Household characteristics and under-five mortality in Bankass, Mali

David C. Boettiger[1], Emily Treleaven[2], Kassoum Kayentao[3], Mahamadou Guindo[4], Mama Coumaré[4], Ari D. Johnson[5], Caroline Whidden[6], Naimatou Koné[6], Amadou Beydi Cissé[6], Nancy Padian[7], and Jenny Liu[8]

[1]Kirby Institute, University of New South Wales, Sydney, Australia

[2]Population Studies Center, University of Michigan, Ann Arbor, USA

[3]Malaria Research and Training Center, University of Sciences, Techniques and Technologies of Bamako, Mali

[4]Ministère de la Sante et des Affaires Sociales, Bamako, Mali

[5]Department of Medicine, University of California, San Francisco, USA

[6]MUSO, Bamako, Mali

[7]School of Public Health, University of California, Berkeley, USA

[8]Institute for Health and Aging, University of California, San Francisco, USA

Corresponding author

David C. Boettiger
Wallace Wurth Building
University of New South Wales
Sydney Australia 2252
dboettiger@kirby.unsw.edu.au

What was already known about this topic

- Mali has one of the highest rates of under-five mortality in the world. Rural parts of Mali carry a disproportionate weight of this burden.
- A range of household factors are associated with poor under-five health in resource-limited settings. However, it is unknown which most influence the high U5 mortality rate in Mali.

What new knowledge does this manuscript contribute

- Under-five mortality in Bankass, a large rural district in Mali, is high compared to other parts of the country and is associated with household characteristics that may be amenable to intervention or facilitate program targeting such as living further from a primary health center, monogamy, not owning livestock, poorer reading ability of reproductive-aged women, having access to electricity, and tolerant views of spousal violence.

Abstract

Objective

Describe household characteristics in rural Mali and investigate which are associated with under-five mortality.

Methods

We analysed baseline household survey data from a trial being conducted in Bankass, Mali. The survey was administered to households between December 2016 and January 2017. Under-five deaths in the five years prior to baseline were documented along with detailed information on household characteristics and women's birth histories. Factors associated with female and male under-five mortality were analysed using negative binomial regression and factors associated with multiple under-five deaths in the household were analysed using logistic regression.

Findings

Among 8,963 households included in the analysis, 2,016 (22.5%) reported an under-five death in the past five years. In total, 2,685 under-five deaths (1,273 females, 1,412 males) occurred at a rate of 149 per 1,000 live births (143 and 154 per 1,000 live births for females and males, respectively). Greater distance to a primary health center and higher number of births in the household were consistently associated with a higher probability of under-five mortality in adjusted models. Under-five female mortality was additionally associated with monogamy and not owning livestock, under-five male mortality was additionally associated with poorer reading ability of reproductive-aged women in the household and having access to electricity, and multiple under-five mortality was additionally associated with tolerant views of spousal violence and not owning livestock.

Conclusion

Under-five mortality is high in Bankass compared with other parts of Mali and is associated with household characteristics that may be amenable to intervention or facilitate program targeting.

Background

Although mortality among children under five years-of-age, under-five (U5) mortality, has declined substantially around the world over the past 25 years, estimates for Mali have consistently been among the highest in the world.(1) In 2017 in high-income countries, the average estimated U5 mortality rate was 5 deaths per 1,000 live births, among low-income countries it was 69 deaths per 1,000 live births, and in Mali the estimated U5 mortality rate was 106 deaths per 1,000 live births.(2, 3)

A range of household factors are known to be associated with poor U5 health in resource-limited settings. For example, long distances between the home and healthcare reduce the utilization of health services and increases child mortality,(4-10) lower levels of maternal education and literacy are associated with increased probability of child mortality,(11, 12) poor access to safe water and safe sanitation are leading risk factors for diarrhoea and diarrhoea-associated mortality in U5 children,(13) unfinished housing is associated with a high prevalence of malaria and U5 mortality,(14-17) and indoor air pollution substantially increases the risk of childhood pneumonia and mortality.(18) However, it is unknown which household characteristics most influence the high U5 mortality rate in Mali.

This analysis forms part of a larger study evaluating the effect of proactive case detection by community health workers on U5 mortality in the Bankass health district.(19) Bankass is situated in the Mopti region of Mali, an area that relies heavily on agriculture and that serves as an important crossroad between the country's north, south and bordering countries.(20) It is one of the poorest regions of Mali and has one of the country's highest burdens of U5 mortality.(21) Prior research has documented improvements in early access to care and U5 mortality in peri-urban Mali after the roll out of community and primary healthcare interventions to remove financial, geographic, infrastructural, and gender-based barriers to care.(22) Exploration of household factors associated with U5 mortality will help guide further healthcare system and policy approaches for improving child survival.

We aimed to describe household characteristics in Bankass and investigate which are associated with U5 mortality. We examined these characteristics separately among girls and boys, as boys have a higher biological risk of mortality in early childhood.(23, 24) Further, in settings such as Mali, where females are socially disadvantaged compared to their male counterparts, girls may face a higher risk of mortality due to lower investment, resource allocation, or other forms of discrimination.(25) This research will provide critical information for health policy makers in the region seeking to make long-term and sustainable investments into permanently reducing U5 mortality.

