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Postneonatal under-5 mortality in peri-urban and rural Eastern Uganda, 2005–2015

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ABSTRACT

Introduction Community and individual sociodemographic characteristics play an important role in child survival. However, a question remains how urbanisation and demographic changes in sub-Saharan Africa affect community-level determinants for child survival.

Methods Longitudinal data from the Iganga/Mayuge Health and Demographic Surveillance Site was used to obtain postneonatal under-5 mortality rates between March 2005 and February 2015 in periurban and rural areas separately. Multilevel survival analysis models were used to identify factors associated with mortality.

Results There were 43 043 postneonatal under-5 children contributing to 116 385 person years of observation, among whom 1737 died. Average annual crude mortality incidence rate (IR) differed significantly between periurban and rural areas (9.0 (8.1 to 10.0) per 1000 person-years vs 18.1 (17.1 to 19.0), respectively). In periurban areas, there was evidence for decreasing mortality from IR=11.3 (7.7 to 16.6) in 2006 to IR=4.5 (3.0 to 6.9) in 2015. The mortality fluctuated with no evidence for reduction in rural areas (IR=19.0 (15.8 to 22.8) in 2006; IR=15.5 (13.0 to 18.6) in 2015). BCG vaccination was associated with reduced mortality in periurban and rural areas (adjusted rate ratio (aRR)=0.45; 95% CI 0.30 to 0.67 and aRR=0.56; 95% CI 0.41 to 0.76, respectively). Maternal education level within the community was associated with reduced mortality in both periurban and rural sites (aRR=0.83; 95% CI 0.70 to 0.99; aRR=0.90; 95% CI 0.81 to 0.99). The proportion of households in the poorest quintile within the community was associated with mortality in rural areas only (aRR=1.08; 95% CI 1.00 to 1.18). In rural areas, a large disparity existed between the least poor and the poorest (aRR=0.50; 95% CI 0.27 to 0.92).

Conclusion We found evidence for a mortality decline in peri-urban but not rural areas. Investments in the known key health (eg, vaccination) and socio-economic interventions (education, and economic development) continue to be crucial for mortality declines. Focused strategies to eliminate the disparity between wealth quintiles are also warranted. There may be equitable access to health services in peri-urban areas but improved metrics of socioeconomic position suitable for peri-urban residents may be needed.

Key questions

What is already known?

- National representative survey data suggest a declining under-5 mortality rate in both urban and rural areas of Uganda.
- Increasingly, evidence suggests that community characteristics are key determinants of child mortality even after adjusting for individual factors in sub-Saharan Africa where rapid urbanisation is taking place.

What are the new findings?

- Longitudinal cohort data from the health and demographic surveillance site in Eastern Uganda suggest a decline in the postneonatal under-5 mortality rate in periurban areas between 2005 and 2015 but the mortality rate fluctuated without evidence of a decline in rural areas.
- BCG vaccination and the proportion of mothers educated in the community were associated with a reduction in postneonatal under-5 mortality in both rural and periurban areas.
- The proportion of households in the poorest quintiles in community and being in the lowest wealth quintile were associated with an increase in postneonatal under-5 mortality in rural areas.

What do the new findings imply?

- Investment in the known key health and socioeconomic interventions continue to be crucial for mortality declines.
- Focused strategies to eliminate the disparity between the least poor and the poorest are warranted.
- Improved metrics of socioeconomic position suitable for periurban residents may be needed.

INTRODUCTION

Uganda substantially reduced the under-5 mortality rate between 1990 and 2015,[1] only narrowly missing the Millennium Development Goal (MDG) 4 target of reducing it by 66% between 1990 and 2015. According to the Demographic and Health Surveys (DHS), under-5 mortality rate and postneonatal mortality rate declined from 156 deaths per 1000 live births to 64 deaths and from 46 to 16, respectively.[2] Literature suggests many factors contributed to this decline. Among them are the increased coverage of insecticide treated bed net,[3] which likely contributed to the decreasing prevalence of malaria[3–5]; the increased measles, BCG and DTP vaccination coverage[6] and favourable changes in children's living conditions such as improved water sources in rural areas[7] and general economic growth.

Meanwhile, in many countries in sub-Saharan Africa, the supply of housing, water and sanitation in urban areas cannot keep pace with an increasing demand from rapid urbanisation[8] and Uganda is no exception.[9] The changing demographics may have effects on morbidity and mortality patterns in urban and periurban areas. Evidence suggests that the prevalence of underweight in urban areas is increasing in many countries including Uganda,[10 11] affecting morbidity and mortality risks from diarrhoea and infectious diseases.[12] The poor–rich inequalities in child malnutrition are much wider in urban areas than in rural areas in countries in sub-Saharan Africa.[13] Children of the urban poor households have a lower survival rate than their rural counterparts in a number of resource-limited countries.[14 15]

Overlaid on the demographic trends are increasing evidence that community characteristics (such as community poverty level, community education level, community infrastructure and community access to health facility) are independently associated with health outcomes in urban areas.[16–19] However, literature is limited in understanding the trend and determinants of child mortality in the 'village periurban' or 'perirural'[20] part of sub-Saharan Africa. Thus, a study was warranted to clarify individual and community-level determinants of child mortality in perirural areas vis a vis rural areas. The current study used data on children aged 1 month and 59 months old during the MDG era from the Iganga/Mayuge Health and Demographic Surveillance Site (IMHDSS) in eastern Uganda.

