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Original Article

A Multilevel Decomposition of Time Variation in the Risks of Infant Mortality in Rural Uganda: UDHS 1995–2016

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ABSTRACT

The study assessed the contribution of maternal, child, paternal, household, proximate, and community-level factors to infant mortality risk time variation in rural Uganda between 1995 and 2016. Five rounds of Uganda Demographic and Health Survey data sets were used, and a multilevel mixed-effect logistic regression model was applied to decompose the contribution of different factors to time variation in the risks of infant mortality. All live births that were made five years before the surveys of 1995, 2001, 2006, 2011, and 2016 were considered, with infants who did not survive beyond one year treated as the outcome variable analysis, excluding those who were born less than 12 months before the survey. The fixed part of the model helped us detect the significant variables in determining infant mortality, and yet the random part of the model helped us quantify the amount of time variation in the risks of infant mortality explained by the selected variables. The child-level determinants of infant mortality were sex, birth order, and weight. Among the maternal factors, the study revealed that marital status, access to ANC, use of contraceptives, maternal education level, and preceding birth interval were consistent deterrents of infant mortality, while household size, sanitation, and wealth index remained critical. While controlling for other factors in the rural areas, time variation in the risks of infant mortality was dependent on community factors (such as region, community hygiene, and prenatal care utilization rate), proximate factors (such as access to prenatal care, contraceptives use, place of delivery, and the number of ANC visits), maternal factors (such as marital status, educational level, age, parity, preceding birth interval, desire for pregnancy, and breastfeeding), and endowment. It was observed that the changes in the risks of infant mortality over the period were explained by community (30.7%), proximate (22.7%), maternal (41.0%), and endowment (37.9%). Child-level factors explained 28.2%, and paternal-level education level explained only 30.1%. Remarkably, household-level factors captured 32.3% of the changes in infant mortality. A higher proportion of the explained variation in the risk of infant mortality across communities (PCV) was captured by child, paternal, maternal endowment, and household factors.

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Interventions to accelerate the reduction in infant mortality should target birth spacing to at least two years, girl child education to at least o level, joint household decision-making in having children, avoiding teenage pregnancies, postnatal care utilization, enforcing at least four ANC visits during pregnancy, improving household sanitation, and increasing access to safe water at household-levels.

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INTRODUCTION

Sustainable Development Goal 3 (SDG3) aims to end preventable deaths among newborns and children under 5 years of age by 2030 (GA, 2015). In Uganda, infant mortality rates have shown improvement, declining from 90.5 deaths per 1000 live births in 1995 to 43 deaths per 1000 live births in 2016 (ICF, 2017). These achievements are attributed to various interventions, including primary health care, health education, and expanded health services by the government, private sector, and non-governmental organizations. However, infant mortality in Uganda remains higher than in neighbouring countries.

The major causes of child deaths in Uganda are malaria, pneumonia, diarrhoea, malnutrition, and HIV/AIDS AIDS (Griffiths, Madise, Whitworth, & Matthews, 2004; Nagot et al., 2016). Unfortunately, these interventions have not reached all parts of the country, leading to limited mosquito net coverage (73%) (GA, 2015)., and insufficient access to oral rehydration therapy or Zinc for diarrhoea (A. S. Rwashana, Nakubulwa, Nakakeeto-Kijjambu, & Adam, 2014a). Expanding the availability of proven interventions, such as antibiotics for pneumonia (47.4%), oral rehydration therapy for diarrhoea (43.5%), and insecticide-treated nets (ITNs) to prevent malaria (73.0%), could save millions of children's lives each year (Unicef & UNICEF, 2013); (ICF, 2017).

Studies in East and West Africa have identified various factors associated with infant mortality. In East Africa, infant mortality is significantly associated with the place of delivery, the mother's education, and the husband's approval of contraceptive use (Ssewanyana & Younger, 2008). In West Africa, the place of delivery, the mother's education, and the status of the wanted birth plays a significant role (Singh & Singh, 2017). Maternal education, as well as the level of fathers' education, also influences infant mortality (Corman &

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Grossman, 1985). Maternal age is another important factor, with infants born to mothers less than 20 years old facing higher risks (O. K. Ezeh, K. E. Agho, M. J. Dibley, J. J. Hall, & A. N. Page, 2014b; Osita K Ezeh, Uche-Nwachi, Abada, & Agho, 2019).

Community-level factors, clustering, and spatial inequality in infrastructural development impact infant health outcomes (Antai, 2011). Variations in health outcomes, including infant mortality, are observed between communities with contrasting characteristics (S. A. Adedini, Odimegwu, Imasiku, Ononokpono, & Ibisomi, 2015; Davis et al., 2015; Whitworth & Stephenson, 2002). Addressing these disparities requires focusing on community-level interventions, especially in economically and socially deprived areas (Kayode et al., 2014a; A. S. Rwashana, Nakubulwa, Nakakeeto-Kijjambu, & Adam, 2014b; Stenström Johansson, 2016).

Mothers in rural areas face challenges in accessing quality and affordable healthcare, increasing the risk of infant mortality (Kayode et al., 2014a; A. S. Rwashana et al., 2014b; Stenström Johansson, 2016). Perception of infant body size and delivery by caesarean section also influence infant survival (Osita Kingsley Ezeh et al., 2014b).

