Child Health and Mortality in resource-poor settings: a life-course and systemic approach

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Declaration of authorship

I certify that the thesis I have presented for examination for the MPhil/PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

 I declare that my thesis consists of 55,875 words.

Statement of co-authorship

This thesis conforms to the requirements of a doctoral thesis from the London School of Economics and Political Science. Guidelines state a minimum of three papers of publishable standard out of which at least one should be sole-authored. Accordingly, this thesis presents an introductory chapter that gives an overview, the motivation, and objectives. The second chapter presents the methods applied in sub-studies. The third, fourth, fifth and sixth chapters are presented in the style of a journal article. Finally, chapter 7 brings together the key findings of the thesis, discusses their implications and limitations, and provides areas for further research.

I confirm that my second, third and fourth papers in chapters 4, 5 and 6 are sole-authored papers. I declare that the first paper presented in chapter 3 is jointly co-authored with my supervisors, Tiziana Leone and Arjan Gjonca, the Iganga-Mayuge Health and Demographic Surveillance Site team (Tryphena Nareeba and Dan Kajungu) and Peter Waiswa. For that chapter, I led and carried out most of the work. The details of the contributions are provided in the table below.

Table of authorship contributions

	Chapter 3
RMK	Conceptualisation, data curation, formal analysis, writing – original draft, Writing – review & editing
TL	Conceptualisation, manuscript review and editing
AG	Conceptualisation, manuscript review and editing
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Abstract

While there has been a staggering decline in global child mortality, sub-Saharan Africa (SSA) has consistently contributed the largest share. The 2020 global estimates on child mortality indicate SSA contributing 42%, 53% and 61% of neonatal, under-five, and 5-9 deaths, respectively. Moreover, the 1990-2020 child mortality data indicate an upward trend in SSA's contribution in all age groups. The persistent high child mortality within the region could be attributed, amongst others, to inequities in health services' access within countries. Additionally, there have been limited interventions that target children aged 5 years and beyond due to the limited research and data systems. As the focus of this paper-based thesis, Uganda as the study area shows the same issues within the SSA context. Therefore, it presents a novel opportunity to understand child health and mortality mechanisms among children aged 0-9 years. Guided by the concepts of interdependence, social interactions and health service delivery systems' drawn from social and health systems and life-course perspectives, the thesis' specific objectives are to: 1) determine the under-10 mortality age-specific estimates; 2) assess the epidemiological shift in the under-10 mortality risk factors and causes of death; 3) assess the role of Low Birth Weight (LBW) in mediating the new-born mortality risk factors and the role of institutional delivery in new-born mortality; 4) identify key community and household predictors of suspected pneumonia and diarrhoea, and 5) examine how multiple factors concurrently affect access to appropriate health care services.

Using a decade (2005-2015) of event history data collected by Iganga-Mayuge Health and Demographic Surveillance Site (HDSS) in Eastern Uganda in Chapter 3[1], I found that the under-10 and 5-9 years of age mortality probabilities were 99 per 1000 live births and 11 per 1000 children aged 5-9 years, respectively. The new-born mortality and perinatal mortality were estimated at 22 and 31 per 1000 live births, respectively, with death within the first day of life (0-1 day) contributing the largest share (62%). I found that the magnitude of the association of the risk factors with under-10 mortality varied by age, with a stronger association observed among infants. The order of the top causes of mortality altered with age, with gastrointestinal infections and injuries emerging among 5-9 years old, but malaria and malnutrition remaining among the leading four mortality causes. Using Iganga-Mayuge HDSS data in Chapter 4[2], I found that institutional delivery had an insignificant inverse effect on new-born mortality. The LBW mediated multiple factors, including adolescence age, rural residence, multiple births and unmarried marital status.

