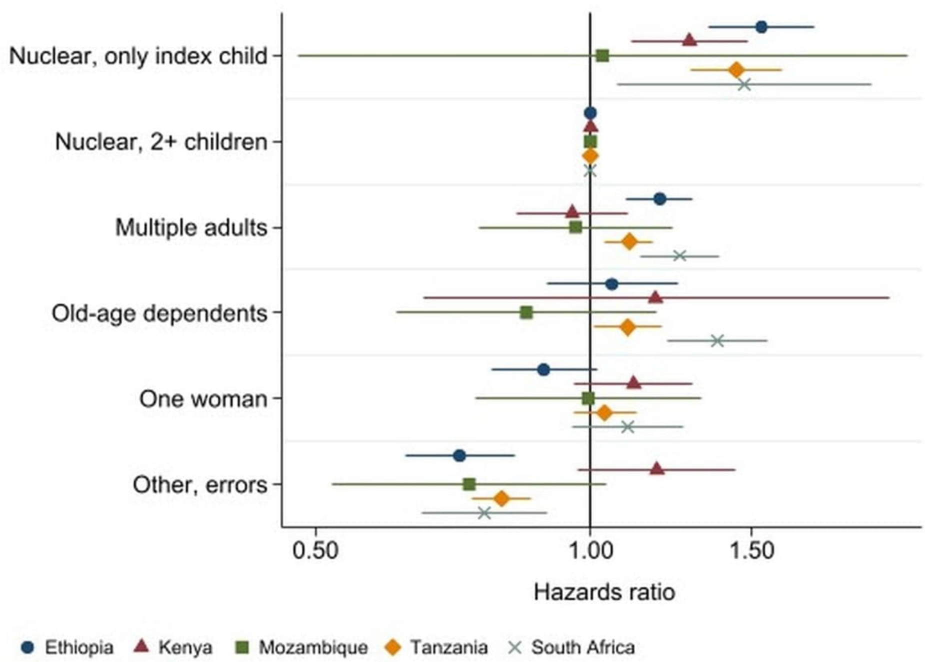
Note: Index child is not included in the household size, but is included in the household typology. Site-year coefficients not shown, see Table A-2 in Appendix for these coefficients.

Figure 5: Effects of household type on under-5 mortality (Model 3 in Table 3), across eastern and southern Africa, based on 15 HDSS



Although our objective is to provide a broad analysis of southern and eastern African populations, there are recognisable differences between the HDSS; for example, higher migration rates in Magu and Nairobi and low under-5 mortality in Harar Urban and Dimamo (see Table 2). Moreover, there are differences between the countries; for instance, higher prevalence of HIV/AIDS in South Africa, and a lower percentage of mothers who foster children in Kenya and Ethiopia. Therefore, in Figure 6 we examine the results of country-specific models (as specified in Model 3 of Table 3). Although this captures only one site for Mozambique and six for Ethiopia, this does give us an idea of the importance of context. In all countries but Mozambique we see that in comparison to households with two or more children, sole children face a higher risk of death, as shown in Figure 5. In Ethiopia, Tanzania, and South Africa, living with multiple adults is detrimental (Figure 5). However, in Kenya and Mozambique confidence intervals are wider and we cannot conclude that living with multiple adults is related to child survival. With insufficient numbers of older-aged adults in some countries, the confidence intervals are wider around the hazard ratio; although notably, in South Africa, where the proportion of such households is higher (as seen in Figure 1), the risk of child death is markedly higher (as seen in Model 3 of Table 3). Lastly, Figure 6 confirms that across countries children in households with only one adult woman are not worse off. Overall, while the pooled sites hide some heterogeneity across sites, the relationship between household structure and under-5 mortality is relatively similar in all countries examined.

Figure 6: Effects of household type on under-5 mortality by country, across eastern and southern Africa, based on 15 HDSS



Finally, we examine the relationship between household structure and under-5 mortality according to the index child's age, since there is some interrelation between household type and age of the child. For example, in households with only one child the index child is likely closer to age 1 than 3. We replicate Model 3 from Table 4, separately modelling children aged under 12 months (infants) and 12–59 months (Table 5). Unsurprisingly, the effect of a mother's age at birth is more important among infants (Model 4), with children to mothers aged 15–17 or over 42 years old facing a higher risk of death. Across both age groups, the death of a mother is detrimental to child survival. Similarly, a non-coresident mother increases the risk of both infant and child death.

The type of household a child lives in remains important, and quite similar whether in infancy or between ages 12–59 months. An only child has a higher risk of death than nuclear-type households with at least two children, up to 57% higher across models 4 and 5 (0–12 months – HR: 1.45, 95% CI: 1.34–1.57; 12–59 months – HR: 1.34, 95% CI: 1.15–1.57). Similarly, children in households with members over age 65 have an increased risk of death, from a risk of at least 13% during infancy, up to a maximum risk of 40% up to age 5. There is also a higher risk (up to 23%) of both infant and child death in households with multiple adults. Children up to 12 months old in households with only one woman are at higher risk of death than infants in nuclear-type households with at least two children, although the confidence intervals are quite wide, and the risk quite low (HR: 1.07, 95% CI: 1.00–1.14). The hazard ratios are even more inconclusive about this relationship among children aged 12–59 months.

Table 5: Cox model results of the relationship between household structure and infant mortality, mortality among 12–59 month olds, across eastern and southern Africa, based on 15 HDSS

	Model 4: Infant	Model 5: 12–59 months
	Hazard ratio & 95% Confidence Interval	
Female	0.871	0.926
	[0.839,0.903]	[0.877,0.979]
Twin	3.196	1.252
	[2.941,3.472]	[1.035,1.514]
Mother's age at birth (ref= 21–23)		
15–17	1.285	1.022
	[1.190,1.388]	[0.906,1.153]
18–20	1.067	0.967
	[0.998,1.139]	[0.874,1.069]
24–26	1.049	0.947
	[0.981,1.121]	[0.856,1.048]
27–29	1.025	1.046
	[0.956,1.099]	[0.944,1.159]
30–32	1.059	1.070
	[0.985,1.139]	[0.962,1.189]
33–35	1.035	0.966
	[0.955,1.122]	[0.857,1.089]
36–38	1.167	1.090
	[1.070,1.273]	[0.957,1.241]
39–41	1.085	1.106
	[0.973,1.211]	[0.946,1.292]
42+	1.368	1.046
	[1.220,1.534]	[0.872,1.254]

Table 5: (Continued)