METHODS

Study setting

Set up in 2004, the IMHDSS is an open population cohort, located in Iganga and Mayuge districts, Eastern Uganda, a 2 hours drive east of the capital Kampala. Since the baseline census in 2005, all residents in 65 villages within a clearly demarcated area have been prospectively followed up at biannual censuses, during which an adult member of each household is interviewed to collect information about births, deaths and migration. In addition, the IMDSS relies on trusted members of the communities 'village scouts' who report pregnancies and births to the IMDSS office throughout the year, in order to improve the capture of the key events as they occur. Roughly one-third of the residents in the IMHDSS live in urbanised parts of the rural districts and the rest in rural parts. Further details of the surveillance site have been previously described.[21]

Study subjects

The current study includes all postneonatal under-5 children (ie, >28 days old and <60 months) who were residents in the IMDSS at any time during the 10 years between the 1 March 2005 and 28 February 2015. They were retrospectively entered into the current study either at 28 days old if they had been born to resident women, or at the time they became resident of the IMDSS if they had been born to non-resident women and moved into the surveillance site, and were followed up until their fifth birthday or censored at death or migration. A resident is an individual who has lived in the same location within the IMHDSS for more than 4 months. While immortal time bias is a threat to cohort studies, measures have been put in place to reduce such bias. They include the short interval between biannual update rounds, the recording of pregnancies during update rounds, and the use of key informants village scouts. The entry to the current study at 28 days was chosen to facilitate interpretation because the main causes of deaths during neonatal period and their determinants differ from those during 1–59 months.

Individual-level variables

The first component of a principal component analysis (PCA) was used to calculate the wealth quintiles for periurban and rural areas.[22] Data from the socioeconomic surveys were used. Variables with more than two categories were recoded into binary variables which were then included in the PCA. Because the socioeconomic surveys are conducted every 3–4 years, the socioeconomic status of the household at the nearest to the time of the entry into the cohort was assigned to each individual. BCG vaccination data had been collected at every or every other update round from 2010. The presence or absence of BCG scar was observed by an interviewer, if the child was present, and the date of vaccination was copied from the child's vaccination card if available. As BCG vaccinations are normally given at birth or soon after, we assumed that children had received the vaccination by the time they entered into the current study (at 28 days or when they became residents thereafter). Other vaccinations such as measles, polio and DTP were also collected but only BCG was used because it did not rely on the availability of vaccination card alone to collect data in this rural setting. Furthermore, vaccinations normally given later in the infancy period were not considered in the current study in which the outcome of interest may occur before exposure, such as to measles vaccination at 9 or 12 months, in order to ensure that the exposure and outcome relationship was causal. Mother's education was recoded to a binary variable to indicate the mother completed 7 years of primary education or not.

Community-level variables

Population density, building structure and facilities (modernised vs unmodernised), and main occupation of residents (ie, trading vs farming) were used by the HDSS team to determine periurban or rural areas. Depending on the location of their residence, periurban or rural was assigned to individuals. If one migrated from rural to periurban area or vice versa during the study period, and lived in the new location for more than 4 months, their residence status also changed. Maternal education in community is the percentage of the mothers educated at least to primary school (year 7) per village. The proportion of households in the poorest quintiles was calculated per village. Overcrowded households in community are the percentage of households with at least four people per sleeping room; households with improved sanitation in community indicate the percentage of households with own flush toilet or vip pit latrine; households with improved water source in community is the percentage of households with tap or piped water, well water on residency and protected spring. Mosquito net ownership in community is the percentage of households who own a mosquito net. All the community-level variables were time-varying covariates to take into consideration changes that may have taken place over the study period of 10 years. All the community-level continuous variables were standardised to have mean zero and unit variance.