[1] Kananura, R., M., Leone, T., Tryphena, N., Kajungu, D., Waiswa, P., & Gjonca, A. (2020). Under 10 mortality patterns, risk factors, and mechanisms in low resource settings of Eastern Uganda: An analysis of event history demographic and verbal social autopsy data. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0234573

[2] Kananura, R. M. (2021). Mediation role of low birth weight on the factors associated with newborn mortality and the moderation role of institutional delivery in the association of low birth weight with newborn mortality in a resource- - poor setting. *BMJ Open*, 1–13. https://doi.org/10.1136/bmjopen-2020-046322

The novel machine learning technique applied on 2006-2016 Uganda DHS data in Chapter 5[3] helps us identify rural-urban differentials in the deterministic pattern of a child's diarrhoea and acute respiratory infection (ARI). The study findings confirm the notion that ARI and diarrhoea risk factors overlap. These factors relate to the household's structure and composition, which is characterised by poor hygiene and sanitation and poor household environments that make children more suspectable of developing these diseases; maternal socio-economic factors such as education, occupation, and fertility (birth order); individual risk factors such as child age, birth weight and nutritional status; and protective interventions (immunisation). Furthermore, the qualitative data analysis collected in Chapter 6[4] revealed how multiple factors concurrently affect access to obstetric and child health care services. Chapter 6 findings were used to develop a multisectoral and multidimensional implementation framework for obstetric and child health care services in resource-poor settings.

Overall, the application of life course and systemic approach in the analysis and interpretation of the results provides an insight into the need for holistic interventions (social, structural, and health systems) throughout the stages of child development. Each paper brings new insights into the mechanisms and determinants of under-10 mortality in resource-poor settings. Together, the papers help us build a stronger life-course and health systems framework for child health and survival, contributing to the recent call for redesigning child health programs.

[3] Kananura, R. M. Machine learning predictive modelling for identification of predictors of acute respiratory infection and diarrhoea in Uganda's rural and urban settings. Under production in PLOS Global Public Health (https://doi.org/10.1371/journal.pgph.0000430).

[4] Kananura, R. M. Towards a multidimensional and multisectoral approach: rethinking access to obstetric and under-5 child healthcare implementation framework. *To be submitted in a peer review journal (Social science and medicine or BMJ Global Health)*

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List of abbreviations

ANC	Antenatal care
ARI	Acute Respiratory Infections
AUC	Area under the ROC curve
CHW	Community Health Workers
DHS	Demographic Health Surveys
EBW	Extreme Birth Weight
FGD	Focus Group Discussions
GBM	Gradient Boosted Model
HC	Health Center
HDSS	Health and Demographic Surveillance Site
HIC	High Income Countries
INDEPTH	International Network for the Demographic Evaluation of Populations and their Health
KI	Key Informant
LBW	Low Birth Weight
LMIC	Low- and Middle-Income Countries
LSE	London School of Economics
MDG	Millennium Development Goals
NM	Neonatal Mortality
OR	Odds Ratio
PM	Perinatal Mortality
RA	Research Assistant
RF	Random Forest
ROC	Receiver Operating Characteristic
SDG	Sustainable Development Goals
SE	Standard Error
UDHS	Uganda Demographic Health Surveys
UN IGME	United Nations Inter-Agency Group for Child Mortality Estimation
UNICEF	United Nations Children's Emergency Fund
VHT	Village Health Teams
WHO	World Health Organisation

CHAPTER ONE
INTRODUCTION

1.1. Why study child health and survival

There has been a remarkable global reduction in child mortality (0-9 years old) (UNICEF, 2014; United Nations Inter-agency Group for Child Mortality Estimation (UN IGME), 2017, 2020; World Health Organization (WHO), 2010), partly due to the governments, funder, and international agencies' commitments, and global economic and health technological improvements (Tomlinson et al., 2021). Since 2000, when the global Millennium Development Goals (MDGs) were initiated, there has been an increase in global accountability for economic and health indicators, including child health (WHO, 2015a). The countries and global reporting, investment and research have been majorly aligned to global commitments' objectives, which contributed to having standard indicators that have been used to measure the countries' and regions' progress. Nontheless, comparing the regional estimates, inequalities in child mortality and health care access have persistently remained high (Figure 1.1). The under-five and neonatal mortality rates in sub-Saharan Africa (SSA) have recurrently remained above the global average and even higher than other regions within the African continent in the past 10-20 years (Fig 1.1). For instance, the under-five mortality rate in sub-Saharan Africa is two times higher than the global rates and almost 15 times higher than in high-income countries (Figure 1.1). Similarly, the neonatal mortality rate is 56% higher than the global estimate and about nine times higher than in high-income countries. The rates are even higher than in North Africa – a region within the same continent (Figure 1.1).