	Model 4: Infant	Model 5: 12–59 months
	Hazard ratio & 95% Confidence Interval	
Mother survival status (ref=alive & resident)		
3–6 months before mother's death	4.870	7.187
	[3.488,6.800]	[4.580,11.28]
15 days to 3 months before mother's death	7.497	5.559
	[5.716,9.833]	[3.152,9.802]
+/– 15 days around mother's death	23.48	39.46
	[19.64,28.07]	[27.58,56.46]
15 days to 3 months after mother's death	18.99	16.14
	[14.96,24.12]	[11.05,23.59]
3–6 months after mother's death	9.257	6.464
	[6.212,13.79]	[3.670,11.38]
6+ months after mother's death	3.470	4.689
	[2.160,5.576]	[3.641,6.039]
Mother non-resident	1.438	2.138
	[1.314,1.574]	[1.917,2.385]
Mother migration status (ref=permanent resident)		
In-migrated 6–24 months before	1.015	1.076
	[0.964,1.069]	[0.953,1.214]
In-migrated 2–5 years before	1.055	1.084
	[0.992,1.122]	[1.000,1.177]
Household typology (ref= 'nuclear' with 2+ children)		
'Nuclear', only index child	1.451	1.342
	[1.336,1.574]	[1.147,1.570]
Multiple adults	1.158	1.144
	[1.103,1.215]	[1.064,1.230]
Older-aged adults	1.215	1.251
	[1.128,1.310]	[1.122,1.395]
One woman	1.069	0.984
	[1.002,1.141]	[0.891,1.087]
Other	0.780	0.873
	[0.729,0.835]	[0.794,0.959]
chi2	5597	7512
Number of children	281,892	246,065
PYARs	260972.1	701122.2
Number of deaths	11,612	5,089

Note: Index child is not included in the household size, but is included in the household typology. Site-year coefficients not shown.

6. Discussion

Our analysis of the role of household structures in child survival in southern and eastern Africa has first and foremost demonstrated the importance of considering households as elastic. Households are shifting entities, as members join and leave as children in the household grow up. Unlike the commonly analysed household structure at a specific time (typically at date of survey), we examine household structure as a time-varying covariate. We find that this household churning is mostly through residential mobility, and, to a lesser extent, births.

We find that, when we consider household size, the risk of under-5 mortality is higher in smaller households. In larger households, with every additional member (disregarding age or sex) the risk of child death is relatively stable. In addition to household size, we examined household structure through a typology of households based on the presence of members according to age and sex. Although we sought to consider the effect of the presence of each household member by age and sex separately, we found that this was not sensible due to collinearity. We therefore considered the combined effect of the presence of a variety of household members by forming a household typology. The effects of household type are important both during infancy and among 12–59-month-old children. These effects of household type were estimated independent of the presence, or absence, of the mother and other maternal covariates.

Overall, the important effects of household type in addition to maternal covariates confirm certain associations more than others outlined in Table 1. For sole children, exclusive care and no competition is insufficient to overcome the first-born child effect. In families with at least two young children, the effects of short birth intervals, sibling competition, and greater division of resources are not as strong as ‘health clustering’. The lack of an association between one-woman households and child survival may be balancing previous findings of a lower risk of child death among single mothers in some settings (Akinyemi, Chisumpa, and Odimegwu 2016), and a higher risk among single mothers in other settings, especially among never-married women (Clark and Hamplová 2013; Ntoimo and Odimegwu 2014). This contradictory evidence could be explained by the association of poorer economic status and single parenting (Rogers et al. 2020; Thomson, Hanson, and Mc Lanahan 1994), or whether the extent of kin support was accounted for (Clark, Madhavan, and Kabiru 2018). Although our finding is not in regard to single mothers but to households with only one female adult, it could indicate that on average, across various contexts in southern and eastern Africa, children living with only one woman (sometimes single mothers) fare as well as those living in ‘nuclear’ families with two or more children.

We further find that although over-65 year olds can assist with childcare, having an older-aged adult in the household increases the risk of child death. This could be because they also require care and compete for resources (and are often in large households where resources may be spread thinly), or because the care that they provide is out-dated. The later explanation is unlikely, since it has been shown that although older adults, especially grandmothers, are often perceived as guardians of tradition, they are open to change and are active advisors to and carers of young children (Aubel 2021; Aubel, Touré, and Diagne 2004). We did not look at the sex composition of these older adults. However, there is some evidence that if the household members are men, they are less likely to care for or invest in the children in the household (Compaoré 2021; Duflo 2003). It is possible that the older-aged adults are also more distantly related and have less of an interest in childminding.

Finally, in households with multiple working-age adults supposedly bringing in additional resources and care, child death is not lower. Rather, these households seem to be associated with resource dilution and child death, confirming some previous findings (Bronte-Tinkew and Dejong 2004; Omariba and Boyle 2007). It is likely that accounting for kinship ties with coresident adults in these household types would underscore differences between these households, since related adults seem to have a protective effect on child well-being (Houle et al. 2013), while coresident non-parental adults do not seem to offset increased under-5 mortality when parent(s) are absent (Gaydosh 2019). Close kin ties are thus key to consider (Compaoré 2021). Alternatively, these households with multiple adults could be capturing deprivation and fewer resources available per capita. In fact, lower socioeconomic status could be what is leading these individuals to live together, and household structure could be capturing the mediating effect of socioeconomic status.

The HDSS data we use lack a measure of socioeconomic status, so we could not determine whether accounting for wealth would change the relationship we find between household size and type, and child survival. Socioeconomic status can affect household size; for example, an adult member may leave to work elsewhere or the household may foster out a child when experiencing an economic shock (Akresh 2009; Frankenberg, Smith, and Thomas 2003; Winters, Stecklov, and Todd 2009). Household structure could similarly affect socioeconomic status; for example, more hands to work the land could increase production. Despite a seemingly intertwined relationship between socioeconomic status and household structure, using DHS data we find that in rural areas wealth is not related to household size. Moreover, we posit that socioeconomic status does not directly affect child survival, and that the absence of a measure of wealth in our analysis does not drastically confound our results. However, socioeconomic status could interact with household type and nuance the effect of household type. For example, in richer households the relationship between household structure and mortality may be weaker.

Moreover, there are other proximate determinants of under-5 mortality which we do not account for in our models that are also influenced by socioeconomic status. For instance, clean drinking water is important for a child's survival, but access to such a water source may depend on whether or not it is affordable. If they differ at the micro level (i.e., between households within the HDSS sites), such household environment factors could be biasing our results. However, we can assume differences between the households to be small because of substantial homogeneity of amenities within sites. We capture the variance in household environment between sites by controlling for the HDSS site in the models, and therefore anticipate little bias. To sufficiently isolate the effect of household structure in more heterogenous settings (or at the national level), studies should ideally include indicators of household environment, especially when examining post-neo-natal deaths where infectious diseases play a dominant role.