Methods

Household surveys

We analysed baseline household survey data from a three-year cluster randomized controlled trial being conducted in 137 village cluster sites distributed across seven of the 22 health catchment areas in Bankass (Kanibonzon, Ende, Dimbal, Doundé, Soubala, Koulongon, and Lessagou). The study area has a population of approximately 100,000 people. The trial primarily aims to determine whether door-to-door proactive case detection by community health workers reduces U5 mortality compared to passive, site-based care offered under the standard Integrated Community Case Management protocol.(26) Further details on the trial protocol are available elsewhere.(19)

As a part of the trial, a survey is administered to all households in the study area at baseline and every 12 months thereafter during the study period. All households were censused between December 2016 and January 2017, just prior to the launch of the intervention, with the aim of enumerating all permanent residents (present more than 50% of the time in the past year). The census included a household roster to collect the age, date of birth, and sex for permanent residents, as well as information pertaining to deaths in the household in the past five years. Then all women in the household aged 15-49 years (i.e., women of reproductive age) who provided written informed consent were enrolled and completed a baseline survey. The survey was adapted from the Demographic and Health Surveys (DHS),(27) and included detailed information on household characteristics. Based on standard DHS modules, women were given a reading test to assess literacy and asked if they contribute to household decision-making, if their husband has more than one wife or partner, and if they felt their husband hitting or beating them was justified under certain circumstances. Geographical co-ordinates were collected using global positioning technology. We supplemented the baseline survey data with information from the year-one follow-up survey, administered from February to March 2018, which used the same structure as the baseline survey but added details on women's birth histories (i.e., probes to distinguish between live and still births, clarification of multiple births, and greater precision on birth dates); this enabled us to correct any misreporting in the birth histories recorded at baseline.

Ethics

The trial is registered with ClincialTrials.gov (NCT02694055). Ethical approval was obtained from the Ethics Committee of the Faculty of Medicine, Pharmacy and Dentistry, University of Bamako (2016/03/CE/FMPOS). The University of California, San Francisco exempted secondary analysis of the deidentified trial data from ethical approval. All participants provided written informed consent prior to enrolling in the study, which included the baseline survey.

Inclusion Criteria

All households with a woman aged 15-49 years who participated in both the baseline and year-one surveys and indicated they had housed a child under five years-of-age at any time in the five years preceding baseline were included in this analysis. Women were required to have participated in the year-one survey as the additional birth history data collected at this time (see *Household Surveys*) was required to calculate mortality rates.

Definitions

We defined the number of births in the household as the sum of live births by resident women of reproductive age in the past 10 years. Women were considered to contribute to household decisions if they indicated participation in decision-making. Literacy was categorized based on the highest level of reading ability among women surveyed within the household. Polygamy was defined as a survey respondent in the household indicating that her husband/partner had more than one wife/partner. Women were considered to have tolerant views towards spousal violence if they indicated that their husband hitting or beating them was justified under any of the circumstances evaluated in the survey. We used the World Health Organization definitions of improved/unimproved water supply and sanitation.(28) Households were also asked if they treated their water to make it safer for drinking. Treatment included boiling, adding sterilising chemicals,

filtering, and solar disinfection. Roofing, wall and flooring materials were defined as finished, rudimentary or natural as per DHS definitions.(27)

Distance to the nearest primary health center was defined as the Euclidean distance from the household village to the closest primary health center. All distance calculations were conducted in QGIS Version 3.4.6-Madeira (QGIS Development Team (2019), QGIS Geographic Information System, Open Source Geospatial Foundation Project, http://qgis.osgeo.org).

U5 mortality rates

U5 mortality rates for the five-year period immediately preceding the baseline survey were calculated using full birth history data. Women reported all live births using a birth history module modelled on the DHS.(27) We used a synthetic cohort life table approach to estimate the number of deaths per 1,000 live births.(29)

Statistical Analysis

We conducted three main regression analyses to evaluate: 1) factors associated with female U5 mortality in the household (among households that housed at least one female under five-years-old in the past five years); 2) factors associated with male U5 mortality in the household (among households that housed at least one male under five-years-old in the past five years); and 3) factors associated with more than one U5 death in the household (among households that housed at least two children under five-years-old in the past five years).

For analyses 1) and 2) we used negative binomial regression to account for the possibility of multiple deaths in a household. For analysis 3) we used logistic regression as multiple U5 deaths was coded as a binary outcome variable. All analyses were adjusted for village clustering. Covariates were subject to univariate analysis and all were included in our multivariate analyses. Households with missing covariate data were included in analyses but incidence rate ratios (IRRs) and odds ratios (ORs) for missing categories are not reported. Analyses were conducted with Stata 14 (Stata Corp., College Station, Texas).

Sensitivity Analysis

We did not directly adjust for household wealth in our main analyses as many of the included variables are strongly associated with wealth and we were primarily interested in identifying specific household characteristics that may be modified to improve U5 mortality. Nevertheless, given the importance of financial barriers to healthcare in many low- and middle-income parts of the world,(30) we ran sensitivity analyses evaluating household wealth. Wealth was defined in quintiles using a principal components analysis.(31)

Findings

Of 15,839 households censused at baseline, 15,571 (98.3%) included a woman aged 15-49 years who agreed to participate in the survey. An additional 3,144 households were excluded due to not housing an U5 child in the five years prior to baseline, and 3,464 were excluded due to a lack of year-one birth history data. This left a final sample of 8,963 households. Characteristics of these households are summarized in Table 1. Two thousand sixteen households (22.5% of the sample)

reported an U5 death in the five years preceding baseline. In total, 2,685 U5 deaths occurred at a rate of 149 per 1,000 live births (95% confidence interval [95%CI] 142-156).