Data analysis

After describing the study subjects, the incidence mortality rate for each year and for each age band was calculated using the stsplit command and the strate commands in STATA V.13. As BCG vaccination status was available in 5405 children and maternal education in 25 062 children only, missing values were imputed using multiple imputation by chained equations ('mi impute chained' in STATA V.13) because data were missing in more than one variable.[23] Variables that are predictive of missingness as well as the variables correlated with the variables used in the data analysis (birth year, residence village, rural–urban residence, wealth quintiles, child survival status) were included in the imputation model. Twenty imputed datasets were created which were then combined using Rubin's rule. Then, piecewise exponential mixed effects multilevel survival analysis models, which are equivalent to a Poisson regression model, were used to estimate mortality incidence.[24] The analysis methods incorporate the change in exposure status by splitting the exposure time into shorter time scales so that the appropriate exposure value may be assigned to each of the time scales. In addition, the multilevel modelling techniques take into account the hierarchical structure of our data where individual children were nested within villages. The analysis was conducted separately for periurban and rural samples to assess whether explanatory variables differ between the two before deciding to combine them. Several models were fitted. Model 0 (empty model) contained no explanatory variable, which provides an estimation of the degree of correlation in mortality that existed at the village level. In the next models (models 1, 2, 3), each of the individual factors was included while adjusting for the age and year. Finally, community factors were included (models 4 and 5). Fixed effects were expressed as rate ratios (RRs). The random effects, that is measures of variations in mortality across communities, were expressed as proportional change in variance (PCV) and general contextual effects were quantified by the median rate ratio (MRR).[25] The MRR compares mortality incidence rates between identical children from two randomly selected different clusters.

Patient and public involvement

As the IMHDDS is an open cohort surveillance site, recruitment of new participants is key. For this, IMHDSS work particularly closely with community volunteers who identify and report pregnancies and births. For this particular study, patients and the public were not involved in the study design, data analysis or writing of the manuscript.

RESULTS

Altogether, 43 043 resident children were included in the analysis with 15 791 periurban residents and 27 252 rural residents. The periurban cohort contributed 40 180 and the rural cohort contributing 76 206 person years of observation (online supplemental appendix 1). The median time at risk was 2.3 years for periurban areas and 2.7 years for rural areas but it varied from 0.6 year for those born in 2014 to 3.3 years for those born between 2006 and 2010 (data not shown). There was an upward trend in the number of children residing in the study area over the study period from 11 190 to 12 335. The increasing trend was mostly attributable to a faster increase in periurban residents as the ratio between periurban and rural areas increased steadily. In the first year, a third (33%) of the children lived in periurban areas, increasing to 38% in 2015 (online supplemental appendix 2). The average proportion of mothers who completed primary education per village increased steadily from 40% (95% CI 35.14% to 44.2%) in 2005 to 56% (95% CI 50.23% to 59.32%) in 2015. The average proportion of overcrowded households per village decreased from over 40% to 33%. The average proportion of children with BCG vaccination per village did not increase from 83% over the study period. The average proportion of households in the lowest wealth quintile was 21% over the study years (table 1).

There were 1737 deaths during the study period, with 1376 (79%) occurring in rural areas and 361 (21%) in periurban areas. The incidence rate during the entire study period was 14.9 deaths per 1000 person years (data not shown) with the rates for rural and periurban areas differing significantly (18.1 (17.1 to 19.0) vs 9.0 (8.1 to 10.0) per 1000 person years, respectively; RR=2.01 (1.79 to 2.26); p<0.001). The overall incidence mortality rate showed a 32% decline from 16.8 (14.2 to 19.9) in 2006 to 11.4 (9.7 to 13.4) in 2015 (RR=0.68; 95% CI (0.54 to 0.85)) and a more consistent decline from 2010 (figure 1) (18.8 in 2010 and 11.4 per 1000 person years in 2015). However, when disaggregated by quintile groups, the first

Table 1 Community characteristics, Eastern Uganda (2005–2015)

	All areas		Periurban		Rural areas	
	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD
Maternal education (% completed primary education per village)						
2006	39.89	20.39	64.28	18.51	29.81	9.97
2008	43.28	17.97	63.29	13.96	35.02	11.94
2011	49.98	19.84	72.46	13.37	40.69	13.66
2014	52.86	17.69	73.01	12.37	44.53	11.90
Total	48.52	19.42	70.08	15.67	39.61	12.65
% of poorest quintile per village						
2006	23.66	17.74	3.08	6.09	32.16	13.42
2008	19.16	14.2	1.91	4.32	26.29	10.09
2011	20.24	16.52	1.93	5.21	27.80	13.33
2014	21.9	17.44	1.33	4.13	30.39	13.17
Total	21.24	16.53	2.06	4.94	29.16	12.68
Mosquito net ownership per village						
2006	67.94	6.98	69.84	8.79	67.15	6.02
2008	59.13	9.67	47.89	7.85	63.78	5.72
2011	61.94	6.51	57.98	6.03	63.57	6.02
2014	65.14	5.98	61.48	6.57	66.65	5.06
Total	63.54	8.09	59.29	10.73	65.29	5.90
Overcrowded household (% households with ≥4 people per sleeping room)						
2006	40.69	8.02	43.89	8.99	39.37	7.29
2008	36.03	6.15	32.07	6.47	37.67	5.26
2011	34.78	5.98	32.82	5.34	35.59	6.09
2014	33.74	7.65	32.21	7.78	34.37	7.58
Total	36.31	7.46	32.71	10.16	35.79	8.12
Household with improved sanitation						
2006	27.48	10.51	23.44	8.74	29.15	10.81
2008	28.79	11.81	26.58	12.15	29.70	11.68
2011	26.35	11.22	22.49	8.91	27.94	11.77
2014	25.42	11.99	25.72	10.88	25.29	12.54
Total	27.01	11.4	24.94	12.53	27.89	12.51
Household with improved water						
2006	65.8	21.45	62.90	15.77	66.99	23.46
2008	67.54	20.2	66.40	13.38	68.01	22.53
2011	68.22	20.15	67.16	12.79	68.66	22.61
2014	66.22	19.7	65.97	11.02	66.32	22.45
Total	66.94	20.29	62.30	17.67	66.37	23.33
Proportion of children with BCG						
2006	83.12	6.14	91.13	3.21	79.81	3.33
2008	83.43	5.57	89.82	2.50	80.79	4.16
2011	84.39	5.83	90.62	3.69	81.81	4.45
2014	82.42	6.28	91.09	2.50	80.25	4.31
Total	83.59	5.95	90.66	3.00	80.66	4.12