Our analysis of the role of household structure on under-5 mortality is partly constrained by a definition of households that does not sufficiently accommodate changing social contexts and diverse forms of social organisation (Randall et al. 2015). We assume that individuals living together are a single cohesive unit, in which decisions on allocation of resources, including time or food consumption, pertain to and affect all individuals. By examining households as time-varying, we have been able to accommodate changes in households over time, but we have continued to assume that households are defined within a particular space, or location. Therefore, connected households, dual-location households, or less traditional living arrangements are not fully captured in our analysis. We do not consider the support from non-resident members of the household, and a more extensive definition of this aspect may be beneficial (Tillman and Nam 2008). Non-resident kin may have a positive effect on child well-being, especially if they send remittances (Housen, Hopkins, and Earnest 2013; Zhunio, Vishwasrao, and Chiang 2012). Moreover, the transfer of resources between family members who do not live together could affect child survival, and economic support may be more vital than practical day-to-day assistance (Clark, Madhavan, and Kabiru 2018). Similarly, maternal multifunctioning social networks have been found to increase child survival chances (Adams, Madhavan, and Simon 2002).

The meaning of what households are may also differ across the SSA countries we examine. Our analysis combined 15 sites which, although not nationally representative, cover a range of settings in southern and eastern Africa, allowing us to generalize at an aggregate level. However, there are differences between eastern and southern Africa, such as the larger household size in southern countries (Table 2). Analyses incorporating regional characteristics as well as in-depth contextual characteristics would be valuable in future research. All the same, our country-specific models suggest that there are not large differences in the relationship between household structure and under-5 mortality across countries in the region.

Households, or the micro-level social structures surrounding children, are important to consider when examining child survival. In mostly rural SSA, where households are generally large, we find that children in smaller households fare worse. It is likely that these households are unstable, with members in- or out-migrating frequently, or comprise only one adult on whom multiple children are dependent. It is also possible they are poorer or less equipped to deal with shocks. However, as we note with the household typology, sole children face the highest risk of death, and the greater risk noted in small household size largely reflects this. Therefore, in future analyses caution is needed in using simple household size, and in its interpretation.

While further research is required to investigate the mechanisms behind our findings, in particular what elements of the (in)stability of household structure are important for child survival, this study has contributed important evidence on the dynamic and varied nature of household structures in southern and eastern Africa. As we demonstrate here, future studies would benefit from accounting for time-varying household structure in order to deepen investigations of child health. Moreover, as our novel methodological approach has shown, further research should handle households as fluid entities. In 'doing households', social ties are created, maintained, or deconstructed, and households are transitional. The use of a dynamic household typology has an advantage over approaches that characterise households in terms of individual members' characteristics, and the methods demonstrated here may be applied to alternative longitudinal data sources. Expanding on this approach while also accounting for close kin relations would be of value. Ideally, longitudinal data on households, family ties, and a child's extended network – all involved in children's lives whether coresidential or not (Dasré, Samuel, and Hertrich 2019; Sear 2021) – could provide a holistic perspective of the role of social relations in children's health and survival.

7. Acknowledgements

This research was conducted under the Multi-centre Analysis of the Dynamics of Internal Migration and Health (MADIMAH) project, and is supported in part by the National Research Foundation of South Africa and the Fonds De La Recherche Scientifique FNRS through the South Africa/Wallonia-Brussels Federation Science and Technology Collaboration (Grant Numbers: 95284; 120330). We are grateful for the use of data from INDEPTH iShare, to the F.S.R-FNRS Fonds de le Recherche Scientific for Menashe-Oren's fellowship, and to Bruno Masquelier for his careful reading of an earlier draft.

References

Adams, A.M., Madhavan, S., and Simon, D. (2002). Women's social networks and child survival in Mali. *Social Science and Medicine* 54(2): 165–178. doi:10.1016/S0277-9536(01)00017-X.

Adhikari, R. and Podhisita, C. (2010). Household headship and child death: Evidence from Nepal. *BMC International Health and Human Rights* 10(1). doi:10.1186/1472-698X-10-13.

Agadjanian, V. and Ezeh, A.C. (2000). Polygyny, gender relations, and reproduction in Ghana. *Journal of Comparative Family Studies* 31(4). doi:10.3138/jcfs.31.4.427.

Akinyemi, J.O., Afolabi Bamgboye, E., and Ayeni, O. (2012). New trends in under-five mortality determinants and their effects on child survival in Nigeria: A review of childhood mortality data from 1990–2008. *Etude de la Population Africaine* 27(1): 25–42. doi:10.11564/27-1-5.

Akinyemi, J.O., Chisumpa, V.H., and Odimegwu, C.O. (2016). Household structure, maternal characteristics and childhood mortality in rural sub-Saharan Africa. *Rural and Remote Health* 16(2): 1–19. doi:10.22605/RRH3737.

Akresh, R. (2009). Flexibility of household structure: Child fostering decisions in Burkina Faso. *Journal of Human Resources* 44(4): 976–997. doi:10.3368/jhr.44.4.976.

Anderson, F.W.J., Morton, S.U., Naik, S., and Gebrian, B. (2007). Maternal mortality and the consequences on infant and child survival in rural Haiti. *Maternal and Child Health Journal* 11(4): 395–401. doi:10.1007/s10995-006-0173-0.

Antai, D., Wedrén, S., Bellocco, R., and Moradi, T. (2010). Migration and child health inequities in Nigeria: A multilevel analysis of contextual- and individual-level factors. *Tropical Medicine and International Health* 15(12): 1464–1474. doi:10.1111/j.1365-3156.2010.02643.x.

Aubel, J. (2021). Grandmothers: A neglected family resource for saving newborn lives. *BMJ Global Health* 6(2): e003808. doi:10.1136/bmjgh-2020-003808.

Aubel, J., Touré, I., and Diagne, M. (2004). Senegalese grandmothers promote improved maternal and child nutrition practices: The guardians of tradition are not averse to change. *Social Science and Medicine* 59(5): 945–959. doi:10.1016/j.socscimed.2003.11.044.

Becher, H., Müller, O., Jahn, A., Gbangou, A., Kynast-Wolf, G., and Kouyaté, B. (2004). Risk factors of infant and child mortality in rural Burkina Faso. *Bulletin of the World Health Organization* 82(4): 265–273.

Beegle, K., Filmer, D., Stokes, A., and Tiererova, L. (2010). Orphanhood and the living arrangement of children in sub-Saharan Africa. *World Development* 38(12): 1727–1746. doi:10.1016/j.worlddev.2010.06.015.

Beguy, D., Elung'ata, P., Mberu, B., Oduor, C., Wamukoya, M., Nganyi, B., and Ezeh, A. (2015). Health and demographic surveillance system profile: The Nairobi Urban Health and Demographic Surveillance System (NUHDSS). *International Journal of Epidemiology* 44(2): 462–471. doi:10.1093/ije/dyu251.

Bocquier, P., Beguy, D., Zulu, E.M., Muindi, K., Konseiga, A., and Yé, Y. (2011). Do migrant children face greater health hazards in slum settlements? Evidence from Nairobi, Kenya. *Journal of Urban Health* 88(Suppl. 2): 266–281. doi:10.1007/s11524-010-9497-6.