A study on maternal and newborn intervention in Uganda revealed factors associated with high infant mortality, including parity of 5, newborn low birth weight, and presence of newborn danger signs, while home visits by community health workers and attending at least 4 antenatal visits were associated with lower risk (Kananura et al., 2016a). Proper modelling is required to separate area-level and individual/family-level factors contributing to health outcomes (Diez Roux, 2004; Kolenikov & Angeles, 2005). The importance of safe water and sanitation on child health and survival has been emphasized (Haddad et al., 2015; Kassebaum et al., 2016; C. J. Mutunga, 2011). Mothers in rural areas face reduced access to safe drinking water, impacting infant health (Acheampong & Avorgbedor, 2017). Challenges in the health system and social determinants also affect women's and children's health (O'hare & Southall, 2007; A. S. Rwashana, Nakubulwa, S., Nakakeeto-Kijjambu, M., & Adam, T., 2014). It is crucial to consider the correlation between individuals within the same group to draw accurate inferences (Zanini & Migueles, 2013).

Studies on child survival highlight the hierarchical nature of mortality data and the need for appropriate modelling (Griffiths et al., 2004). However, there is a lack of research on time variation in infant mortality risks in rural areas of Uganda. A multi-level decomposition of time variation in rural infant mortality risks is essential to understand the contribution of different factors to this variation.

METHODS

The study used 1995, 2001, 2006, 2011, and 2016 Uganda Demographic and Health Survey (UDHS) datasets accessed from the Measure DHS program/ICF International. Primary Sampling Units (PSU) are Enumeration Areas (EAs) and are used as clusters. Data were gathered from 7,070 women aged 15-49 in 1995, 7,717 in 2001, 8,531 in 2006, 8,674 in 2011, and 18,506 in 2016. Our study considered infant mortality as the outcome variable in binary form (i.e., if a child was born alive but died before 12 months (infant mortality), authors coded 1 if the child survived less than 12 months and 0 otherwise).

Independent Variables

The independent variables considered were community-level variables (such as region, residence, cluster wealth index, and prenatal care utilization rate), maternal factors (age at birth, education, marital status, time taken to breastfeed, preceding birth interval, and desire for pregnancy), childhood factor (child's sex, birth order, birth size), household factors (household size, wealth index, household decision making, sex of household head, source of drinking water, type of toilet facility), proximate determinants (contraceptive use, ANC

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utilization, place of delivery, access to postnatal care), and paternal factors (education level).

Data Analysis

Multilevel variance decomposition was done based on significant predictors associated with infant deaths.

To assess if the risks of infant mortality varied over time in the rural, a two-way interaction of infant mortality with time and predictors was fitted. The authors tested if the effect of different predictors changed over time ($\beta_3 = 0$).

$$logit\left(p(y_{ij}=1)\right) = log\left(\frac{p(y_{ij}=1)}{1-p(y_{ij}=1)}\right) = \beta_0 + \beta_{1i}x_{ij} + \beta_{2i}t_{ij} + \beta_3 x_{ij} * t_{ij} \quad [1]$$

Quantification of the contribution of different factors to time variation in the risks of infant mortality.

In order to quantify the contribution of different predictors to the time variation in infant mortality between 1995 and 2016 in the presence of contextual variables, a multilevel logistic regression model was used. A multilevel mixed-effect regression model, which is often called a hierarchical multilevel linear model (HLM), was used. Studies have revealed that for hierarchical multilevel data sets, with a single dependent variable that is measured at the lowest level and explanatory variables at all existing levels, the study needed to consider the structure of the data (Hox, 1995; Tom, Bosker, & Bosker, 1999). Traditional linear regression techniques are not capable of handling data with a hierarchical multilevel structure since data with a hierarchical structure violates an important assumption of the linear regression model (Gelman, 2006). As a result, regression coefficients are not efficient, and their standard errors are understated. Therefore, other scholars have used HLM to analyse the role of individual, family, and community factors in determining infant mortality in other social contexts (S. A. Adedini, Odimegwu, C., Bamiwuye, O., Fadeyibi, O., & Wet, N. D., 2014; Boco & Paper, 2010; S. Desai & S. J. D. Alva, 1998; E. J. H. t. r. Frankenberg, 1995).

A two-level multilevel model was fitted due to its ability to generate both fixed and random effects, coupled with the hierarchical nature of DHS data in which households are nested within the communities. This study explored the contribution of community and individual-level variables towards infant mortality time variation in Uganda. This was done to isolate groups of variables that contributed more to the reduction of infant mortality in the study period. Therefore, the use of multilevel models allowed us to divide the variance in the outcome variable at the group (random effect) and individual (fixed effect) levels. A two-level multilevel model assigns households to level 1 and clusters to level 2. Consider a collection of q independent covariates **X** = $\left(X_1, X_2, X_3, \ldots\ldots X_q\right)$. Then the conditional probability of infant mortality can be denoted by $p_{ij} = p\left(y_{ij} = 1/x = x\right)$. The ratio of success probability to failure probability is known as the odds of success.