*The proportions were derived by using the ‘collapse’ command of STATA and obtaining the average proportion per village per year.

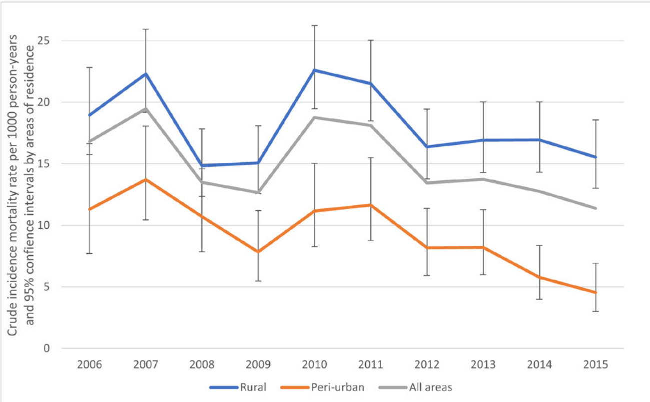

Figure 1 Yearly crude incidence mortality rates per 1000 person years by areas of residence and 95% CIs, Eastern Uganda (2005–2015).

and the second quintiles experienced stagnation over the 10 years (online supplemental appendix 3).

In periurban areas, the mortality incidence rate was reduced by 60% between 2005 and 2015 (11.3 per 1000 person years (7.7 to 16.6) in 2006; 4.5 (3.0 to 6.9) in 2015; RR=0.40 (0.23 to 0.71)) but similar evidence was not observed in rural areas (RR=0.82 (95% CI 0.63 to 1.06) (online supplemental appendix 3). Furthermore, in both in periurban and rural areas, the mortality incidence rate fluctuated over the period (figure 1). To assess trends over time, the slope of a linear regression of mortality incidence on year was calculated. The slope is the average annual change in mortality incidence per 1000 person years. There was evidence for a decreasing linear trend in periurban area (–0.77; 95% CI -0.32 to –1.22; p=0.004). In contrast, a similar linear trend was not observed in rural areas (–0.33; 95% CI –1.10 to 0.43; p=0.345). The yearly crude mortality rate and age-adjusted mortality rate in the study area show similar patterns (online supplemental appendices 4 and 5).

The MRR of the null model for periurban areas was 1.32 (table 2) suggesting that, on average, a child from a higher mortality cluster had 32% increased mortality incidence rate compared with a child with similar characteristics from a lower mortality cluster. The household wealth quintile was not associated with mortality (model 1 in table 3). However, because PCV indicated that 70% of cluster-level variance was attributable to the difference in the composition of individual wealth status in each village, the variable was kept for further model building. Mother's education was not associated with mortality, thus, was excluded from further models. BCG vaccination status remained significantly associated with a 56% mortality reduction, after adjustment by the age and the year (aRR=0.44; 95% CI 0.30 to 0.65). When the former model with individual level determinants was expanded by community-level determinants one by one, only community maternal education was associated with mortality (aRR=0.83; 95% CI 0.70 to 0.99; table 3; online supplemental appendix 6a). The MRR in model 4 was 1.06 (table 2) suggesting that unexplained between-cluster variation was negligible after accounting for the five factors. The PCV of model 4 suggested that 96% of between-cluster variance was now explained (table 2).