Figure 1.1: Comparing sub-Saharan Africa trends in under five and neonatal mortality with global and other regional trends.

a. Under-five mortality

	1990	1995	2000	2005	2010	2015	2019
Northern Africa	83.6	70.9	58.9	48.2	39.0	32.8	29.3
Sub-Saharan Africa	180.3	172.1	152.4	125.5	102.2	86.4	76.4
World	93.0	86.5	75.8	62.6	51.2	42.6	37.7

b. Neonatal mortality

	1990	1995	2000	2005	2010	2015	2019
Northern Africa	33.0	29.2	26.1	23.0	20.0	17.1	15.9
Sub-Saharan Africa	45.4	43.5	40.2	35.8	32.3	29.5	27.5
World	36.6	34.1	30.3	25.9	22.2	19.2	17.5

Source: *Analysis of UNICEF data on global child mortality*

Worryingly, the SSA's share of global under-five and neonatal mortality has been increasing: under-five mortality increased from 30% in 1990 to 55% in 2019, and neonatal mortality increased from 20% in 1990 to 43% in 2019 (Table 1.1).

Table 1.1: Trends in the percentage share of the number of global child mortality

	Under-five mortality						
	1990	1995	2000	2005	2010	2015	2019
Total number of global under-five mortality	12,493,789	11,199,745	9,749,206	8,234,218	6,950,022	5,861,991	5,188,872
Sub-Saharan Africa	30.6	36.1	40.9	44.4	47.5	51.8	54.8
West and Central Africa	16.2	19.3	22.5	25.4	28.6	32.9	35.4
Eastern and Southern Africa	14.5	16.8	18.4	19	18.9	19	19.4
Middle East and North Africa	4.4	3.7	3.3	3.3	3.5	4.1	4.2
South Asia	38	37.4	36.4	35.4	32.7	29.3	27.1
East Asia and Pacific	18.4	15.2	12.9	11	10	9.2	8.4
Latin America and Caribbean	5.1	4.5	3.9	3.5	3.8	3.3	3.3
North America	0.4	0.4	0.4	0.4	0.5	0.5	0.5
Europe and Central Asia	3.1	2.7	2.2	2	1.9	1.8	1.7
Eastern Europe and Central Asia	2.6	2.3	1.9	1.7	1.6	1.5	1.3
Western Europe	0.5	0.4	0.3	0.3	0.3	0.3	0.4
	Neonatal mortality						
Total number of global new-born mortality	5,013,549	4,491,365	3,995,551	3,492,048	3,061,645	2,687,706	2,440,464
Sub-Saharan Africa	20.3	24	27.8	31.5	35.6	40.1	43.4
West and Central Africa	10.3	12.5	14.7	16.9	19.6	22.9	25.2
Eastern and Southern Africa	9.9	11.5	13.1	14.5	16	17.2	18.2
Middle East and North Africa	4.7	4.3	4.1	4.2	4.7	5	5.1
South Asia	43.7	44.7	44.6	43.7	41.3	38.1	36.2
East Asia and Pacific	22.1	18.4	15.9	13.5	11.6	10.1	8.9
Latin America and Caribbean	5.3	5	4.6	4.1	3.9	3.9	3.9
North America	0.5	0.5	0.5	0.6	0.6	0.6	0.6
Europe and Central Asia	3.5	3	2.6	2.4	2.3	2.1	1.9
Eastern Europe and Central Asia	2.9	2.5	2.2	2	1.9	1.7	1.5
Western Europe	0.6	0.5	0.4	0.4	0.4	0.4	0.5