That is, $\frac{p_{ij}}{1-p_{ij}}$; $i = 1,2,3,4,\ldots.n$; $j = 1,2,3,4,\ldots h$

The two-level model is given by;

$$logit(p_{ij}) = log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \beta_{0j} + \sum_{l=0}^{q} \boldsymbol{\beta}_{ij} \boldsymbol{X}_{lij}; i = 1,2,3,\ldots n; j = 1,2,3,4,\ldots h \quad [2]$$

$\beta_{0j} = \beta_0 + u_{0j}; \beta_{1j} = \beta_1 + u_{1j}; \beta_{2j} = \beta_2 + u_{2j}, \ldots\ldots\ldots \beta_{qj} = \beta_q + u_{qj},$
Where

Hence, equation 2 becomes

$$logit(p_{ij}) = log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \beta_{0j} + \sum_{l=0}^{q} \boldsymbol{\beta}_{ij} \boldsymbol{X}_{lij} + \sum_{l=1}^{q} \boldsymbol{u}_{ij} \boldsymbol{X}_{lij} + \boldsymbol{u}_{0j} \quad [3]$$

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Represents the set independent variables, $\left(\beta_0, \beta_1, \beta_2, \ldots\ldots \beta_q\right)$ are regression coefficients, $u_{0j}, u_{1j}, u_{2j}, \ldots\ldots u_{kj}$ are the random effect of model parameters at level two. It was assumed that these level-two random effects are distributed normally with mean 0 and variance δ_u^2.

A multi-level logistic regression model was used to examine the contribution of child, maternal, and paternal level factors (Endowments) independently to assess how much of the time variation in the risks of infant mortality was attributed to individual-level factors. In addition, The study assessed the contribution of contextual factors like household, community, and proximate factors to the variation in infant mortality risks over the study period.

In order to understand how the periodic variation in the risks of infant mortality was built up, different models were fitted to examine the relationship between infant mortality and characteristics at various levels. The authors used fixed effects to model association and random effects to model variation in infant mortality risks over the study period. The study used measures of variation to represent the extent to which infants raised in the same period (five years) before the survey were exposed to similar situations, such as the availability or non-availability of health services, medical personnel, electricity, water, and hygiene coverage, among others. The measures of association used in this study are odds ratios (OR). The random effects, which were regarded as measures of variations in infant mortality across years, were expressed in this study as intra-class (PCV). The precision of the random effect was determined by the standard error (SE) of the covariates. Finally, the goodness of fit of the regression was diagnosed using Akaike Information Criteria (AIC).

The first model was the empty model (Model 1) fitted with only the dependent variable without the predictors, which aimed at decomposing the total variation in the odds ratio of infant mortality into individual and community level components and determining if the variation of infant mortality between household and community was large enough to support the use of a multi-level model. The second model (Model 2) contained the years of data collection as the only predictor to understand the effect of years (time) on infant mortality. The third model (Model 3) added community-level predictors to years of surveys; the fourth model (Model 4) incorporated child-level factors; the fifth model (Model 5) considered paternal-level characteristics; the sixth (Model 6) looked at proximate predictors of infant mortality, the seventh model (Model 7) concentrated more on household-level factors; the eighth model (Model 8) considered maternal-level predictors, the ninth model (Model 9) looked at endowment (child, maternal, and paternal level factors together), tenth model (Model 10) was the full model. Finally, model 11 (Model 11) was the final model, which incorporated only significant predictors selected through forward selection at a 5% level of significance.

RESULTS

Child-level Factors

The proportion of infants by sex over the study period was about the same, although female children had reduced odds of death before one year compared to their male counterparts. More reduction was seen in the risks of female infant mortality than in male mortality. Our study showed that most infants were born in birth order (2-4). Firstborn infants and those of birth order 5 and above had increased risks of dying before one as compared to infants born in birth order (2-4). With respect to the perceived birth size of the infant, authors found that the proportion of infants with an average or larger than average birth size has been decreasing during the period. Infants whose sizes were perceived as smaller than or larger than average size had increased odds of death as compared to average-sized children over the study period.

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Paternal Factors

The proportion of infants whose fathers had primary or no education decreased during the study period. On a good note, being born to a father with at least secondary education was protective against infant mortality in both rural and urban areas.

Maternal Factors

The study found that over the study period, the percentage of infants born to women with a secondary education gradually increased. It was seen that infants born to mothers with secondary or higher education were less likely to die in the first year. In the same way, there was a drop in the proportion of infants who received postnatal care, and it only exhibited a steady increase in recent years. Infants who accessed prenatal care were less likely to die in the first year as compared to those who did not receive prenatal care over the study period. The proportion of infants whose mothers used modern methods or did not use any of the methods was high throughout the study period as compared to those whose mothers used traditional methods. Overall, being born to mothers who use modern contraceptives was protective of infant mortality throughout the study period. Our study found more infants born to married mothers during the study period. Infants born to currently married or previously married mothers had increased odds of death in the first year as compared to those born to never-married mothers in both urban and rural areas. The study did not observe a significant association between maternal age and infant mortality in the study period based on these data. Our study registered a high prevalence of unplanned pregnancies across the study period. Infants born to mothers who wanted to get pregnant later or never were less likely to die in one year over the study period as compared to infants born to mothers who wanted to get pregnant then.