The MRR in the null model for rural areas was 1.17, much smaller than that for periurban areas, suggesting a much smaller between-cluster variance in rural areas. While the wealth index and BCG vaccination were both significantly associated with mortality in rural areas even after adjustment by age and year (models 1 and 3 in table 4), mother's education was not (model 2 in table 4), similarly to the periurban samples. Among the community-level determinants, the proportion of mosquito net ownership, the proportion of households with improved sanitation and with improved water source and the proportion of overcrowded households were not associated with mortality (online supplemental appendix 6b). The final model for rural residents included community maternal education (aRR=0.90; 95% CI 0.81 to 0.99) and the proportion of household in the poorest quintile (aRR=1.08; 95% CI 1.00 to 1.18) in addition to household wealth quintile and BCG vaccination status at individual level (model 5 in table 4). The MRR for the final model (model 5) was 1.08, which is close to unity; thus, there is now negligible cluster heterogeneity after including the six factors into the model. The PCV suggests that 76% of between-cluster variance was now explained by them.

Table 2 Cluster variance and contextual effects, Eastern Uganda (2005–2015)

	Null model	Model 1	Model 2	Model 3	Model 4	Model 5
Periurban						
PCV*	(reference)	70%	1%	5%	**96%**	79%
MRR†	1.32	1.16	1.31	1.31	**1.06**	1.13
Rural						
PCV	(reference)	47%	27%	23%	65%	**76%**
MRR	1.17	1.12	1.14	1.15	1.10	**1.08**

The final model is in bold.
*PCV=proportional change in variance; it is the share of the total variance from the empty model (reference) that is attributable to the variables included in each model.
†MRR=median rate ratio; it can be interpreted as the median value of the rate ratio between the village at highest risk and the village at lowest risk when randomly picking out two villages.

Table 3 Results of multilevel poisson regression model for postneonatal under-5 (1–59 months) mortality, periurban Iganga, Eastern Uganda (2005–2015)

	Model 1	Model 2	Model 3	Model 4	Model 5
Individual-level determinants					
Household wealth quintile					
Poorest	1.00			1.00	1.00
Very poor	1.34 (0.59 to 3.03)			1.38 (0.61 to 3.13)	1.43 (0.63 to 3.24)
Poor	0.71 (0.34 to 1.48)			0.79 (0.61 to 1.65)	0.82 (0.39 to 1.72)
Less poor	1.01 (0.49 to 2.66)			1.12 (0.55 to 2.31)	1.16 (0.56 to 2.41)
Least poor	0.54 (0.26 to 1.14)			0.64 (0.31 to 1.35)	0.65 (0.31 to 1.38)
Mother's education					
At least primary education		0.88 (0.50 to 1.54)			
Less than primary education		1.00			
BCG vaccination					
Received			0.44 (0.30 to 0.65)	0.45 (0.30 to 0.67)	0.45 (0.31 to 0.67)
Not received			1.00	1.00	1.00
Age					
Postneonatal (<1 year)	1.00	1.00	1.00	1.00	1.00
1–2 years old	0.49 (0.38 to 0.63)	0.49 (0.38 to 0.62)	0.49 (0.38 to 0.62)	0.49 (0.38 to 0.63)	0.49 (0.38 to 0.62)
2–3 years old	0.24 (0.17 to 0.33)	0.24 (0.17 to 0.33)	0.24 (0.17 to 0.33)	0.24 (0.17 to 0.33)	0.24 (0.17 to 0.33)
3–4 years old	0.17 (0.12 to 0.24)	0.17 (0.12 to 0.24)	0.17 (0.12 to 0.24)	0.17 (0.12 to 0.24)	0.17 (0.12 to 0.24)
4–5 years old	0.04 (0.03 to 0.07)	0.05 (0.03 to 0.07)	0.04 (0.03 to 0.07)	0.04 (0.03 to 0.07)	0.04 (0.03 to 0.07)
Year					
2005–2006	1.00	1.00	1.00	1.00	1.00
2006–2007	1.68 (1.05 to 2.69)	1.67 (1.04 to 2.68)	1.67 (1.04 to 2.68)	1.67 (1.04 to 2.68)	1.68 (1.05 to 2.70)
2007–2008	1.42 (0.86 to 2.32)	1.37 (0.83 to 2.24)	1.37 (0.84 to 2.25)	1.52 (0.92 to 2.51)	1.51 (0.92 to 2.49)
2008–2009	1.00 (0.59 to 1.70)	0.96 (0.57 to 1.63)	0.97 (0.57 to 1.64)	1.09 (0.64 to 1.85)	1.07 (0.63 to 1.83)
2009–2010	1.45 (0.89 to 2.36)	1.38 (0.85 to 2.25)	1.38 (0.84 to 2.24)	1.65 (1.00 to 2.73)	1.54 (0.94 to 2.53)
2010–2011	1.49 (0.92 to 2.41)	1.43 (0.89 to 2.32)	1.43 (0.89 to 2.32)	1.73 (1.05 to 2.85)	1.64 (1.00 to 2.68)
2011–2012	1.04 (0.63 to 1.72)	1.00 (0.60 to 1.66)	1.01 (0.61 to 1.68)	1.26 (0.74 to 2.14)	1.16 (0.69 to 1.94)
2012–2013	1.05 (0.64 to 1.73)	1.01 (0.61 to 1.67)	1.02 (0.62 to 1.69)	1.28 (0.75 to 2.17)	1.18 (0.70 to 1.97)
2013–2014	0.75 (0.44 to 1.28)	0.74 (0.43 to 1.27)	0.75 (0.44 to 1.28)	0.94 (0.53 to 1.67)	0.86 (0.50 to 1.49)
2014–2015	0.65 (0.37 to 1.16)	0.65 (0.37 to 1.16)	0.66 (0.37 to 1.17)	0.84 (0.46 to 1.53)	0.75 (0.42 to 1.35)
Community-level determinants					
Maternal education (% primary education)				0.83 (0.70 to 0.99)	
% of poorest quintile per village					1.57 (0.94 to 2.65)