Bocquier, P., Ginsburg, C., Menashe-Oren, A., Compaoré, Y., and Collinson, M. (2021). The crucial role of mothers and siblings in child survival: Evidence from 29 health and demographic surveillance systems in sub-Saharan Africa. *Demography* 58(5): 1687–1713. doi:10.1215/00703370-9429499.

Bongaarts, J. (2001). Household size and composition in the developing world in the 1990s. *Population Studies* 55(3): 263–279. doi:10.1080/00324720127697.

Bronte-Tinkew, J. and Dejong, G. (2004). Children's nutrition in Jamaica: Do household structure and household economic resources matter? *Social Science and Medicine* 58(3): 499–514. doi:10.1016/j.socscimed.2003.09.017.

Burstein, R., Henry, N.J., ..., and Hay, S.I. (2019). Mapping 132 million neonatal , infant, and child deaths between 2000 and 2017. *Nature* 574: 353–358. doi:10.1038/s41586-019-1545-0.

Chikhungu, L.C., Newell, M.-L., and Rollins, N. (2017). Under-five mortality according to maternal survival: a systematic review and meta-analysis. *Bulletin of the World Health Organization* 95(4): 281–287. doi:10.2471/BLT.15.157149.

Clark, S. and Hamplová, D. (2013). Single motherhood and child mortality in sub-Saharan Africa: A life course perspective. *Demography* 50(5): 1521–1549. doi:10.1007/s13524-013-0220-6.

Clark, S., Cotton, C., and Marteleto, L.J. (2015). Family ties and young fathers' engagement in Cape Town, South Africa. *Journal of Marriage and Family* 77(2): 575–589. doi:10.1111/jomf.12179.

Clark, S., Madhavan, S., and Kabiru, C. (2018). Kin support and child health: Investigating two approaches in an African slum. *Social Science Research* 76(August): 105–119. doi:10.1016/j.ssresearch.2018.08.001.

Clark, S., Madhavan, S., Cotton, C., Beguy, D., and Kabiru, C. (2017). Who helps single mothers in Nairobi? The role of kin support. *Journal of Marriage and Family* 79(4): 1186–1204. doi:10.1111/jomf.12404.

Compaoré, Y. (2021). *Dynamiques familiales et santé des enfants: Perspectives longitudinales en Afrique de l'Ouest.* Université catholique de Louvain.

Cotton, C. (2021). An enduring institution? Child fostering in sub-Saharan Africa. *Population and Development Review* 47(4): 1179–1206. doi:10.1111/padr.12439.

Cotton, C. and Beguy, D. (2020). Long-distance mothering in urban Kenya. *Journal of Marriage and Family* 83(2): 482–497. doi:10.1111/jomf.12719.

Cunningham, S.A., Elo, I.T., Herbst, K., and Hosegood, V. (2010). Prenatal development in rural South Africa: Relationship between birth weight and access to fathers and grandparents. *Population Studies* 64(3): 229–246. doi:10.1080/00324728.2010.510201.

Dasré, A., Samuel, O., and Hertrich, V. (2019). The dynamics of the family network during childhood: A genealogical and longitudinal approach to rural Mali. *Demographic Research* 41(July): 231–262. doi:10.4054/DemRes.2019.41.9.

Desai, S. (1992). Children at risk: The role of family structure in Latin America and West Africa. *Population and Development Review* 18(4): 689–717. doi:10.2307/1973760.

Duflo, E. (2003). Grandmothers and granddaughters: Old-age pensions and intrahousehold allocation in South Africa. *The World Bank Economic Review* 17(1): 1–25. doi:10.1093/wber/lhg013.

Finlay, J.E., Özaltin, E., and Canning, D. (2011). The association of maternal age with infant mortality, child anthropometric failure, diarrhoea and anaemia for first births: Evidence from 55 low- and middle-income countries. *BMJ Open* 1(2). doi:10.1136/bmjopen-2011-000226.

Frankenberg, E., Smith, J.P., and Thomas, D. (2003). Economic shocks, wealth, and welfare. *Journal of Human Resources* XXXVIII(2): 280–321. doi:10.3368/jhr.XXXVIII.2.280.

Gage, A.J. (1997). Familial and socioeconomic influences on children's well-being: An examination of preschool children in Kenya. *Social Science and Medicine* 45(12): 1811–1828. doi:10.1016/S0277-9536(97)00113-5.

Gage, A.J., Sommerfelt, A.E., and Piani, A.L. (1997). Household structure and childhood immunization in Niger and Nigeria. *Demography* 34(2): 295–309. doi:10.2307/2061706.

Garenne, M. (2017). Persistent high fertility in rural Africa. *N-IUSSP*(Septermber 14).

Garenne, M., Kahn, K., Collinson, M.A., Gómez-Olivé, F.X., and Tollman, S. (2013). Maternal mortality in rural South Africa: The impact of case definition on levels and trends. *International Journal of Women's Health* 5(1): 457–463. doi:10.2147/IJWH.S45983.

Gaydosh, L. (2019). Does it take a village? Kin coresidence and child survival in Tanzania. *Social Forces* 97: 1665–1692. doi:10.1093/sf/soy081.

Gibbs, C.M., Wendt, A., Peters, S., and Hogue, C.J. (2012). The impact of early age at first childbirth on maternal and infant health. *Paediatric and Perinatal Epidemiology* 26(Suppl. 1): 259–284. doi:10.1111/j.1365-3016.2012.01290.x.

Gibson, M.A. and Mace, R. (2005). Helpful grandmothers in rural Ethiopia: A study of the effect of kin on child survival and growth. *Evolution and Human Behavior* 26(6): 469–482. doi:10.1016/j.evolhumbehav.2005.03.004.

Gyimah, S.O. (2009). Polygynous marital structure and child survivorship in sub-Saharan Africa: Some empirical evidence from Ghana. *Social Science and Medicine* 68(2): 334–342. doi:10.1016/j.socscimed.2008.09.067.

Heymann, J., Earle, A., Rajaraman, D., Miller, C., and Bogen, K. (2007). Extended family caring for children orphaned by AIDS: Balancing essential work and caregiving in a high HIV prevalence nations. *AIDS Care - Psychological and Socio-Medical Aspects of AIDS/HIV* 19(3): 337–345. doi:10.1080/09540120600763225.

Hosegood, V. (2009). The demographic impact of HIV and AIDS across the family and household life-cycle: Implications for efforts to strengthen families in sub-Saharan Africa. *AIDS Care – Psychological and Socio-Medical Aspects of AIDS/HIV* 21(SUPPL. 1): 13–21. doi:10.1080/09540120902923063.

Hosegood, V., Floyd, S., Marston, M., Hill, C., McGrath, N., Isingo, R., Crampin, A., and Zaba, B. (2007). The effects of high HIV prevalence on orphanhood and living arrangements of children in Malawi, Tanzania, and South Africa. *Population Studies* 61(3): 327–336. doi:10.1080/00324720701524292.