Among the 7,296 households that had housed an U5 female in the five years preceding baseline, 1,273 U5 female deaths occurred at a rate of 143 per 1,000 live births (95%CI 134-153). Table 2 shows that household factors most strongly associated with death of an U5 female were greater distance from a primary health center (adjusted IRR [aIRR] 1.84 for ≥10 kilometers versus <2 kilometers, 95%CI 1.35-2.50, p<0.001), higher number of births in the past 10 years (aIRR 6.35 for >7 versus 1-3 births, 95%CI 5.33-7.57, p<0.001), monogamy (aIRR 0.83 for polygamy versus monogamy, 95%CI 0.72-0.96, p=0.011), and not owning livestock (aIRR 0.76 for owning versus not owning, 95%CI 0.63-0.93, p=0.008).

Among the 7,419 households that had housed an U5 male in the five years preceding baseline, 1,412 U5 male deaths occurred at a rate of 154 per 1,000 live births (95%CI 145-163). Table 3 shows that the factors most strongly associated with death of an U5 male were greater distance from a primary health center (aIRR 1.60 for ≥10 kilometers versus <2 kilometers, 95%CI 1.22-2.10, p=0.001), higher number of births in the past 10 years (aIRR 5.96 for >7 versus 1-3 births, 95%CI 4.91-7.23, p<0.001), poorer reading ability of women in the household (aIRR 1.59 for can partly read versus can read, 95%CI 1.02-2.46, p=0.039), and having electricity (aIRR 1.23 versus not, 95%CI 1.09-1.37, p<0.001).

Of the 7,433 households that housed more than one child U5 in the five years preceding baseline, 462 (6.2%) reported more than one U5 death. Of households reporting more than one U5 death, 108 (23.4%) reported all female deaths and 114 (24.7%) reported all male deaths. Table 4 shows that greater than one U5 death in the household was associated with greater distance from a primary health center (adjusted OR [aOR] 2.07 for ≥10 kilometers versus <2 kilometers, 95%CI 1.27-3.36, p=0.003), higher number of births in the past 10 years (aOR 37.24 for >7 versus 2-3 births, 95%CI 24.58-56.41, p<0.001), tolerant views of spousal violence (aOR 1.27 versus non-tolerant views, 95%CI 1.02-1.57, p=0.032), and not owning livestock (aOR 0.65 for owning versus not owning, 95%CI 0.45-0.93, p=0.019).

In univariate and multivariate sensitivity analyses including household wealth index, we did not find an association between wealth quintile and U5 mortality in our female, male or multiple mortality models.

Discussion

U5 mortality is common among households in Bankass. In our main analyses, greater distance from a primary health center and higher number of live births in the household were consistently associated with a high probability of U5 mortality. Monogamy and not owning livestock were also associated with a high probability of female U5 mortality, poorer reading ability of reproductive-aged women in the household and having access to electricity were also associated with a high probability of male U5 mortality, and tolerant views of spousal violence and not owning livestock were also associated with multiple U5 deaths.

We estimated an U5 mortality rate of 149 per 1,000 live births for the five-year period prior to our baseline survey. Although the U5 mortality rate in Mopti is high compared with the rest of Mali (111 per 1,000 live births versus the national estimate of 95 per 1,000 live births in 2012-2013 (21)), our findings indicate rates are particularly high in Bankass. Consistent with earlier data from the region, we also found that U5 mortality rates were higher among males than females.(21)

Large distances between home and healthcare have previously been found to reduce the utilization of health services (4-6) and have been linked to increased child mortality in other parts of sub-Saharan Africa.(7-10) Importantly, the association we found between distance and U5 mortality became significant at much shorter distances for females than for males. These findings reinforce the primary motivation for our clinical trial evaluating the benefit of community health workers conducting proactive case detection and management in rural Mali, as compared to passive site-based care. Elsewhere, community case management has proven to increase care seeking outside the home,(32) and reduce U5 mortality.(22, 33-35) The finding that higher number of births was associated with U5 mortality is not surprising, as a greater number of children in the household inherently increases the probability that a child in the household will die.

Owning livestock was associated with a lower probability of U5 mortality in both our female and multiple mortality analyses. Despite the risk of exposure to zoonotic infection, livestock plays an essential role as a source of income and nutrition for households, as well as a means of transport. Consumption of animal source foods, including eggs, milk, milk products, meat and poultry has been shown to be protective against stunting and undernutrition in low-income countries.(36-38) A recent meta-analysis involving countries in sub-Saharan Africa found that owning livestock was associated with a greater risk of child mortality in 22 of the 30 countries included (pooled OR 1.04, 95%CI 1.02-1.06). However, the authors noted that there was significant heterogeneity in their findings, indicating the importance of country-specific data.