Table 4 Results of multilevel Poisson regression model for postneonatal under-5 (1–59 months) mortality, Rural Iganga, Eastern Uganda (2005–2015)

	Model 1	Model 2	Model 3	Model 4	Model 5
Individual-level determinants					
Household wealth quintile					
Poorest	1.00			1.00	1.00
Very poor	1.03 (0.90 to 1.18)			1.04 (0.91 to 1.20)	1.06 (0.92 to 1.22)
Poor	0.96 (0.84 to 1.10)			0.99 (0.86 to 1.14)	1.01 (0.88 to 1.16)
Less poor	0.81 (0.66 to 0.98)			0.86 (0.70 to 1.04)	0.88 (0.72 to 1.08)
Least poor	0.42 (0.23 to 0.77)			0.47 (0.26 to 0.87)	0.50 (0.27 to 0.92)
Mother's education					
At least primary education		0.88 (0.53 to 1.47)			
Less than primary education		1.00			
BCG vaccination					
Received			0.55 (0.40 to 0.75)	0.55 (0.41 to 0.76)	0.56 (0.41 to 0.76)
Not received			1.00	1.00	1.00
Age					
<1 year	1.00	1.00	1.00	1.00	1.00
1–2 years old	0.68 (0.60 to 0.77)	0.68 (0.60 to 0.77)	0.68 (0.60 to 0.77)	0.68 (0.60 to 0.77)	0.68 (0.60 to 0.77)
2–3 years old	0.31 (0.26 to 0.36)	0.31 (0.26 to 0.36)	0.31 (0.26 to 0.36)	0.31 (0.26 to 0.36)	0.31 (0.26 to 0.36)
3–4 years old	0.15 (0.12 to 0.18)	0.15 (0.12 to 0.18)	0.15 (0.12 to 0.18)	0.15 (0.12 to 0.18)	0.15 (0.12 to 0.18)
4–5 years old	0.04 (0.03 to 0.05)	0.04 (0.03 to 0.05)	0.04 (0.03 to 0.05)	0.04 (0.03 to 0.05)	0.04 (0.03 to 0.05)
Year					
2005–2006	1.00	1.00	1.00	1.00	1.00
2006–2007	1.39 (1.10 to 1.77)	1.39 (1.10 to 1.77)	1.40 (1.10 to 1.77)	1.43 (1.12 to 1.82)	1.43 (1.12 to 1.81)
2007–2008	0.94 (0.72 to 1.22)	0.93 (0.72 to 1.21)	0.94 (0.72 to 1.22)	0.98 (0.75 to 1.28)	1.00 (0.77 to 1.31)
2008–2009	0.97 (0.75 to 1.26)	0.96 (0.74 to 1.25)	0.97 (0.75 to 1.26)	1.04 (0.80 to 1.35)	1.06 (0.81 to 1.38)
2009–2010	1.44 (1.13 to 1.83)	1.43 (1.13 to 1.82)	1.44 (1.13 to 1.83)	1.58 (1.23 to 2.02)	1.60 (1.25 to 2.05)
2010–2011	1.37 (1.07 to 1.74)	1.37 (1.07 to 1.74)	1.38 (1.08 to 1.76)	1.50 (1.17 to 1.92)	1.52 (1.18 to 1.95)
2011–2012	1.03 (0.80 to 1.33)	1.04 (0.80 to 1.35)	1.06 (0.82 to 1.38)	1.17 (0.90 to 1.53)	1.18 (0.91 to 1.54)
2012–2013	1.07 (0.84 to 1.38)	1.08 (0.84 to 1.40)	1.10 (0.85 to 1.32)	1.22 (0.94 to 1.60)	1.24 (0.95 to 1.61)
2013–2014	1.13 (0.88 to 1.45)	1.15 (0.89 to 1.48)	1.16 (0.90 to 1.49)	1.28 (0.98 to 1.67)	1.28 (0.98 to 1.67)
2014–2015	1.11 (0.86 to 1.44)	1.13 (0.87 to 1.47)	1.14 (0.87 to 1.48)	1.28 (0.97 to 1.68)	1.28 (0.97 to 1.68)
Community-level determinants					
Maternal education (% primary education)				0.88 (0.80 to 0.97)	0.90 (0.81 to 0.99)
% of poorest quintile per village					1.08 (1.00 to 1.18)