Source: *Analysis of UNICEF data on global child mortality*

Worse still, universal access to obstetric and child health care services in sub-Saharan Africa is below the average. For instance, access to acute respiratory infection (ARI), fever and diarrhoea treatment for children aged 0-5 years is estimated at 45%, 60% and 51%, respectively (United Nations Children's Emergency Fund (UNICEF), n.d.). Similarly, access to early ANC services, attending the recommended number of ANC, and skilled birth attendance are estimated at 82%, 53%, and 60%, respectively (Table 1.2). Furthermore, health facilities in sub-Saharan Africa usually lack life-saving technologies. For instance, access to cesarean sections is estimated at 5% (Table 1.2). These disparities in access to health care services may explain the persistent child mortality attributed to sub-Saharan Africa.

Table 1.2: Comparing access to obstetric health care services across regions as of 2019.

Indicators/regions	Estimates
ANC first attendance	
Global (Reporting)	87.2
East Asia and the Pacific	97.5
Eastern Europe and Central Asia	97.6
Western Europe	-
Latin America and the Caribbean	97.0
South Asia	79.9
Sub-Saharan Africa	82.5
Middle East and North Africa	88.0
ANC 4 times attendance	
Global (Reporting)	60.1
Western Europe	-
Eastern Europe and Central Asia	-
East Asia and the Pacific	-
Latin America and the Caribbean	90.6
South Asia	49.3
Sub-Saharan Africa	53.8
Middle East and North Africa	70.8
Institutional delivery	
Global (Reporting)	77.5
East Asia and the Pacific	91.9
Eastern Europe and Central Asia	98.1
Western Europe	99.0
Latin America and the Caribbean	93.7
Middle East and North Africa	88.6
South Asia	73.7
Sub-Saharan Africa	60.2
Caesarean Section	
Global (Reporting)	21.2
Western Europe	-
East Asia and the Pacific	32.6
Eastern Europe and Central Asia	30.0
Latin America and the Caribbean	43.7
South Asia	19.3
Sub-Saharan Africa	4.6
Middle East and North Africa	33.9

Note: - Data not available

Source: *Unicef 2019*

Certainly, the inadequacies in accessing appropriate obstetric and child health care services explain the reasons for mortality due to preventable causes. For instance, complications due to preterm birth, asphyxia or trauma during birth, infections, severe malformations, or other related perinatal complications that occur during and after delivery are well known as significant causes of death (Bhutta et al., 2014; Black et al., 2008; Liu, Hill, et al., 2016). It is also well known that the complications due to preterm birth, asphyxia and those that occur during and immediately after delivery contribute to the highest proportion (75%) of early neonatal mortality (death within one week) (Upadhyay et al., 2017; Zupan, 2005). However, despite the available evidence on when, why and how to intervene, the puzzle is the persistent wider disparities between and within regions (UN IGME, 2015, 2017, 2019, 2020).

Furthermore, until recently (UN IGME, 2015, 2017, 2019, 2020), evidence on the health and mortality of children aged 5-10 years has been limited in global publications (Abajobir, Abate, et al., 2017; Abajobir, Abbafati, et al., 2017; Were et al., 2015). Nevertheless, children aged 5-9 years, particularly those living in SSA, may remain susceptible to infections, including pneumonia, diarrhoea, malaria, and other life events such as accidents/injuries and non-communicable diseases (Were et al., 2015). As it is for new-born and under-five mortality, the reanalysis of the UN estimates on 5-9 mortality indicates sub-Saharan Africa persistently contributing the highest share with an increasing trend observed (Table 1.3). While the 2020 global report on child mortality provides mortality estimates for children aged 5-9 years (UN IGME 2020), the 5-9 mortality risk factors and causes remain elusive.