Rates of childhood malnutrition and mortality are known to be high in polygamous households in sub-Saharan Africa.(39-42) Others have also shown that the utilization of maternal and child healthcare services tends to be lower among women in polygamous marriages, which may contribute to higher mortality in the neonatal and infant periods.(43) In our univariate analyses, polygamy was consistently associated with a higher probability of U5 mortality. However, this association was nullified or reversed (to the point of statistical significance in the female analysis) when we adjusted our models for number of live births in the household. This indicates polygamous households in Bankass have a higher probability of U5 mortality because there are more children living in these households, but that polygamy itself is protective against U5 mortality. This could be due to the greater number of adults capable of caring for children in a polygamous household.

The number of surveyed households without a woman of reproductive age able to read was over 90% in our sample. Higher levels of maternal education and literacy have been shown to reduce the probability of infant and child mortality in sub-Saharan Africa.(11, 12) Educated women have stronger cognitive, comprehension, and communication skills, which may support healthier behaviors that ultimately lead to lower child mortality.(12) Literacy becomes particularly important for children's survival when mothers have greater decision-making abilities.(12) Educated women also have a better chance of securing employment and are thus able to garner financial resources for their children's health needs.(44) Interestingly, the association between maternal reading ability and U5 mortality in our study was only seen for males. Why girls appear to be less effected warrants further investigation.

An unexpected finding was that households with electricity were more likely to have had an U5 death. This association was only significant in our male analysis, but the effect size was similar (14-26% increased risk) and approached significance in our other analyses. Access to electricity in the home is generally considered a marker of improved living standard and has been associated with a lower child mortality in low- and middle-income countries.(45) In Bankass, there is no electricity grid. Hence, households must rely on fuelled generators, solar power, and batteries. It is possible that

some households use funds to maintain access to electricity while reducing their budget for healthcare. However, this association requires further exploration.

We found that a high proportion (almost 75%) of surveyed women had tolerant views of spousal violence. This is consistent with the most recent DHS data for Mali.(21) Although we did not directly measure whether spousal violence took place in households, we found an increased probability of multiple U5 mortality in households where women held tolerant views of spousal violence. Rawlings and Siddique (46) found that children of women who were ever victims to spousal violence had a 1.1% increased risk of death in the first five years of life compared with children born to mothers who never experienced violence. Spousal violence may lead to poor maternal health (e.g. depression, substance dependence, injury) which could in turn make child care more difficult.(47) The death of a child may also lead to a woman being considered a bad mother and more likely to tolerate or be subjected to abuse.

The main limitation to this study is that many responses were subjective or subject to recall bias. Birth histories are particularly subject to recall bias as mothers may be more likely to omit information about births that occurred in the distant past or births of children who died.(48) Nevertheless, birth histories are one of the most reliable ways to obtain birth data in settings where vital records are lacking (as they are in Mali).(49) Given the remoteness of Bankass, it is also likely there was some imprecision in the geographical coordinates documented. Further, Euclidian distance is an imperfect indicator of geographic barriers to care as it does not consider topographic characteristics that could affect true distance travelled. Nevertheless, Euclidian distance is well correlated with true distance travelled,(50) and the association we found between greater distance from a primary health provider and a high probability of U5 mortality is consistent with current knowledge.(7-10)

U5 mortality is common among households in Bankass and is associated with several household characteristics that may be amenable to intervention or facilitate program targeting. Health policy makers should consider these findings when developing future interventions aimed at curbing U5 mortality in the region.

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Table 1 – Household characteristics

Household characteristic		Households surveyed = 8,963
Inhabitants	Median (IQR)	7 (5-9)
Inhabitants aged <5 years	Median (IQR)	1 (1-2)
Female inhabitants	Median (IQR)	3 (2-5)
Female inhabitants aged <5 years	Median (IQR)	1 (0-1)
Female inhabitants aged 15-49 years	Median (IQR)	1 (1-2)
Average age, years	Median (IQR)	16.8 (14.5-20.2)
Inhabitant/bedroom ratio	Median (IQR)	3 (2-5)
Live births in past 10 years	Median (IQR)	3 (2-5)
Ethnicity	Dogon	8,246 (92.0)
	Fulani	496 (5.5)
	Other	221 (2.5)
Decision-making of women in household	Do not contribute	6,275 (70.0)
	Contribute	2,681 (29.9)
	Unknown	7 (0.1)
Reading ability of women in household	Can read	409 (4.6)
	Can partly read	325 (3.6)
	Cannot read	8,183 (91.3)
	Unknown	46 (0.5)
Polygamy	Monogamous	5,628 (62.8)
	Polygamous	3,169 (35.4)
	Unknown	166 (1.9)
Spousal violence	Not tolerated	2,174 (24.3)
	Tolerated	6,668 (74.4)
	Unknown	121 (1.4)
Water source	Improved/treated	1,472 (16.4)
	Improved/untreated	3,384 (37.8)
	Unimproved/treated	788 (8.8)
	Unimproved/untreated	3,260 (36.4)
	Unknown	59 (0.7)
Sanitation	Improved	4,345 (48.5)
	Unimproved	4,559 (50.9)
	Unknown	59 (0.7)
Roofing material	Natural	294 (3.3)
	Rudimentary	769 (8.6)
	Finished	7,853 (87.6)
	Unknown	47 (0.5)
Wall material	Natural	2,951 (32.9)
	Rudimentary	837 (9.3)
	Finished	5,022 (56.0)
	Unknown	153 (1.7)
Flooring material	Natural	8,491 (94.7)
	Rudimentary	128 (1.4)
	Finished	325 (3.6)
	Unknown	19 (0.2)
Electricity	Yes	3,248 (36.2)
	No	5,715 (63.8)
Primary cooking fuel	Wood	7,669 (85.6)
	Straw	1,128 (12.6)
	Animal dung	111 (1.2)
	Other	55 (0.6)