Proximate Factors

The proportion of infants born to mothers who made at least four ANC visits preceding the delivery has been increasing over the study period. Having at least four ANC visits during pregnancy was protective against infant mortality. The proportion of infants delivered in hospitals has been increasing across the study period. Giving birth in the hospital had a protective effect on infant mortality over the study period; as such, being born at home increases the risk of dying in the first year. In line with breastfeeding, the proportion of infants breastfed within one hour has been increasing throughout the study period. The study revealed that putting infants late to breast increases the risks of infant mortality,

Household Factors

The proportion of infants born into households with joint decision-making has been increasing over the study period. Infants born in households where mothers are the sole decision-makers had high odds of death throughout the study period. Our study further revealed that the proportion of infants from poor households has been increasing over the study period. The authors did not observe any significant association between infant mortality and household wealth status. Infants born in households headed by females had increased odds of dying in the first year as compared to those from male-headed households. Our study further revealed that the proportion of infants born into households with access to safe drinking water has been increasing, with infants born into households with access to safe water being less likely to die in the first year as compared to those born into households with no access to safe drinking water. The proportion of infants from households with access to improved hygiene has increased over the study period. Infants born in households with unimproved hygiene were more likely to die in the first year.

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Contextual Factors

The study further noted that the pattern of infant mortality risks was not uniform across regions over the study period. It was discovered that infants from communities with a high or medium rate of access to improved hygiene had reduced odds of infant mortality. In a similar way, the proportion of infants from communities with high postnatal care utilization ratings has been increasing over the study period. Infants born in communities with high use of postnatal care were less likely to die in the first year as compared to those born in communities with low use of postnatal care.

The overall assessment indicated that infants born in Central and Northern Uganda were at higher risk of dying before one year as compared to infants born in Eastern and Western Uganda (*Figure 1*). The MH test results revealed that, across all the sub-regions of Uganda, the odds of infant mortality were significantly different over time, with a significant downward trend in the progression of infant mortality over the study period *Table 1*.

Figure 1: Progression of infant mortality odds ratio by region

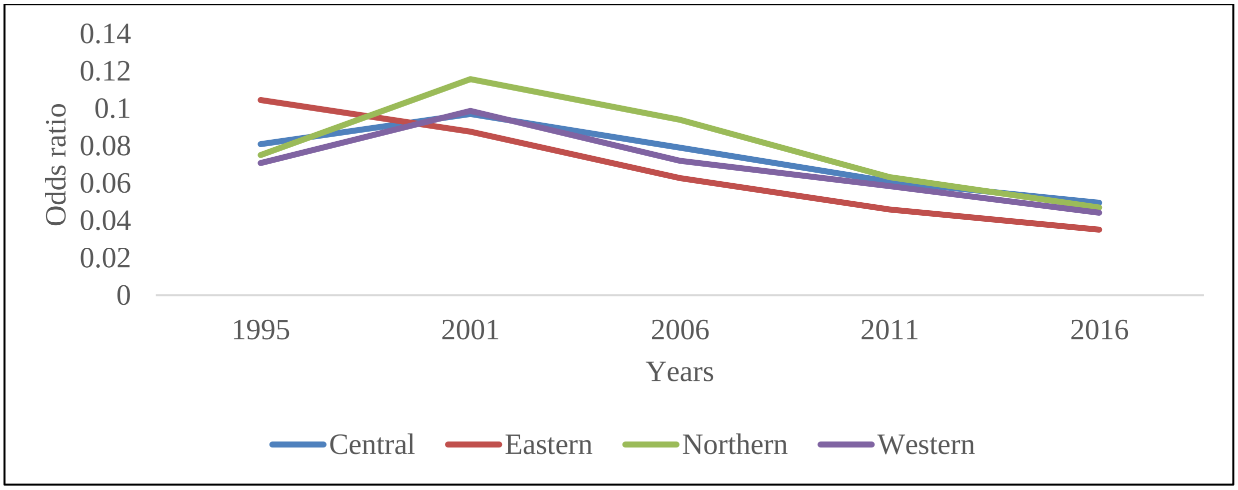

Table 1: Test for homogeneity and trend in infant mortality odds ratio, Uganda 1995-2016.

Region	1995 (OR)	2001 (OR)	2006 (OR)	2011 (OR)	2016 (OR)	HM test for heterogeneity	Score test for trend
Central	0.08089	0.09707	0.07902	0.06088	0.04955	χ^2=26.72: p=0.000	χ^2=20.22: p= 0.000
Eastern	0.10452	0.08762	0.06270	0.04600	0.03514	χ^2=95.82: p=0.000	χ^2=94.96: p= 0.000
Northern	0.07512	0.11571	0.09395	0.06320	0.047	χ^2=66.40: p=0.000	χ^2=43.23: p= 0.000
Western	0.07073	0.09870	0.07198	0.05853	0.04422	χ^2=47.53: p=0.000	χ^2=31.37: p= 0.000

The results presented in *Table 1* indicated a significant change in the odds of infant mortality over the study period and further revealed the existence of a trend across all the regions, calling for an investigation into the factors that could have led to the time variation in the risks of infant mortality. The variance in the risks of infant mortality could be explained by the differences in access to social services and the environments where infants are born and raised, among others.