Table 1.3: Trends in the percentage share of global 5-9 child mortality

	1991	**1996**	**2001**	**2006**	**2011**	**2016**	**2020**
Total number global 5-9 mortality	1,122,836	1,035,719	856,712	736,967	649,330	554,239	505,915
Sub-Saharan Africa	36.3	39.5	44.6	48.7	51.4	57.4	61.2
West and Central Africa	16.6	18.4	22.2	25.7	29.6	35.1	38.4
Eastern and Southern Africa	19.7	21.2	22.5	22.9	21.8	22.3	22.8
Middle East and North Africa	4.0	3.3	3.0	3.3	3.0	4.8	4.1
South Asia	35.6	34.3	32.9	31.2	27.8	23.6	20.8
East Asia and Pacific	17.9	17.1	13.9	11.7	10.0	9.4	9.1
Latin America and Caribbean	3.0	2.6	2.7	2.8	5.7	2.7	2.6
North America	0.4	0.4	0.4	0.4	0.4	0.5	0.5
Europe and Central Asia	2.8	2.9	2.5	2.0	1.7	1.6	1.6
Eastern Europe and Central Asia	2.3	2.4	2.0	1.7	1.3	1.3	1.2
Western Europe	0.6	0.5	0.4	0.4	0.4	0.4	0.4

Source: *Analysis of UNICEF data on global child mortality*

The global sustainable development goals, target 3 ambitiously aims to reduce new-born and under-five mortality rate in each country to no more than 12 per 1000 live births and 25 per 1000 live births, respectively. The SDGs also aim to reduce the prematurity death resulting from preventable and treatable causes of death such as pneumonia, malaria, and diarrhoea. Achieving such ambitious SDGs targets in low-resource settings requires optimum delivery of

high impact interventions to the most vulnerable groups, which was also recognised and emphasised toward the end of the millennium development goals (MDG) era (Barros et al., 2012; Boerma et al., 2008; Hosseinpoor et al. 2011). Moreover, the need for attention to the vulnerable groups is not new, as, in 1989, the World Health Assembly mandated the WHO to turn its attention to the plight of the poorest countries (Jancloes, 1998). While access to maternal and child health preventive interventions, labour and new-born health interventions, and appropriate treatment and management of sick children are known as the most effective interventions in averting child mortality (Darmstadt et al., 2005; Haws et al., 2007; Rutherford, Mulholland, and Hill, 2010), access is still challenging in sub-Saharan Africa (Table 1.2). For the interventions to reach those in need, we need to go beyond the national and regional (inequality) estimates by understanding the micro-level mechanisms that generate vulnerability and disparities. There is a need to identify the vulnerable groups by understanding the pathway to health care access and how mortality risk factors and causes vary across the age groups.

The life-course as a concept and a framework has been shown through evidence to better understand different levels and groups of vulnerability over the life span of child development (Settersten et al., 2020; Smith, 2007). In fact, the life-course approach to health corresponds to SDG 3 calls for holistic, people-centred, and multisectoral approaches to human health and development (WHO, 2015a). However, the approach is less applied in LMIC, particularly in the sub-Saharan context, because of inadequate skills in the application and inadequate investments in life-course data systems and research such as longitudinal (Ye et al., 2012). The SSA countries majorly depend on donor sponsored demographic and health surveys, usually collected every five years (Lawn et al., 2008; Mikkelsen et al., 2015; Waiswa et al., 2012). As such, while national surveys such as DHS data have been used to understand the inequalities in mortality and health access in SSA at the macro-level (Barros et al., 2012; Boerma et al., 2008; Hosseinpoor et al., 2011), they may mask the invisible vulnerable groups within the community (Bhuiya et al., 2009). Additionally, the national surveys may insufficiently monitor (changes in) cause-specific mortality, social, behavioural and health systems determinants of health (Waiswa et al., 2012). Furthermore, frameworks that have been enormously applied in studying child mortality and health care access (Marsh et al., 2002; Mosley and Chen, 1984; Thaddeus and Maine, 1994) overlook the interplay and multidimensional nature of survival and health care access factors.