Food shortage in past 30 days	Yes	1,313 (14.7)
	No	7,650 (85.4)
Livestock	Any	8,064 (90.0)
	Cows/bulls	5,854 (65.3)
	Horses/donkeys/mules	5,917 (66.0)
	Goats	4,179 (46.6)
	Sheep	6,514 (72.7)
	Chickens	6,292 (70.2)
Motorized transport	Any	4,532 (50.6)
	Motorbike/scooter	4,520 (50.4)
	Car/truck	56 (0.6)
Nearest primary health center, kilometers	<2	1,812 (20.2)
	2 - 4.99	2,077 (23.2)
	5 - 6.99	1,764 (19.7)
	7 - 9.99	2,012 (22.5)
	≥10	1,298 (14.5)

All values are n (%total) unless otherwise specified. IQR, interquartile range

Table 2 – Factors associated with the death of an under-five female household member in the five years preceding the baseline survey (N=7,296)

Household characteristic		Households	Mean number of deaths per household (SD)	Univariate IRR (95%CI)	p	Multivariate IRR (95%CI)	p
Overall		7,296	0.17 (0.45)				
Live births in past 10 years	1-3	3,621	0.09 (0.29)	1.00		1.00	
	4-5	2,250	0.19 (0.46)	2.23 (1.92-2.59)	<0.001	**2.22 (1.92-2.57)**	**<0.001**
	6-7	800	0.28 (0.55)	3.25 (2.79-3.79)	<0.001	**3.45 (2.87-4.13)**	**<0.001**
	>7	625	0.50 (0.74)	5.89 (5.11-6.79)	<0.001	**6.35 (5.33-7.57)**	**<0.001**
Ethnicity	Dogon	6,725	0.17 (0.45)	1.00		1.00	
	Fulani	391	0.15 (0.38)	0.85 (0.66-1.09)	0.201	0.96 (0.72-1.28)	0.770
	Other	180	0.23 (0.53)	1.30 (0.92-1.85)	0.133	1.37 (0.99-1.89)	0.058
Decision-making of women in household	Contribute	2,191	0.19 (0.47)	1.00		1.00	
	Do not contribute*	5,105	0.17 (0.44)	0.88 (0.76-1.02)	0.097	0.97 (0.85-1.10)	0.636
Reading ability of women in household	Can read	332	0.16 (0.46)	1.00		1.00	
	Can partly read	254	0.15 (0.41)	0.92 (0.57-1.47)	0.727	0.84 (0.53-1.31)	0.439
	Cannot read	6,678	0.18 (0.45)	1.09 (0.79-1.50)	0.613	0.84 (0.64-1.12)	0.234
	Unknown	32	0.03 (0.18)	-		-	
Polygamy	Monogamous	2,839	0.15 (0.41)	1.00		1.00	
	Polygamous	4,341	0.21 (0.50)	1.42 (1.27-1.59)	<0.001	**0.83 (0.72-0.96)**	**0.011**
	Unknown	116	0.08 (0.35)	-		-	
Spousal violence	Not tolerated	1,771	0.15 (0.42)	1.00		1.00	
	Tolerated	5,428	0.18 (0.46)	1.22 (1.04-1.43)	0.014	1.15 (0.99-1.33)	0.076
	Unknown	97	0.13 (0.40)	-		-	
Water source	Improved/treated	1,233	0.15 (0.43)	1.00		1.00	
	Improved/untreated	2,738	0.18 (0.46)	1.23 (1.00-1.52)	0.055	1.18 (0.97-1.45)	0.101
	Unimproved/treated	642	0.19 (0.45)	1.30 (0.96-1.76)	0.092	1.20 (0.91-1.58)	0.191
	Unimproved/untreated	2,639	0.17 (0.44)	1.14 (0.90-1.43)	0.268	1.08 (0.87-1.35)	0.473
	Unknown	44	0.14 (0.35)	-		-	
Sanitation	Improved	3,549	0.17 (0.44)	1.00		1.00	
	Unimproved	3,697	0.18 (0.46)	1.08 (0.94-1.25)	0.256	1.09 (0.96-1.23)	0.197
	Unknown	50	0.16 (0.37)	-		-	
Roofing material	Finished	6,390	0.17 (0.45)	1.00		1.00	
	Rudimentary	622	0.17 (0.42)	0.97 (0.78-1.20)	0.761	1.03 (0.86-1.25)	0.728
	Natural	250	0.19 (0.48)	1.10 (0.72-1.67)	0.656	1.09 (0.74-1.62)	0.654
	Unknown	34	0.12 (0.41)	-		-	
Wall material	Finished	4,061	0.18 (0.45)	1.00		1.00	
	Rudimentary	690	0.17 (0.44)	0.97 (0.78-1.22)	0.820	0.99 (0.79-1.23)	0.914
	Natural	2,420	0.17 (0.45)	0.97 (0.84-1.11)	0.620	1.00 (0.88-1.13)	0.995
	Unknown	125	0.17 (0.38)	-		-	