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Table 2: Individual, household, contextual and proximate factors associated with infant mortality (OR) time variation

Characteristics	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11
Fixed effects	**Empty (OR)**	**Years (OR)**	**Community level (OR)**	**Child-level (OR)**	**Father level (OR)**	**Proximate variables (OR)**	**Household OR**	**Maternal level (OR)**	**Endowment level OR**	**Full model (OR)**	**Final model (OR)**
Year											
1995		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2001		1.163	0.888	1.163	1.143	0.648**	1.186	0.933	0.934	0.852	0.737
2006		0.972	0.693**	0.958	0.956	0.588**	1.006	1.752**	1.568**	0.973	0.781
2011		0.675**	0.493**	0.658**	0.668**	0.499**	0.707*	1.203	1.073	0.83	0.677
2016		0.485**	0.376**	0.474**	0.491**	0.432**	0.467**	0.856	0.776*	0.704	0.646*
Paternal level Paternal education level											
Primary below					1.000				1.000	1.000	1.000
Secondary or higher					0.859**				0.904	0.863	0.867
Maternal-level Marital status											
Never married								1.000	1.000	1.000	1.000
Currently married								1.201	1.291	1.771	1.661
Previously married								1.505*	1.633*	2.372**	2.227*
Education level											
Primary and below								1.000	1.000	1.000	1.000
Secondary or higher								0.879	0.883**	0.845	0.868
Age at birth								0.985*	1.002	1.016	1.011
Parity											
<3 children								1.000	1.000	1.000	1.000
3-4 children								0.953	1.567**	0.914	0.757*
5+								1.415**	3.710**	1.041	1.366*
Birth interval											
Less than 2 years								1.000	1.000	1.000	1.000
2 years or longer								0.721**	0.578**	0.646**	0.691**
Desired pregnancy											
Wanted then;								1.000	1.000	1.000	1.000
Wanted later;								0.733**	0.744**	0.906	0.901
Wanted no more								0.798*	0.811*	0.977	0.989
Breastfeeding											
Immediately								1.000	1.000	1.000	1.000
Later								0.931	0.922	0.881	0.888
Child-level Child's sex,											

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Characteristics	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11
Fixed effects	**Empty (OR)**	**Years (OR)**	**Community level (OR)**	**Child-level (OR)**	**Father level (OR)**	**Proximate variables (OR)**	**Household OR**	**Maternal level (OR)**	**Endowment level OR**	**Full model (OR)**	**Final model (OR)**
Male				1.000					1.000	1.000	1.000
Female				0.810**					0.776**	0.825**	0.822**
Birth order											
Firstborn				1.000					1.000	1.000	
2_4				0.687**					0.365**	0.652**	
Above 4				0.789**					0.196**		
Birth size											
Average				1.000					1.000	1.000	1.000
Smallest/smaller than average				1.326**					1.235**	1.122*	1.118
Larger/larger than average				1.167**					1.199**	1.338**	1.352
Community level											
Region											
Central			1.000								1.000
Eastern			0.840*								0.771*
Northern			1.079								1.041
Western			0.937								0.879
Community hygiene											
Low			1.000								1.000
Medium			0.986								1.109
High			0.916								1.005
Prenatal care											
Low			1.000								1.000
Medium			0.474*								0.731
High			0.358**								0.640
Access to prenatal care											
No PNC						1.000				1.000	1.000
Received PNC						0.636**				0.582**	0.598**
Contraceptive method used											
Never used						1.000				1.000	1.000
Traditional						0.737				0.792	0.796
Modern						0.702**				0.703**	0.702**

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Characteristics	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11
Fixed effects	**Empty (OR)**	**Years (OR)**	**Community level (OR)**	**Child-level (OR)**	**Father level (OR)**	**Proximate variables (OR)**	**Household OR**	**Maternal level (OR)**	**Endowment level OR**	**Full model (OR)**	**Final model (OR)**
Place of delivery											
Home						1.000				1.000	1.000
Hospital						1.063				1.189*	1.198*
ANC visits											
Less than 4						1.000				1.000	1.000
Four and above						0.861*				0.825*	0.814*
Household-level Decision making											
Mother							1.000			1.000	1.000
Both							1.059			1.304**	1.323**
Father							0.97			1.039	1.067
Wealth index											
Poorer/poorest							1.000			1.000	1.000
Middle							0.892			1.059	1.081
Richer/Richest							0.959			1.206	1.209
HH Size							0.902**			0.839**	0.841**
Sex of HH head											
Male							1.000			1.000	1.000
Female							0.978			0.899	0.900
Source of drinking water											
Unsafe water							1.000			1.000	1.000
Safe water							0.870*			0.932	0.945
Type of toilet facility											
Unimproved							1.000			1.000	1.000
Improved							0.876*			1.036	1.055
Random effects											
Community-level (SE)	0.04	0.05	0.05	0.05	0.05	0.08	0.06	0.07	0.07	0.13	0.13
Variance	0.366	0.255	0.253	0.262	0.255	0.283	0.247	0.216	0.227	0.213	0.208
ICC	0.030	0.015	0.015	0.016	0.015	0.020	0.014	0.011	0.012	0.014	0.013
VPC (%)	9.992	7.187	7.142	7.380	7.198	7.906	6.986	6.146	6.450	6.076	5.949
Explained variation (PCV) %		30.241	30.710	28.222	30.133	22.666	32.347	41.005	37.894	41.730	43.025