Note that incorporating life-course perspective into the implementation of interventions and studies that address health disparities requires a systemic approach: individual, family, community, and responsiveness and organisation of health institutions (Jones et al., 2019). Such an approach considers a broader system with its specific functions related to health care access and health outcomes. The systemic approach aims to identify prevention and protection means in response to health risk factors, vulnerability, and health outcomes over the life course. The life-course and systemic approach showcase the interdependence within the multiple sectors, thus acknowledging multisectoral approaches to addressing health

challenges. For instance, the economic and social policies should, to a large extent, be considered health policies (Jones et al., 2019).

With the aim of understanding how social and health systems elements shape children's health in their life-course of development in a poor-resource setting, I use Uganda Demographic Health Surveys, health demographic surveillance data, and qualitative interviews. Using multiple data sources in this thesis, I apply the life-course and systemic perspective in the design, interpretation, and analysis of data to describe various vulnerability categories across childhood life span. More importantly, methodological approaches applied in the analysis and synthesis of the evidence contribute to the current call to redesign child health programs (Requejo & Strong, 2021) in resource-poor settings.

1.2. Why Uganda

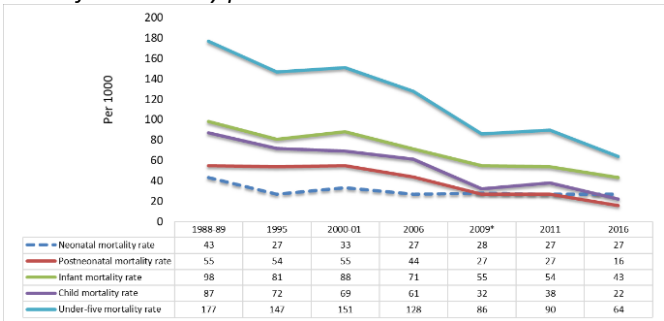
1.2.1. Under-five mortality

While under-five mortality in Uganda has plummeted over the years, slow progress in reducing neonatal mortality has been observed. In fact, neonatal mortality has stagnated at 27 per 1000 live births in the last two decades, while child and infant mortalities have significantly dropped to less than a half and by a quarter, respectively (Figure 1.2). It is also evident that the under-five mortality patterns are unevenly distributed between the places of residence. Though the reduction in the mortality gaps between rural and urban areas has significantly reduced, under-five mortality remains high in rural areas and remains comparatively high in urban areas (Figure 1.2).

The major causes of under-five mortality are labour and preterm related complications, infections (pneumonia, diarrhoea, fever, malaria), and injuries (Uganda Ministry of Health, 2019, 2020). However, the data is mainly based on the health facility reports, and it is not well disaggregated to show how the causes vary across the age groups (Uganda Ministry of Health 2019, 2020), which affects the true estimates of mortality causes since the community deaths are excluded in the reporting. Additionally, the health facility reporting faces challenges such as reporting completion and timely reporting that affect the reliability of the results (Amouzou et al., 2013; Diaz et al., 2021; Kiberu et al., 2014; Maïga et al., 2019). Further, despite the paucity of research on mortality among children aged 5-10 years and the lack of health programs and policies that target them, in countries with high mortality levels, such as Uganda, children aged 5-10 years are susceptible to the high risk of infection and injuries. While the Iganga-Mayuge health demographic and surveillance data may be seen to represent eastern Uganda, the results may provide national estimates given the homogeneity in the community and health systems characteristics across most of the districts in Uganda. The HDSS data also provides an insight into the under-10 age-specific mortality causes.