Flooring material	Finished	266	0.13 (0.37)	1.00		1.00	
	Rudimentary	103	0.14 (0.40)	1.03 (0.47-2.29)	0.936	1.01 (0.47-2.18)	0.987
	Natural*	6,927	0.18 (0.45)	1.34 (0.86-2.10)	0.195	1.14 (0.76-1.72)	0.513
Electricity	No	4,624	0.16 (0.44)	1.00		1.00	
	Yes	2,672	0.19 (0.47)	1.16 (1.02-1.33)	0.025	1.14 (1.00-1.29)	0.056
Primary cooking fuel	Wood	6,239	0.17 (0.45)	1.00		1.00	
	Straw	920	0.19 (0.46)	1.10 (0.91-1.33)	0.338	0.99 (0.83-1.19)	0.948
	Animal dung	93	0.23 (0.55)	1.31 (0.70-2.45)	0.395	1.50 (0.83-2.72)	0.182
	Other	44	0.09 (0.29)	0.53 (0.17-1.66)	0.274	0.64 (0.23-1.78)	0.389
Food shortage in past 30 days	No	6,197	0.17 (0.44)	1.00		1.00	
	Yes	1,099	0.20 (0.47)	1.20 (1.03-1.41)	0.022	1.11 (0.97-1.28)	0.133
Livestock	No	657	0.19 (0.45)	1.00		1.00	
	Yes	6,639	0.17 (0.45)	0.91 (0.73-1.13)	0.388	**0.76 (0.63-0.93)**	**0.008**
Motorized transport	No	3,529	0.16 (0.43)	1.00		1.00	
	Yes	3,767	0.18 (0.47)	1.11 (0.98-1.26)	0.102	1.01 (0.89-1.14)	0.889
Nearest healthcare center, kilometers	<2	1,479	0.11 (0.36)	1.00		1.00	
	2 - 4.99	1,651	0.18 (0.45)	1.66 (1.25-2.20)	0.001	**1.49 (1.13-1.96)**	**0.004**
	5 - 6.99	1,768	0.17 (0.45)	1.64 (1.21-2.23)	0.002	**1.51 (1.14-1.99)**	**0.004**
	7 - 9.99	1,311	0.20 (0.47)	1.75 (1.30-2.34)	<0.001	**1.53 (1.15-2.02)**	**0.003**
	≥10	1,087	0.22 (0.52)	2.02 (1.47-2.78)	<0.001	**1.84 (1.36-2.50)**	**<0.001**

Multivariate IRRs with p-value ≤0.05 are bolded. Households with missing covariate data were included in all analyses but IRRs for missing categories are not reported. *Merged with unknown category. SD, standard deviation; IRR, incidence rate ratio; CI, confidence interval

Table 3 – Factors associated with the death of an under-five male household member the five years preceding the baseline survey (N=7,419)

Household characteristic		Households	Mean number of deaths per household (SD)	Univariate IRR (95%CI)	p	Multivariate IRR (95%CI)	p
Overall		7,419	0.19 (0.48)				
Live births in past 10 years	1-3	3,691	0.10 (0.31)	1.00		1.00	
	4-5	2,314	0.19 (0.45)	2.02 (1.76-2.33)	<0.001	**2.02 (1.75-2.34)**	**<0.001**
	6-7	797	0.34 (0.63)	3.54 (2.92-4.28)	<0.001	**3.70 (3.04-4.50)**	**<0.001**
	>7	617	0.54 (0.83)	5.66 (4.83-6.64)	<0.001	**5.96 (4.91-7.23)**	**<0.001**
Ethnicity	Dogon	6,843	0.19 (0.48)	1.00		1.00	
	Fulani	397	0.16 (0.44)	0.88 (0.64-1.20)	0.406	0.86 (0.66-1.11)	0.246
	Other	179	0.17 (0.47)	1.17 (0.75-1.82)	0.499	0.91 (0.66-1.26)	0.557
Decision-making of women in household	Contribute	2,246	0.19 (0.46)	1.00		1.00	
	Do not contribute*	5,173	0.19 (0.49)	0.84 (0.72-0.98)	0.031	1.09 (0.97-1.21)	0.139
Reading ability of women in household	Can read	327	0.13 (0.40)	1.00		1.00	
	Can partly read	254	0.22 (0.52)	1.72 (1.11-2.66)	0.015	**1.59 (1.02-2.46)**	**0.039**
	Cannot read	6,802	0.19 (0.48)	1.50 (1.06-2.12)	0.023	1.25 (0.90-1.75)	0.185
	Unknown	36	0.19 (0.47)	-		-	
Polygamy	Monogamous	4,473	0.16 (0.43)	1.00		1.00	
	Polygamous	2,831	0.24 (0.55)	1.55 (1.37-1.75)	<0.001	0.89 (0.77-1.03)	0.117
	Unknown	115	0.12 (0.38)	-		-	
Spousal violence	Not tolerated	1,783	0.19 (0.48)	1.00		1.00	
	Tolerated	5,541	0.19 (0.48)	1.01 (0.87-1.16)	0.919	0.98 (0.86-1.11)	0.720
	Unknown	95	0.21 (0.56)	-		-	
Water source	Improved/treated	1,209	0.19 (0.50)	1.00		1.00	
	Improved/untreated	2,805	0.19 (0.47)	1.02 (0.81-1.30)	0.853	1.04 (0.85-1.28)	0.703
	Unimproved/treated	660	0.18 (0.44)	0.97 (0.70-1.35)	0.851	0.96 (0.72-1.29)	0.805
	Unimproved/untreated	2,697	0.19 (0.49)	1.04 (0.82-1.32)	0.721	1.05 (0.85-1.30)	0.624
	Unknown	48	0.21 (0.46)	-		-	
Sanitation	Improved	3,605	0.18 (0.46)	1.00		1.00	
	Unimproved	3,762	0.20 (0.49)	1.12 (0.99-1.28)	0.081	1.11 (0.99-1.25)	0.064
	Unknown	52	0.19 (0.44)	-		-	
Roofing material	Finished	6,509	0.19 (0.48)	1.00		1.00	
	Rudimentary	647	0.20 (0.48)	1.04 (0.86-1.26)	0.661	1.10 (0.92-1.33)	0.307
	Natural	228	0.22 (0.50)	1.19 (0.85-1.66)	0.304	1.15 (0.87-1.52)	0.341
	Unknown	35	0.29 (0.62)	-		-	
Wall material	Finished	4,176	0.19 (0.46)	1.00		1.00	
	Rudimentary	696	0.20 (0.47)	1.05 (0.86-1.29)	0.622	1.02 (0.84-1.23)	0.844
	Natural	2,417	0.19 (0.50)	1.02 (0.88-1.18)	0.789	1.05 (0.92-1.19)	0.485
	Unknown	130	0.25 (0.63)	-		-	