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Characteristics	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11
Fixed effects	**Empty (OR)**	**Years (OR)**	**Community level (OR)**	**Child-level (OR)**	**Father level (OR)**	**Proximate variables (OR)**	**Household OR**	**Maternal level (OR)**	**Endowment level OR**	**Full model (OR)**	**Final model (OR)**
Household-level (SE)	0.060	0.060	0.060	0.060	0.060	0.200	0.070	0.080	0.080	0.530	0.540
Variance	1.043	1.023	1.011	1.039	1.018	0.756	0.975	0.942	0.934	0.000	0.000
ICC	0.271	0.252	0.248	0.259	0.251	0.165	0.235	0.221	0.219	0.014	0.013
VPC (%)	24.066	23.700	23.500	23.988	23.618	18.682	22.842	22.245	22.099	0.000	0.004
Explained variation (PCV) %		1.994	3.074	0.425	2.435	27.510	6.591	9.731	10.493	99.999	99.988
Log-likelihood	-8301.4	-8214.6	-8199.5	-8176.3	-8146.4	-4261.3	-7394.4	-6404.3	-6286.3	-3071.8	-3071.0
Model fit Statistics AIC	16608.8	16443.2	16427.1	16376.7	16308.8	8546.6	14818.9	12842.5	12618.7	6213.6	6224.0

*Where * p-value<0.05 and ** p-value<0.01 p-value<0.001*

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The study presented a significant time variation in the risks of infant mortality $SD = SD =(SD = 0.366(SE=0.04))$ across clusters and $SD = 1.043(SE=0.06)$ across households). (Model 1; *Table 2*). This translated to a high intraclass correlation coefficient (ICC) or variance partition coefficient (VPC) of 9.992%. With only years of surveys included in the model (Model 2 in *Table 2*), it was observed that infants born five years prior to 2011 and 2016, respectively, were less likely to die within one year as compared to those born five years before 1995. Up to 30.24% of the variance associated with the risks of infant mortality across communities was explained by the period in which the infants were born and raised. With the inclusion of community-level factors (region, prenatal care utilization, and hygiene), as shown in Model 3, *Table 2*. This implied that a PCV of 30.71% could be explained by community-level factors.

Results presented in Model 4 in *Table 2* showed that the inclusion of child-level factors (such as Sex, birth size, and birth order) in the multi-level model did not significantly change the time variation in the risk of infant mortality. The PCV indicated that up to 28.222% of the variation in the risks associated with infant mortality across the time period could be accounted for by child-level factors. Similar findings were observed when paternal level factors were included, the effect of time in which infants were born, and the risk of infant mortality was independent of paternal level factors. The PCV for the risk of infant mortality was 30.133%. This meant that most of the time, variations in the risks of infant mortality were accounted for by the father's education level.

When proximate level factors were considered in a multi-level analysis (Model 6, Tables 2), a remarkable reduction in the risk of infant mortality over the study period was noticed. The PCV results revealed that much of the variation in the risk of infant mortality across the study period was explained by the proximate determinants (22.666%). Meanwhile, the incorporation of household-level factors into the multilevel models in Model 7 (*Table 2*) revealed that time variation in the risks of infant mortality was significant across the study period. Factors such as wealth index, source of drinking, household size, and hygiene were significantly associated with the risks of infant mortality. It was further observed that the PCV of 32.347% (Model 8, *Table 2*) in the risks of infant mortality across time was accounted for by household-level factors. Considering mother-level factors in the multilevel analysis in Model 8 (Tables 2), the following findings were presented: Results presented in *Table 2* Model 8 showed that marital status, age of the mother, parity, preceding birth interval, and desire for pregnancy were significantly associated with infant mortality, with the exception of time to breastfeed and education level. The PCV in the odds of infant mortality of 41.005% across communities could be explained by maternal-level factors.

The construction of Model 9 involved the aggregation of all the individual-level factors considered in this study (such as maternal, paternal, and child-level factors) and branded them as endowments. Our results suggested that the effect of time on infant mortality was dependent on individual-level factors. The study found that up to 37.894% of the variation in the risks of infant mortality across communities could be explained by individual-level factors.

Furthermore, results from Model 10 (full model) revealed that the effect of time on infant survival was dependent on all factors included in the multilevel analysis, as time variation in the risks of infant mortality became insignificant. The assessment of the extent to which each independent factor included in the full model is associated with the risk of infant mortality revealed that maternal-level factors (such as marital status and preceding birth interval), child-level factors (such as sex, birth order, and size of the baby at birth), proximate factors (such as contraceptive use, prenatal care utilization, place of delivery, and number of ANC attended), household-level factors (such as decision making, and household size), and were significantly associated with infant mortality.