Houle, B., Clark, S.J., Kahn, K., Tollman, S., and Yamin, A.E. (2015). The impacts of maternal mortality and cause of death on children's risk of dying in rural South Africa: Evidence from a population based surveillance study (1992–2013). *Reproductive Health* 12(Suppl. 1): S7. doi:10.1186/1742-4755-12-S1-S7.

Houle, B., Kabudula, C., Gareta, D., Herbst, K., and Clark, S.J. (2023). Household structure, composition and child mortality in the unfolding antiretroviral therapy era in rural South Africa: Comparative evidence from population surveillance, 2000–2015. *BMJ Open* 13(3): e070388. doi:10.1136/bmjopen-2022-070388.

Houle, B., Stein, A., Kahn, K., Madhavan, S., Collinson, M., Tollman, S.M., and Clark, S.J. (2013). Household context and child mortality in rural South Africa: The effects of birth spacing, shared mortality, household composition and socio-economic status. *International Journal of Epidemiology* 42(5): 1444–1454. doi:10.1093/ije/dyt149.

Housen, T., Hopkins, S., and Earnest, J. (2013). Internal remittances on poverty and consumption in developing countries: Implicationd for policy. *Population, Space and Place* 19: 610–632. doi:10.1002/psp.1743.

ICF International (2012). *Demographic and Health Surveys Sampling and Household Listing Manual*. Calverton, Maryland, USA: MEASURE DHS.

INDEPTH (2017). INDEPTH i-Share Data Repository [electronic resource]. http://www.indepth-ishare.org/index.php/home.

Jurczyk, K. (2014). Doing Family–der Practical Turn der Familienwissenschaften. In: Steinbach, A., Hennig, M., and Arránz Becker, O. (eds.). *Familie im Fokus der Wissenschaft*. Wiesbaden: Springer VS: 117–138. doi:10.1007/978-3-658-02895-4_6.

Justesen, A. and Kunst, A. (2000). Postneonatal and child mortality among twins in Southern and Eastern Africa. *International Journal of Epidemiology* 29(4): 678–683. doi:10.1093/ije/29.4.678.

Kahn, K., Collinson, M.A., Xavier Gómez-olivé, F., Mokoena, O., Twine, R., Mee, P., Afolabi, S.A., Clark, B.D., Kabudula, C.W., Khosa, A., Khoza, S., Shabangu, M.G., Silaule, B., Tibane, J.B., Wagner, R.G., Garenne, M.L., Clark, S.J., and Tollman, S.M. (2012). Profile: Agincourt health and socio-demographic surveillance system. *International Journal of Epidemiology* 41(4): 988–1001. doi:10.1093/ije/dys115.

Kishamawe, C., Isingo, R., Mtenga, B., Zaba, B., Todd, J., Clark, B., Changalucha, J., and Urassa, M. (2015). Health and demographic surveillance system profile: The Magu Health and Demographic Surveillance System (Magu HDSS). *International Journal of Epidemiology* 44(6): 1851–1861. doi:10.1093/ije/dyv188.

Kravdal, Ø. (2018). New evidence about effects of reproductive variables on child mortality in sub-Saharan Africa. *Population Studies* 72(2): 139–156. doi:10.1080/00324728.2018.1439180.

Lawson, D.W. and Gibson, M.A. (2018). Polygynous marriage and child health in sub-Saharan Africa: What is the evidence for harm? *Demographic Research* 39(6): 177–208. doi:10.4054/DemRes.2018.39.6.

Lee, D. and McLanahan, S. (2015). Family structure transitions and child development: Instability, selection, and population heterogeneity. *American Sociological Review* 80(4): 738–763. doi:10.1177/0003122415592129.

Lloyd, C.B. and Desai, S. (1992). Children's living arrangements in developing countries. *Population Research and Policy Review* 11(3): 193–216. doi:10.1007/BF00124937.

Madhavan, S. (2004). Fosterage patterns in the age of AIDS: Continuity and change. *Social Science and Medicine* 58(7): 1443–1454. doi:10.1016/S0277-9536(03)00341-1.

Madhavan, S., Mee, P., and Collinson, M. (2014). Kinship in practice: Spatial distribution of children's kin networks. *Journal of Southern African Studies* 40(2): 401–418. doi:10.1080/03057070.2014.906211.

Masquelier, B., Reniers, G., and Pison, G. (2014). Divergences in trends in child and adult mortality in sub-Saharan Africa: Survey evidence on the survival of children and siblings. *Population Studies* 68(2): 161–177. doi:10.1080/00324728.2013.856458.

Monasch, R. and Boerma, J.T. (2004). Orphanhood and childcare patterns in sub-Saharan Africa: An analysis of national surveys from 40 countries. *AIDS* 18(Suppl. 2): S55–S65. doi:10.1097/00002030-200406002-00007.

Mosley, W.H. and Chen, L.C. (1984). An analytical framework for the study of child survival in develoiping countries. *Population and Development Review* 10(Suppl.): 25–45. doi:10.2307/2807954.

Mrema, S., Kante, A.M., Levira, F., Mono, A., Irema, K., De Savigny, D., and Masanja, H. (2015). Health and demographic surveillance system profile: The Rufiji Health and Demographic Surveillance System (RUFIJI HDSS). *International Journal of Epidemiology* 44(2): 472–483. doi:10.1093/ije/dyv018.

Ntoimo, L.F.C. and Odimegwu, C.O. (2014). Health effects of single motherhood on children in sub-Saharan Africa: A cross-sectional study. *BMC Public Health* 14(1): 1–13. doi:10.1186/1471-2458-14-1145.

Omariba, D.W.R. and Boyle, M.H. (2007). Family structure and child mortality in sub-Saharan Africa: Cross-national effects of polygyny. *Journal of Marriage and Family* 69(2): 528–543. doi:10.1111/j.1741-3737.2007.00381.x.

Omariba, D.W.R. and Boyle, M.H. (2010). Rural-urban migration and cross-national variation in infant mortality in less developed countries. *Population Research and Policy Review* 29(3): 275–296. doi:10.1007/s11113-009-9140-y.

Page, G.E., Hassan, A., Emmott, E., Viguier, S., Dyble, M., Smith, D., and Migliano, A. (2021). Demography, grandmothers and childcare: Understanding cooperative childrearing in Agta foragers from the Philippines. BSPS.

Perlesz, A., Brown, R., Lindsay, J., McNair, R., De Vaus, D., and Pitts, M. (2006). Family in transition: Parents, children and grandparents in lesbian families give meaning to ‘doing family’. *Journal of Family Therapy* 28(2): 175–199. doi:10.1111/j.1467-6427.2006.00345.x.