Flooring material	Finished	265	0.20 (0.55)	1.00		1.00	
	Rudimentary	106	0.21 (0.53)	1.06 (0.60-1.87)	0.848	1.01 (0.62-1.64)	0.979
	Natural*	7,048	0.19 (0.48)	0.97 (0.65-1.43)	0.869	0.85 (0.62-1.18)	0.329
Electricity	No	4,729	0.18 (0.47)	1.00		1.00	
	Yes	2,690	0.22 (0.50)	1.23 (1.09-1.38)	0.001	**1.23 (1.09-1.37)**	**<0.001**
Primary cooking fuel	Wood	6,342	0.19 (0.48)	1.00		1.00	
	Straw	938	0.21 (0.49)	1.12 (0.96-1.30)	0.138	1.03 (0.90-1.18)	0.657
	Animal dung	91	0.22 (0.53)	1.17 (0.71-1.94)	0.536	1.34 (0.87-2.06)	0.178
	Other	48	0.13 (0.33)	0.67 (0.30-1.49)	0.322	0.79 (0.38-1.67)	0.542
Food shortage in past 30 days	No	6,306	0.19 (0.47)	1.00		1.00	
	Yes	1,113	0.21 (0.52)	1.11 (0.95-1.30)	0.173	1.04 (0.91-1.19)	0.581
Livestock	No	699	0.18 (0.48)	1.00		1.00	
	Yes	6,720	0.19 (0.48)	1.09 (0.90-1.32)	0.372	0.91 (0.75-1.10)	0.331
Motorized transport	No	3,600	0.18 (0.47)	1.00		1.00	
	Yes	3,819	0.20 (0.49)	1.12 (0.99-1.27)	0.070	0.98 (0.87-1.10)	0.721
Nearest healthcare center, kilometers	<2	1,493	0.14 (0.40)	1.00		1.00	
	2 - 4.99	1,720	0.18 (0.46)	1.24 (0.93-1.66)	0.141	1.07 (0.80-1.43)	0.668
	5 - 6.99	1,455	0.19 (0.49)	1.34 (1.02-1.76)	0.035	1.16 (0.88-1.54)	0.293
	7 - 9.99	1,678	0.20 (0.49)	1.42 (1.08-1.88)	0.012	1.24 (0.97-1.59)	0.086
	≥10	1,073	0.26 (0.56)	1.80 (1.36-2.37)	<0.001	**1.60 (1.22-2.10)**	**0.001**

Multivariate IRRs with p-value ≤0.05 are bolded. Households with missing covariate data were included in all analyses but IRRs for missing categories are not reported. *Merged with unknown category. SD, standard deviation; IRR, incidence rate ratio; CI, confidence interval

Table 4 – Factors associated with more than one under-five death in the household in the five years preceding the baseline survey (N=7,433)