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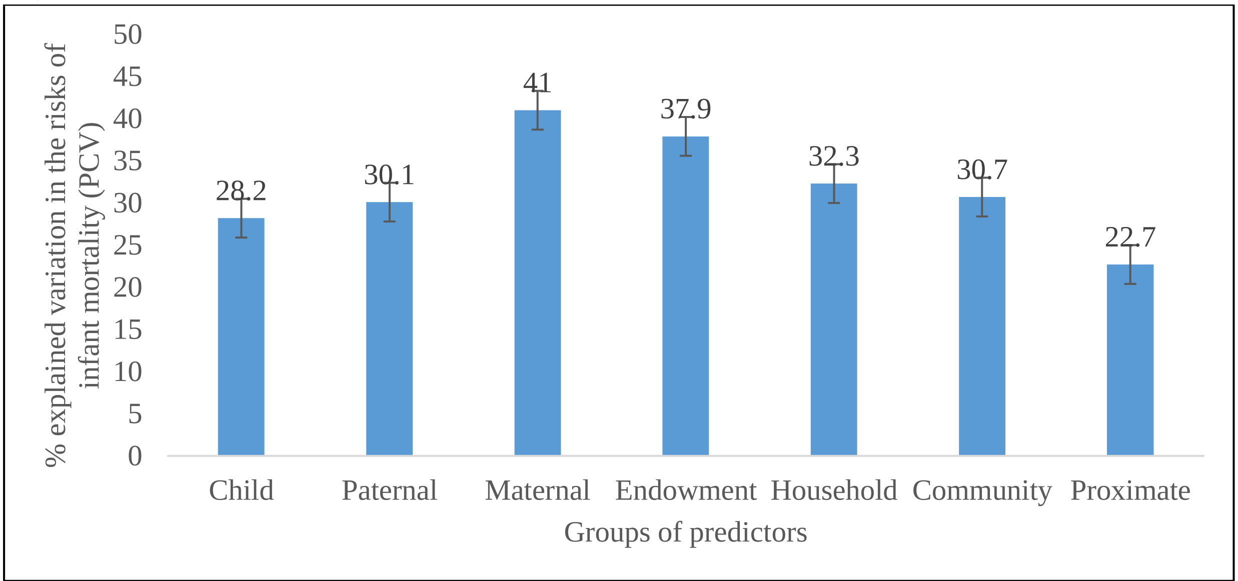
Comparing Model 9 (endowment) and Model 10 (Full model), measures of variation across communities were significant in both cases (*Table 2*). The ICC slightly decreased from 6.45% to 6.076%. In a similar way, the PCV associated with the odds of infant mortality across communities increased from 37.894% to 41.73%.

Results of the final model (Model 10 in *Table 2*), which included only variables that were significantly associated with infant mortality at group levels, indicated that the risk of infant mortality decreased (Model 2 and Model 11 in *Table 2*). Since by including the selected variables in the multilevel analysis (Model 11), the odds ratio in Model 2 (*Table 2*) changed significantly; it is suggested that the selected factors are important factors that influence time variation in the risks of dying during infancy. In rural areas, there were decreases in 2001 and 2006, and the rest of the periods had slight increments in the risk of infant mortality. The intra-class correlation associated with the risks of infant mortality across communities decreased from 6.076% (Model 9) to 5.949% (Model 11; *Table 2*). It was important to note that the proportional change in variance in the risks of infant mortality was 43.025% (Model 11, *Table 2*) and could be explained partly by factors included in the final model and due to unobserved characteristics not included in the model (Model 11).

Figure 2: Proportion of explained time variation in the risk of infant mortality (1995-2016)



Results of the multilevel logistic regression analysis based on rural data (*Table 2*) revealed that time variation in the risks of infant mortality was dependent on community, proximate, maternal, and endowment. It was, however, unaffected by child-level factors (like sex, birth order, and infant birth size), paternal-level factors (like educational level), and household-level factors (like decision-making, wealth index, size, sex of household head, source of drinking water, and hygiene). A higher proportion of the explained variation in the risk of infant mortality across communities (PCV) was captured by child, paternal, maternal endowment, and household factors (*Figure 2*).

DISCUSSIONS

In this study, authors investigated the contribution of different factors of infant mortality to the time variation in the risk of infant mortality so as to understand if they contributed equally, and key factors were singled out. A study by Golding et al. (2017) showed significant regional variation in the odds of infant mortality, which was in agreement with our findings. The study found that infants born in Central and Northern Uganda were at higher risk of dying before one year, as compared to infants born in Eastern and Western Uganda due to civil strives in these regions. The odds of infant mortality were significantly different over time, with a significant downward

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trend in the reduction of infant mortality over the study period. This was in agreement with Nalwadda (2014), who reported that the odds of under-five mortality have been trending downward.

Our study further revealed a significant variation in the risk of infant mortality over time, which could be due to varying socio-demographic and economic conditions over the study period. It was further realized that time was a key factor in explaining the variation in infant mortality. This finding was supported by those of Hill (2003); Nasejje & Mwambi (2017); Owor et al. (2016); Mutunga (2007); Forouzanfar et al. (2016); Kayode et al. (2014b). The authors found that communities where children were raised played a critical role in the time variation in infant mortality, as asserted by Mosley & Chen (1984). The significance of selected variables in reducing infant mortality varied across regions, with infants born and raised in Eastern Uganda less likely to die before one year as compared to those born in Central Uganda. Infants born and raised in Northern Uganda had an increased risk of dying before one year. This could be attributed to the prolonged war and economic disadvantage of the region, which made access to health facilities impossible. Community level factors explained more variation in the risks of infant mortality due to urbanization and widening income inequality in urban than rural areas. Child-level factors (such as sex, birth size, and birth order) did not significantly change time variation in the risk of infant mortality, probably due to the fact that the effects of the selected variables tend to be time invariant. The sex of the infants was found to be significantly associated with infant mortality, with girls having a lower chance of dying before one year as compared to boys. Similarly, the perceived birth size of the baby was found to be significantly associated with the risk of infant mortality.