Randall, S., Coast, E., and Leone, T. (2011). Cultural constructions of the concept of household in sample surveys. *Population Studies* 65(2): 217–229. doi:10.1080/00324728.2011.576768.

Randall, S., Coast, E., Antoine, P., Compaore, N., Dial, F.B., Fanghanel, A., Gning, S.B., Thiombiano, B.G., Golaz, V., and Wandera, S.O. (2015). UN Census “households” and local interpretations in Africa since independence. *SAGE Open* 5(2). doi:10.1177/2158244015589353.

Rogers, R.G., Hummer, R.A., Tilstra, A.M., Lawrence, E.M., and Mollborn, S. (2020). Family structure and early life mortality in the United States. *Journal of Marriage and Family* 82(4): 1159–1177. doi:10.1111/jomf.12674.

Roth, G.A., Abate, D., Abate, K.H., Abay, S.M., Abbafati, C., Abbasi, N., Abbastabar, H., et al. (2018). Global, regional, and national age-sex-specific mortality for 282 causes of death in 195 countries and territories, 1980–2017: A systematic analysis for the Global Burden of Disease Study 2017. *The Lancet* 392(10159): 1736–1788. doi:10.1016/S0140-6736(18)32203-7.

Schoumaker, B. (2019). Male fertility around the world and over time: How different is it from female fertility? *Population and Development Review* 45(3): 459–487. doi:10.1111/padr.12273.

Sear, R. (2008). Kin and child survival in rural Malawi: Are matrilineal kin always beneficial in a matrilineal society? *Human Nature* 19(3): 277–293. doi:10.1007/s12110-008-9042-4.

Sear, R. (2021). The male breadwinner nuclear family is not the 'traditional' human family, and promotion of this myth may have adverse health consequences. *Philosophical Transactions of the Royal Society B: Biological Sciences* 376(1827). doi:10.1098/rstb.2020.0020.

Sear, R. and Coall, D. (2011). How much does family matter? Cooperative breeding and the demographic transition. *Population and Development Review* 37(Suppl. 1): 81–112. doi:10.1111/j.1728-4457.2011.00379.x.

Sear, R. and Mace, R. (2008). Who keeps children alive? A review of the effects of kin on child survival. *Evolution and Human Behavior* 29(1): 1–18. doi:10.1016/j.evolhumbehav.2007.10.001.

Sear, R., Mace, R., and McGregor, I.A. (2000). Maternal grandmothers improve nutritional status and survival of children in rural Gambia. *Proceedings of the Royal Society B: Biological Sciences* 267(1453): 1641–1647. doi:10.1098/rspb.2000.1190.

Shapiro, D. and Tambashe, O. (1999). Fertility transition in urban and rural areas of sub-Saharan Africa. Population Research Institute, Pennsylvania State University.

Smith-Greenaway, E. and Trinitapoli, J. (2014). Polygynous contexts, family structure, and infant mortality in sub-Saharan Africa. *Demography* 51(2): 341–366. doi:10.1038/jid.2014.371.

Ssengonzi, R., De Jong, G.F., and Stokes, C.S. (2002). The effect of female migration on infant and child survival in Uganda. *Population Research and Policy Review* 21: 403–431. doi:10.1023/A:1021164416703.

Strasser, E., Kraler, A., Bonjour, S., and Bilger, V. (2009). Doing family: Responses to the constructions of 'the migrant family' across Europe. *History of the Family* 14(2): 165–176. doi:10.1016/j.hisfam.2009.02.005.

Strassmann, B.I. and Garrard, W.M. (2011). Alternatives to the grandmother hypothesis. *Human Nature* 22(1): 201–222. doi:10.1007/s12110-011-9114-8.

Thomson, E., Hanson, T.L., and Mc Lanahan, S.S. (1994). Family structure and child well-being: Economic resources vs.parental behaviors. *Social Forces* 73(1): 221–242. doi:10.1093/sf/73.1.221.

Tillman, K.H. and Nam, C.B. (2008). Family structure outcomes of alternative family definitions. *Population Research and Policy Review* 27(3): 367–384. doi:10.1007/s11113-007-9067-0.

Timæus, I.M. and Reynar, A. (1998). Polygynists and their wives in sub-Saharan Africa: An analysis of five demographic and health surveys. *Population Studies* 52(2): 145–162. doi:10.1080/0032472031000150346.

Townsend, N., Madhavan, S., Tollman, S., Garenne, M., and Kahn, K. (2002). Children's residence patterns and educational attainment in rural South Africa, 1997. *Population Studies* 56(2): 215–225. doi:10.1080/00324720215925.

Treleaven, E. (2023). The relationship between extended kin resources and children's healthcare utilization: An analysis of family networks. *Social Science and Medicine* 321(June 2022): 115720. doi:10.1016/j.socscimed.2023.115720.

van Blerk, L. and Ansell, N. (2006). Children's experiences of migration: Moving in the wake of AIDS in southern Africa. *Environment and Planning D: Society and Space* 24(3): 449–471. doi:10.1068/d65j.

van Dijk, I.K. (2018). Early-life mortality clustering in families: A literature review. *Population Studies* 73(1): 79–99. doi:10.1080/00324728.2018.1448434.

Weinreb, A.A. (2002). Lateral and vertical intergenerational exchange in rural Malawi. *Journal of Cross-Cultural Gerontology* 17(2): 101–138. doi:10.1023/A:1015834300553.

Winters, P., Stecklov, G., and Todd, J. (2009). Household structure and short-run economic change in Nicaragua. *Journal of Marriage and Family* 71(3): 708–726. doi:10.1111/j.1741-3737.2009.00628.x.

Yaya, S., Bishwajit, G., Okonofua, F., and Uthman, O.A. (2018). Under five mortality patterns and associated maternal risk factors in sub-Saharan Africa: A multi-country analysis. *PLoS ONE* 13(10): 1–14. doi:10.1371/journal.pone.0205977.

You, D., Hug, L., Ejdemyr, S., Idele, P., Hogan, D., Mathers, C., Gerland, P., New, J.R., and Alkema, L. (2015). Global, regional, and national levels and trends in under-5 mortality between 1990 and 2015, with scenario-based projections to 2030: A systematic analysis by the UN Inter-Agency Group for Child Mortality

Estimation. *The Lancet* 386(10010): 2275–2286. doi:10.1016/S0140-6736(15)00120-8.

Zagheni, E. (2011). The impact of the HIV/AIDS epidemic on kinship resources for orphans in Zimbabwe. *Population and Development Review* 37(4): 761–783. doi:10.1111/j.1728-4457.2011.00456.x.

Zhunio, M.C., Vishwasrao, S., and Chiang, E.P. (2012). The influence of remittances on education and health outcomes: A cross country study. *Applied Economics* 44(35): 4605–4616. doi:10.1080/00036846.2011.593499.