Household characteristic		Households	Households with >1 death (% within category)	Univariate OR (95%CI)	p	Multivariate OR (95%CI)	p
Overall		7,433	462 (6.2)				
Live births in past 10 years	2-3	3,523	40 (1.1)	1.00		1.00	
	4-5	2,461	145 (5.9)	5.45 (3.82-7.79)	<0.001	**5.50 (3.84-7.88)**	**<0.001**
	6-7	819	107 (13.1)	13.09 (8.61-19.89)	<0.001	**14.62 (9.25-23.10)**	**<0.001**
	>7	630	170 (27.0)	32.18 (22.59-45.83)	<0.001	**37.24 (24.58-56.41)**	**<0.001**
Ethnicity	Dogon	6,865	428 (6.2)	1.00		1.00	
	Fulani	389	19 (4.9)	0.77 (0.53-1.13)	0.179	1.08 (0.62-1.90)	0.788
	Other	179	15 (8.4)	1.38 (0.76-2.48)	0.290	1.53 (0.88-2.65)	0.132
Decision-making of women in household	Contribute	2,255	149 (6.6)	1.00		1.00	
	Do not contribute*	5,178	313 (6.0)	0.91 (0.73-1.13)	0.396	1.08 (0.87-1.35)	0.488
Reading ability of women in household	Can read	321	17 (5.3)	1.00		1.00	
	Can partly read	240	15 (6.3)	1.19 (0.55-2.58)	0.656	1.06 (0.45-2.50)	0.886
	Cannot read	6,840	429 (6.3)	1.20 (0.65-2.20)	0.564	0.90 (0.47-1.71)	0.752
	Unknown	32	1 (3.1)	-		-	
Polygamy	Monogamous	4,437	195 (4.4)	1.00		1.00	
	Polygamous	2,904	263 (9.1)	2.17 (1.80-2.61)	<0.001	0.79 (0.61-1.03)	0.081
	Unknown	92	4 (4.3)	-		-	
Spousal violence	Not tolerated	1,782	89 (5.0)	1.00		1.00	
	Tolerated	5,559	370 (6.7)	1.36 (1.09-1.68)	0.005	**1.27 (1.02-1.57)**	**0.032**
	Unknown	92	3 (3.3)	-		-	
Water source	Improved/treated	1,237	70 (5.7)	1.00		1.00	
	Improved/untreated	2,788	170 (6.1)	1.08 (0.74-1.57)	0.678	1.07 (0.73-1.58)	0.728
	Unimproved/treated	657	47 (7.2)	1.28 (0.82-2.01)	0.273	1.25 (0.79-1.98)	0.330
	Unimproved/untreated	2,704	172 (6.4)	1.13 (0.78-1.64)	0.511	1.15 (0.78-1.70)	0.474
	Unknown	47	3 (6.4)	-		-	
Sanitation	Improved	3,627	209 (5.8)	1.00		1.00	
	Unimproved	3,754	250 (6.7)	1.17 (0.94-1.45)	0.163	1.21 (0.97-1.50)	0.084
	Unknown	52	3 (5.8)	-		-	
Roofing material	Finished	6,538	408 (6.2)	1.00		1.00	
	Rudimentary	622	35 (5.6)	0.90 (0.63-1.27)	0.537	0.98 (0.68-1.40)	0.905
	Natural	235	17 (7.2)	1.17 (0.70-1.97)	0.550	1.14 (0.67-1.95)	0.620
	Unknown	38	2 (5.3)	-		-	
Wall material	Finished	4,181	269 (6.4)	1.00		1.00	
	Rudimentary	697	41 (5.9)	0.91 (0.65-1.28)	0.583	0.88 (0.60-1.28)	0.497
	Natural	2,426	143 (5.9)	0.91 (0.72-1.15)	0.431	0.93 (0.75-1.17)	0.544
	Unknown	129	9 (7.0)	-		-	

Flooring material	Finished	262	15 (5.7)	1.00		1.00	
	Rudimentary	107	6 (5.6)	0.98 (0.38-2.49)	0.963	0.99 (0.38-2.55)	0.976
	Natural*	7,064	441 (6.2)	1.10 (0.61-1.97)	0.759	0.89 (0.49-1.59)	0.688
Electricity	No	4,713	267 (5.7)	1.00		1.00	
	Yes	2,720	195 (7.2)	1.29 (1.04-1.59)	0.020	1.26 (0.98-1.61)	0.068
Primary cooking fuel	Wood	6,365	391 (6.1)	1.00		1.00	
	Straw	925	63 (6.8)	1.12 (0.86-1.45)	0.408	0.93 (0.71-1.22)	0.594
	Animal dung	94	6 (6.4)	1.04 (0.43-2.52)	0.928	1.35 (0.50-3.65)	0.557
	Other	49	2 (4.1)	0.65 (0.09-4.64)	0.668	0.89 (0.12-6.55)	0.905
Food shortage in past 30 days	No	6,301	383 (6.1)	1.00		1.00	
	Yes	1,132	79 (7.0)	1.16 (0.88-1.53)	0.292	1.12 (0.87-1.44)	0.375
Livestock	No	626	43 (6.9)	1.00		1.00	
	Yes	6,807	419 (6.2)	0.89 (0.63-1.26)	0.506	**0.65 (0.45-0.93)**	**0.019**
Motorized transport	No	3,568	191 (5.4)	1.00		1.00	
	Yes	3,865	271 (7.0)	1.33 (1.11-1.60)	0.002	1.12 (0.92-1.36)	0.269
Nearest healthcare center, kilometers	<2	1,457	54 (3.7)	1.00		1.00	
	2 - 4.99	1,727	108 (6.3)	1.73 (1.12-2.68)	0.013	1.50 (0.98-2.31)	0.065
	5 - 6.99	1,475	97 (6.6)	1.83 (1.12-2.97)	0.015	**1.75 (1.10-2.78)**	**0.019**
	7 - 9.99	1,677	112 (6.7)	1.86 (1.19-2.91)	0.007	1.58 (0.99-2.51)	0.056
	≥10	1,097	91 (8.3)	2.35 (1.46-3.78)	<0.001	**2.07 (1.27-3.36)**	**0.003**

Multivariate ORs with p-value ≤0.05 are bolded. Households with missing covariate data were included in all analyses but ORs for missing categories are not reported. *Merged with unknown category. OR, odds ratio; CI, confidence interval