Infants who were perceived to have smaller or larger sizes at birth were more likely to die within one year as compared to those born with average sizes respectively. Birth order was protective against infant mortality due to the fact that rural mothers had less access to contraceptives to help with better spacing, putting the lives of the children at risk. This finding was in agreement with that of Forouzanfar et al. (2016); Adedini et al. (2014); Desai & Alva (1998), and Frankenberg (1995). More variation in the risks associated with infant mortality across the time period in rural settings than in urban areas was explained by the selected child factors. These results were indeed similar to that of Ayiko, Antai, & Kulane (2009), Ezeh et al. (2014a); Hug et al. (2019); Nasejje et al. (2015); Wang et al. (2016) and reports by World Health Organization (2019) who found child factors highly relevant in explaining infant mortality.

The study revealed that paternal factors, just like child-level factors, had more influence on infant mortality variability, probably due to the fact that fathers who were educated in the villages were more likely to make quick decisions and have resources to take the child for medication.

It was discovered that proximate factors considered in this study, such as utilization of PNC, number of ANC visits, and utilization of contraceptives, were protective against infant mortality, with the exception of the place of delivery. The place of delivery (delivery at home or hospital) could not protect infants from dying unless they were attended to by skilled and motivated staff, as alluded to by Titaley et al. (2008). Selected variables explained more variation in the risk of infant mortality across the study period in urban areas compared to rural areas. This could be due to the fact that rural mothers tended to follow instructions given by health workers more than their urban counterparts. This result was in agreement with that of Jain et al. (2013) and Corman & Grossman (985), who emphasized the importance of proximate factors in explaining child mortality.

Our study also indicated that household factors such as household size, source of drinking water, decision-making, and hygiene were significantly associated with the risks of infant mortality in rural areas. This could be due to the fact that households in rural were less empowered to counter the effects of household factors than the rural households that made their children survive more. This was supported by the findings of Lee et al. (2017) and Garosi et al. (2016).

The study findings revealed that maternal factors such as marital status, age of the mother, parity, preceding birth interval, and desire for pregnancy were significantly associated with infant mortality in rural areas, with the exception of time to breastfeed and educational level. In light of this, maternal factors were more important in explaining time variation in the risks of infant mortality over time Scholars such as Kousar et al. (2019) and Kamal (2012) similarly showed the importance of maternal factors in protecting children from dying. A higher proportion of the explained variation in the risk of infant mortality across the communities was captured by child, paternal, maternal endowment, and household factors, and in urban settings, most of the variations were explained by community and proximate level variables. Child-level factors did not contribute to time variation in the risk of infant mortality across time. The narrative above was further supported by the studies conducted by Golding et al. (2017); Kananura et al. (2016b); Ahmed, Kamal, & Kamal (2016); Ezeh et al. (2014a); Titaley et al. (2008).

CONCLUSION

Understanding the progression of infant mortality by analyzing different rounds of data collected, such as the Demographic Health Survey, helps to discover how different factors have contributed to variations in the risks of infant mortality over a period of time. It was clear that changes in the risks of infant mortality over the period were explained by community (30.7%), proximate (22.7%), maternal (41.0%), and endowment (37.9%). Child-level factors explained 28.2%, and paternal-level education level explained only 30.1%. Remarkably, household-level factors captured 32.3% of the changes in infant mortality. A higher proportion of the explained variation in the risk of infant mortality across communities (PCV) was captured by child, paternal, maternal endowment, and household factors. Interventions to accelerate the reduction in infant mortality should target birth spacing to at least two years, girl child education to at least o level, joint household decision-making in having children, avoiding teenage pregnancies, postnatal care utilization, enforcing at least four ANC visits during pregnancy, improving household sanitation, and increasing access to safe water at household-levels

ABBREVIATIONS

UBOS: Uganda Bureau of Statistics; UDHS: Uganda Demographic and Health Survey; OR: Odds ratio; WHO: World Health Organization; UNICEF: United Nations Children Funds: IMR: Infant Mortality Rate; NMR: Neonatal Mortality Rate; PMTCT Prevention of Mother to Child Prevention SDG: Sustainable Development Goal: MDG: Millennium Development Goal; HIV/AIDS: Human Immune Virus/Acquired Immune Deficiency Syndrome; PSU: Primary Sampling Unit.

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Availability of Data and Materials

The DHS datasets are available for the public at the DHS program website: https://dhsprogram.com/data/available-datasets.cfm. Registration is required before accessing and downloading the data sets. The study used the UGKR7HFL and UGIR7HFL (Kid Record and Individual Recode –Women with completed interviews).

Authors' Contributions

BO: Participated in the conceptualization of the study, took the lead in conducting the literature review, participated in writing the methodology, data analysis, presentation of findings, discussion and compiled the overall manuscript. **EN**: She participated in data curation, investigation and writing of the manuscript. LA: He guided the investigation and formal analysis of data. RW: Reviewed the manuscript.

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Ethical Approval and Consent to Participate

This paper is based on secondary data that is available in the public domain. The data were accessed with permission from the DHS program. The Demographic and Health Surveys in Uganda were conducted in adherence to the World Health Organization's ethical and safety recommendations for research. Participation in the surveys was on a voluntary basis, and informed consent was obtained from the participants. In order to ensure confidentiality, participants' identifiers were not included in the datasets.

Competing Interests

The authors declare that they have no competing interests.

Consent for Publication

Not applicable

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