Zimmer, Z. and Treleaven, E. (2020). The rise and prominence of skip-generation households in lower- and middle-income countries. *Population and Development Review* 46(4): 709–733. doi:10.1111/padr.12349.

Appendix

A1: Estimating time-varying measures of household structure

Table A-1: Example of HDSS data and estimation of time-varying household size

Household ID	Individual ID	Sex	DoB	Event Code	Event Date	Mother ID	HH enu	HH births	HH deaths	HH out-mig	HH in-mig	HH ent	HH ext	Household size
92	572	Female	29/10/1983	ENU	01/12/2007									0
92	1052	Female	25/03/1978	ENU	01/12/2007									0
92	108	Male	05/06/2010	BTH	05/06/2010	1052	2							2
92	108	Male	05/06/2010	OMG	20/05/2011	1052	2	1						3
92	572	Female	29/10/1983	OMG	20/05/2011		2	1						3
92	108	Male	05/06/2010	IMG	21/08/2013	1052	2	1		2				1
92	572	Female	29/10/1983	IMG	21/08/2013		2	1		2				1
92	572	Female	29/10/1983	EXT	05/03/2015		2	1		2	2			3
92	108	Male	05/06/2010	DTH	10/04/2015	1052	2	1		2	2		1	2
92	108	Male	05/06/2010	OBE	31/12/2017	1052	2	1	1	2	2		1	1
92	1052	Female	25/05/1978	OBE	31/12/2017		2	1	1	2	2		1	1
102	265	Male	14/07/2007	ENT	26/10/2011	535								0
102	572	Female	29/10/1983	ENT	06/03/2015							1		1
102	265	Male	14/07/2007	OBE	31/12/2017	535						2		2
102	572	Female	29/10/1983	OBE	31/12/2017							2		2
163	131	Male	13/08/1966	IMG	27/12/2000									0
163	131	Male	13/08/1966	OMG	23/08/2001						1			1
163	857	Female	15/06/2003	IMG	04/12/2007	3992				1	1			0
163	857	Female	15/06/2003	DTH	17/02/2008	3992				1	2			1
163	131	Male	13/08/1966	IMG	22/02/2008				1	1	2			0
163	857	Female	15/06/2003	OBE	31/12/2017	3992			1	1	3			1
163	131	Male	13/08/1966	OBE	31/12/2017				1	1	3			1
710	346	Male	01/04/1974	ENU	01/12/2007									0
710	535	Female	22/02/1980	ENU	01/12/2007									0
710	265	Male	14/07/2007	BTH	14/03/2008	535	2							2
710	265	Male	14/07/2007	EXT	23/10/2008	535	2	1						3
710	346	Male	01/04/1974	OBE	31/12/2017		2	1					1	2
710	535	Female	22/02/1980	OBE	31/12/2017		2	1					1	2

In this example of the data (Table A-1) there are four households and eight individuals. The table is sorted according to the household identity (Household ID). Individuals 265 and 572 moved from one household to another during the period of observation, as captured by the enter (ENT) and exit (EXT) events. If we were to follow the sequence of events of individual 265, for example, it would start with his birth event (BTH) on 14/3/2008, and then his move from household 710 to household 102, and the end of the observation period (OBE) would be 31/12/2017. For the analysis in this paper the individual is followed over the observation period. However, in order to ascertain the household structure at a given individual event, we use the household as the unit of analysis. So, in Table A-1, household 163 includes two individuals, and their events, when they are members of this household. For each event, a new variable is computed to indicate the cumulative counts of this event as a running sum. This count is lagged so that the count reflects the household composition at the time of the event. When an out-migration (OMG) is recorded in household 163, for example, it counts as one out-migration event in the household, following the time of this event until the end of observation period. Three in-migrations (IMG) are recorded in household 163; therefore, the count of in-migrations at OBE is three, but at time of the second in-migration is it only one. Based on the population equation (Equation 1), we can find the balance between all the moves in (including births) and out (including deaths) of the household, which gives us the household size at the time of the event. For example, at the time of the birth of individual 108 there were two people in the household. Following this logic/ approach, it is also possible to identify these individuals by age and sex; for example, whether those two individuals were adults above age 15, or if they were other children in the household at a given time.

A2: Accounting for especially large households, and 'empty' households

The HDSS indicator for household membership was sometimes inaccurate or did not capture an actual household. For example, when someone new arrived in a site they were temporarily assigned a household membership, but this was not later removed or updated from this individual's record of events. This temporary household identifier was a 'null' ID, and such null households were removed from the analysis. We additionally identified household where the number of members became negative. These households might be unstable households, but are most likely the result of inaccurate recordings of events. It was possible to correct for some of these events through consistency checks, but 0.1% of our sample still had negative-sized households. These households were also removed from analysis.

A3: Supplementary model results

Table A-2: Hazard ratios for site-year covariates from Cox model results depicted in Table 4

	Maternal covariates only	**Household size**	**Household type**
Centre-years (ref= ZA031 2010)			
Gilgel Gibe 2005	4.218	3.952	4.234
	[3.587,4.960]	[3.357,4.652]	[3.603,4.974]
Gilgel Gibe 2010	3.005	2.847	3.095
	[2.573,3.509]	[2.436,3.328]	[2.654,3.611]
Gilgel Gibe 2015	1.504	1.421	1.525
	[1.195,1.892]	[1.128,1.789]	[1.220,1.905]
Kilite Awlaelo 2010	1.275	1.204	1.262
	[1.051,1.546]	[0.992,1.461]	[1.047,1.522]
Kersa 2005	3.879	3.616	3.820
	[3.181,4.732]	[2.962,4.415]	[3.138,4.649]
Kersa 2010	4.127	3.911	4.172
	[3.550,4.799]	[3.361,4.551]	[3.591,4.848]
Kersa 2015	3.352	3.176	3.327
	[2.849,3.944]	[2.697,3.741]	[2.831,3.910]
Harar Urban 2010	0.601	0.543	0.561
	[0.319,1.133]	[0.288,1.025]	[0.320,0.984]
Harar Urban 2015	0.513	0.467	0.487
	[0.317,0.829]	[0.289,0.756]	[0.301,0.788]
Dabat 2005	1.178	1.088	1.158
	[0.644,2.154]	[0.595,1.990]	[0.632,2.120]
Dabat 2010	1.159	1.082	1.182
	[0.942,1.425]	[0.879,1.332]	[0.961,1.454]
Dabat 2015	0.454	0.422	0.459
	[0.291,0.709]	[0.270,0.659]	[0.298,0.705]
Arba Minch 2010	1.478	1.397	1.482
	[1.229,1.778]	[1.161,1.682]	[1.237,1.777]
Arba Minch 2015	0.939	0.887	0.941
	[0.724,1.217]	[0.684,1.150]	[0.732,1.211]
Nairobi 2000	3.058	2.756	2.925
	[2.482,3.768]	[2.234,3.401]	[2.377,3.601]
Nairobi 2005	2.689	2.458	2.641
	[2.293,3.154]	[2.093,2.887]	[2.252,3.098]
Nairobi 2010	2.821	2.582	2.788
	[2.409,3.304]	[2.201,3.029]	[2.381,3.264]
Nairobi 2015	0.979	0.894	0.963
	[0.725,1.320]	[0.662,1.207]	[0.713,1.299]
Kombewa 2010	1.671	1.561	1.682
	[1.372,2.035]	[1.281,1.904]	[1.385,2.042]
Kombewa 2015	1.136	1.064	1.147
	[0.874,1.477]	[0.818,1.385]	[0.885,1.485]