DISCUSSION

Population-based cohort data from a demographic surveillance site in Eastern Uganda suggest that the post-neonatal under-5 mortality incidence rate decreased by 60% in periurban areas between 2005 and 2015. The rural cohort did not witness a similar decrease in mortality as the periurban cohort did. BCG vaccination was associated with a reduced mortality incidence with a larger effect in periurban than rural areas. Household socioeconomic status had an effect on mortality in rural areas only. The proportion of households in the poorest quintile in community was significantly associated with mortality for rural residents only. In both periurban and rural areas, the community maternal education was associated with decreased mortality. The variability between villages was larger in periurban areas than rural areas and much was explained by the level of maternal education in the community.

Population-based vital statistics is hardly available in resource-poor countries due to weak civil registration systems, making it difficult to validate our data. Large national surveys such as the DHS can be used to help understand a mortality trend. A steady decline of post-neonatal under-5 mortality in both rural and urban areas of Uganda was observed from data reported in the recent three DHSs, from 89 deaths per 1000 postneonatal children (1996–2006), to 48 deaths (2001–2011) and further down to 34 deaths (2006–2016) in urban areas and from 124 deaths (1996–2006), to 83 (2001–2011) and finally down to 51 (2006–2016) in rural areas. With regards to the Eastern central region or Busoga region of Uganda where our study site is located, the postneonatal under-5 mortality rate decreased from 85 deaths per 1000 postneonatal children (2001–2011) to 58 (2006–2016) (online supplemental appendix 7). In line with the overall regional mortality trend, our data showed an overall decline in postnatal under-5 mortality. Our analysis disaggregating rural and periurban areas showed a slow overall decline in the HDSS which may be attributable to the lack of decline in rural parts of the HDSS. Our data also suggested that the poorer two quintiles experienced a stagnation. While two-thirds of the population live in rural areas in our study site, the proportion of the rural sample included in the DHS sample in Eastern central or Busoga region is not reported in the DHS. While we observed a fluctuation in mortality over the study period, such a trend was not reported in DHS. Available social autopsy data suggest that the rise in mortality in 2010–2011 may be attributable to an increase in deaths due to anaemia but the lack of clinical data does not allow us to draw a conclusive statement.

BCG vaccination status is likely correlated to utilisation and accessibility of other preventive and curative health service, as BCG vaccination is usually given in health facilities. This partly explains a reduced risk of mortality among BCG vaccinated children. In addition, increasing evidence suggests BCG vaccine has non-specific effects on child survival, protecting vaccinated children from infections beyond tuberculosis (TB).[26] Our study did not attempt to clarify to what extent vaccinated children had a reduced mortality from TB or other causes. But based on existing evidence and a very small proportion of under-5 deaths from TB in Uganda, it is likely that those who received BCG vaccine were protected against non-TB infectious diseases. Further, it has been suggested that BCG-vaccinated children with scar had a more than 50% reduced risk of mortality compared with vaccinated children with no scar and the reduced mortality among those with a scar could not be explained by deaths due to TB alone.[27]

A significant disparity between the wealthiest and the poorest was reported in the recent Ugandan DHS, which did not differentiate between rural and urban areas. Our results suggest that household wealth has a much larger effect in rural areas than in periurban areas. Prior studies conducted in sub-Saharan Africa can shed light on our findings. A study using Kenyan DHS data found an association between household wealth and under-5 mortality in rural areas but not in urban areas,[28] suggesting that a household wealth has a greater effect on health outcomes in rural areas than in urban areas. On the contrary, a study investigating the association between household wealth and the risk of child mortality using data from the Nouna HDSS in rural Burkina Faso reported that household wealth was a predictor of child mortality in semiurban areas but not in rural areas, contrasting results to our findings.[29] Schoeps *et al* attributed the lack of association between household wealth and child mortality in rural areas to the homogeneity of rural household materials and assets, which might have 'prevented adequate distribution of households into wealth quintiles'.[29] Schoeps *et al*' follow-up study in 2015 found decreasing disparities in infant mortality between the most disadvantaged and least disadvantaged groups in the Nouna HDSS.[30] They attributed it to improved geographical and financial access to health services and increased coverage of key interventions such as vaccinations, insecticide-treated bed nets and artemisinin-based combination therapies. The much smaller effect of household wealth we found in periurban areas could be an indication of a decreasing disparity in geographical and financial access to health services in periurban areas. Yet, we cannot rule out that the distribution of households into wealth quintiles using household assets and facilities may not capture socioeconomic differentials of periurban residents. In particular, many periurban households may have been classified to be wealthier than they ought to be because of the availability of publicly provided assets such as piped water which were included in the construction of our wealth quintiles. There are alternative methods to construct wealth indices, apart from PCA.[31] However, the choice of indicators to measure socioeconomic status appear to have an influence on the extent of socioeconomic disparities in health outcomes[32] rather than the methods used. Further research may be warranted using alternative indicators of socioeconomic positions to clarify the relationship between socioeconomic position and under-5 mortality in periurban areas.

In congruence with existing literature, community characteristics were found important predictors of child mortality in our rural district site. An increase by one SD in the proportion of mothers completing primary education in community was associated with a 17% and 12% decrease in mortality in periurban and rural areas. In rural areas, an increase by one SD in the proportion of the poorest household was associated with a 8% increase in mortality. However, community characteristics that seemed more directly associated with risk of morbidity such as the proportion of households with improved sanitation or improved water was not associated with child survival suggesting that human and economic development, both of which provide more opportunities for life and more skills needed to live a decent standard of living, may be a more important contributor to child mortality reduction.

In fact, multiple studies suggest that development across a range of sectors played a role in the reduction of under-5 mortality during the MDG era in low-income and middle-income countries.[33 34] The under-5 mortality decline in China was attributed to social progress including maternal education.[35] Ethiopia's success story can be attributed to its government's multisectoral policies aimed at achieving progress in all the MDGs. Its health sector development plans aligned with the development policies, aiming at the expansion of health services to rural communities.[36] A case study of Tanzania also suggested that an economic growth and other related 'secular trend' likely influenced child survival positively, including maternal education.[37] Malawi's case study also acknowledge the role of social progress in under-5 mortality.[38] In the case of Bangladesh, gender equality appears to have played an important role to its success.[39]

Results of the studies have important policy implications. A multisectoral development together with strategic efforts to increase the coverage of proven, cost-effective interventions may help increase mortality reduction. Among policy options are those related to economic, social and human development, and human rights.[40] Inequities between the poorest and the less poor particularly in rural areas need to be addressed. Individual and household poverty operate through a number of pathways to impact child health in developing countries, from nutrition, access to preventive and curative care, environmental factors (eg, food, water, air, insect vectors) and maternal factors.[41 42] Contextual or community factors also operate through individual socioeconomic status to have an impact. Strategies and policies to increase intervention coverage among the poor and the marginalised in rural areas include task shifting and removal of financial barriers.[43]

The strength of the study is the use of population-based data including both periurban and rural areas for 10 years corresponding to the final 10 years of the MDG era. Cross-sectional data such as DHS and Multiple Indicator Cluster Surveys (MICS) used to estimate mortality rate in low-resource setting can provide a snapshot of an event occurring over a certain period, usually a 5-year period (though shorter periods may be possible[44]). The HDSSs established in rural areas of resource-limited countries can fill the information gap with more frequently updated data capturing an event occurring in a shorter period. With the longitudinal data, it was possible to observe a yearly trend and determinants over a long period. Results of our population-based study are likely generalisable to other village periurban or perirural areas in Uganda. The study also had limitations. In order to be registered in the HDSS, one must reside in the area for 4 months. Recent migrants and transient population may have been excluded, who might have lowered our mortality estimates, particularly in periurban residents. Previous studies suggest that migrants, particularly rural to urban migrants, have poorer health outcomes than non-migrants.[45] It is possible that the areas classed as periurban at the beginning of the study in 2005 expanded over the study period and the boundaries between periurban and rural areas may have shifted. This may have led to misclassification of exposure status and overestimates of risk associated with BCG in the periurban cohort in our studies. Other limitation includes the use of the socioeconomic index which was a measure of relative wealth rather than an absolute measure, based on household facility and asset ownership. Where residents are homogenous, the index may not have captured differentials accurately, leading to the mortality ratio between the poorest and the least poor to unity. Analysis of data on health service utilisation and causes of death would have clarified what contributed to mortality reduction but due to the lack of reliable data during the study period, it could not be incorporated.

CONCLUSION

While periurban areas in the IMHDSS experienced a reduction of postneonatal under-5 mortality rate in the final 10 years of the MDG era, the rural areas appear to have lagged behind with a large disparity between the poorest and the least poor remaining. BCG vaccination and the proportion of educated mothers in community had a significant effect on reducing mortality. In addition to the effort to achieve universal coverage of key health interventions, a multisectoral approach may be needed to further reduce postneonatal child mortality. An improved socioeconomic metrics suitable for periurban dwellers is warranted.

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Data availability statement Data are available in a public, open access repository. Data are available upon request. Original cohort data from the Iganga/Mayuge Health and Demographic Surveillance Site have been shared with the INDEPTH Repository throughits iShare initiative where core HDSS dataare accessible online (http://www.indepth-ishare.org/index.php/catalog/79). Data may be formally requested from the IMHDSS leader(info@muchap.mak.ac.ug).

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