Table A-2: (Continued)

	Maternal covariates only	**Household size**	**Household type**
Centre-years (ref= ZA031 2010)			
Chokwe 2010	1.838	1.754	1.785
	[1.558,2.168]	[1.486,2.070]	[1.515,2.104]
Chokwe 2015	1.263	1.205	1.247
	[1.021,1.562]	[0.974,1.490]	[1.009,1.542]
Ifakara Rural 1995	5.329	4.994	5.177
	[4.510,6.297]	[4.221,5.907]	[4.383,6.114]
Ifakara Rural 2000	4.535	4.221	4.577
	[3.909,5.260]	[3.633,4.904]	[3.947,5.308]
Ifakara Rural 2005	3.565	3.332	3.680
	[3.076,4.130]	[2.872,3.865]	[3.177,4.262]
Ifakara Rural 2010	2.293	2.174	2.365
	[1.977,2.659]	[1.874,2.523]	[2.040,2.740]
Rufiji 1995	5.316	4.812	5.298
	[4.246,6.655]	[3.835,6.038]	[4.231,6.634]
Rufiji 2000	3.473	3.229	3.522
	[2.986,4.039]	[2.773,3.761]	[3.029,4.097]
Rufiji 2005	2.727	2.606	2.798
	[2.342,3.177]	[2.236,3.037]	[2.403,3.257]
Rufiji 2010	1.684	1.635	1.724
	[1.435,1.976]	[1.393,1.920]	[1.470,2.020]
Magu 1990	2.103	2.030	1.948
	[0.867,5.099]	[0.838,4.921]	[0.805,4.717]
Magu 1995	5.134	5.080	4.985
	[4.321,6.101]	[4.276,6.035]	[4.204,5.910]
Magu 2000	5.026	4.987	5.046
	[4.263,5.926]	[4.230,5.879]	[4.292,5.933]
Magu 2005	2.691	2.668	2.767
	[2.248,3.220]	[2.230,3.192]	[2.316,3.307]
Magu 2010	1.009	0.998	1.045
	[0.779,1.305]	[0.771,1.291]	[0.813,1.343]
Agincourt 1990	1.193	1.180	1.110
	[0.886,1.606]	[0.877,1.589]	[0.840,1.468]
Agincourt 1995	1.476	1.470	1.398
	[1.236,1.762]	[1.232,1.756]	[1.171,1.669]
Agincourt 2000	2.391	2.377	2.341
	[2.031,2.815]	[2.019,2.799]	[1.992,2.751]
Agincourt 2005	2.328	2.317	2.324
	[1.984,2.731]	[1.975,2.718]	[1.985,2.721]
Agincourt 2010	1.277	1.269	1.279
	[1.077,1.514]	[1.071,1.505]	[1.080,1.514]
Agincourt 2015	0.928	0.918	0.927
	[0.735,1.170]	[0.728,1.158]	[0.737,1.167]

Table A-2: (Continued)

	Maternal covariates only	Household size	Household type
Centre-years (ref= ZA031 2010)			
Dikgale 1995	1.399	1.394	1.294
	[0.842,2.323]	[0.839,2.317]	[0.813,2.058]
Dikgale 2000	0.821	0.818	0.771
	[0.501,1.344]	[0.499,1.339]	[0.471,1.263]
Dikgale 2005	1.257	1.251	1.217
	[0.847,1.865]	[0.843,1.857]	[0.827,1.792]
Dikgale 2010	0.324	0.319	0.303
	[0.211,0.497]	[0.207,0.490]	[0.197,0.466]
Dikgale 2015	0.393	0.387	0.369
	[0.225,0.688]	[0.221,0.676]	[0.211,0.646]
AHRI 2000	3.159	3.117	2.968
	[2.691,3.707]	[2.655,3.659]	[2.531,3.480]
AHRI 2005	1.893	1.886	1.840
	[1.608,2.228]	[1.602,2.220]	[1.562,2.166]
AHRI 2015	0.629	0.629	0.634
	[0.452,0.874]	[0.453,0.874]	[0.459,0.877]
chi2	7045.0	7199.6	7471.4
Number of children	281,955	281,955	281,923
PYARs	963005.7	963005.7	961947.6
Number of deaths	16,666	16,666	16,665

Note: Exponentiated coefficients, 95% confidence intervals in brackets

Table A-3: Cox model results based on Model 3 in Table 4 but with only one randomly selected child per household (excluding site–period covariates)

	Household type
Female	0.758
	[0.646,0.891]
Twin	4.041
	[2.691,6.068]
Mother's age at birth (ref= 21–23)	
15–17	1.346
	[0.945,1.918]
18–20	1.259
	[0.939,1.687]
24–26	1.076
	[0.798,1.450]
27–29	1.074
	[0.789,1.461]
30–32	1.212
	[0.887,1.656]
33–35	0.932
	[0.646,1.346]
36–38	1.201
	[0.821,1.757]
39–41	1.366
	[0.871,2.141]
42+	1.784
	[1.124,2.831]
Mother survival status (ref=alive & resident)	
3–6 months before mother's death	10.86
	[2.875,41.06]
15 days to 3 months before mother's death	16.18
	[4.943,52.94]
+/– 15 days around mother's death	56.52
	[28.11,113.7]
15 days to 3 months after mother's death	26.29
	[8.098,85.33]
3–6 months after mother's death	4.18e-14
	[2.41e-14,7.22e-14]
6+ months after mother's death	6.317
	[2.235,17.86]
Mother non-resident	1.352
	[0.924,1.977]
Mother migration status (ref=permanent resident)	
In-migrated 6–24 months before	0.779
	[0.598,1.014]

Table A-3: (Continued)

	Household type
In-migrated 2–5 years before	0.905
	[0.686,1.195]
Household typology (ref= 'nuclear' 2+ children)	
'Nuclear', only index child	1.16
	[0.826,1.627]
Multiple adults	1.275
	[1.030,1.579]
Older-aged adults	1.263
	[0.906,1.762]
One woman	1.04
	[0.790,1.369]
Other	0.765
	[0.565,1.037]
chi2	222007.9
Number of children	60,159
PYARs	64166.9
Number of deaths	633

Note: Exponentiated coefficients. 95% confidence intervals in brackets