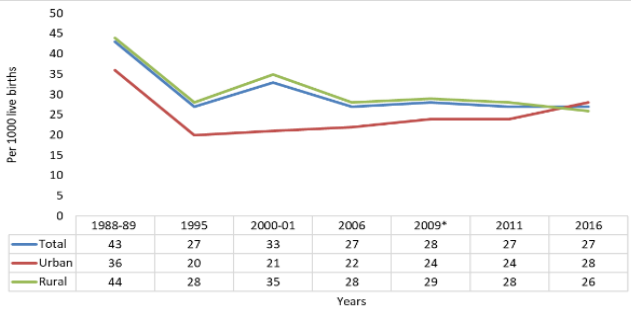
Figure 1.2: Changes in child mortality rate in Uganda (1998-2016)

Under-five mortality patterns



	1988-89	1995	2000-01	2006	2009*	2011	2016
Neonatal mortality rate	43	27	33	27	28	27	27
Postneonatal mortality rate	55	54	55	44	27	27	16
Infant mortality rate	98	81	88	71	55	54	43
Child mortality rate	87	72	69	61	32	38	22
Under-five mortality rate	177	147	151	128	86	90	64

Distribution of Neonatal mortality by place of residence



	1988-89	1995	2000-01	2006	2009*	2011	2016
Total	43	27	33	27	28	27	27
Urban	36	20	21	22	24	24	28
Rural	44	28	35	28	29	28	26

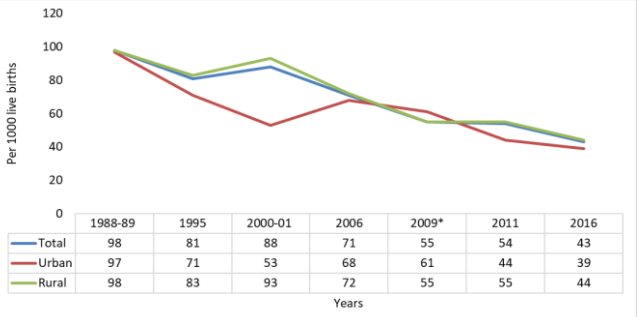
Years

Distribution of postnatal mortality by place of residence

	1988-89	1995	2000-01	2006	2009*	2011	2016
Total	55	54	55	44	27	27	16
Urban	61	52	31	45	38	20	12
Rural	55	55	58	44	26	28	17

Years

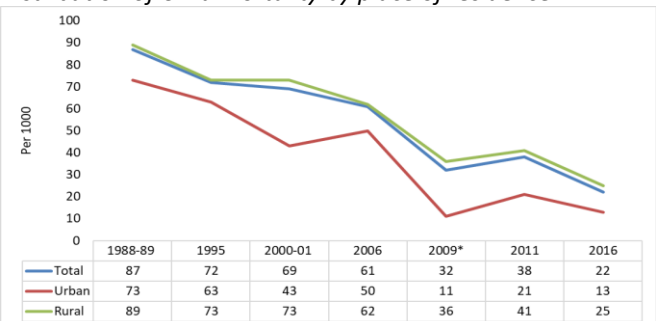
Distribution of Infant mortality by place of residence



	1988-89	1995	2000-01	2006	2009*	2011	2016
Total	98	81	88	71	55	54	43
Urban	97	71	53	68	61	44	39
Rural	98	83	93	72	55	55	44

Years

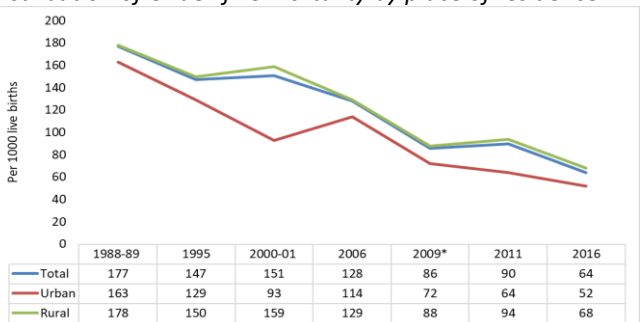
Distribution of Child mortality by place of residence



	1988-89	1995	2000-01	2006	2009*	2011	2016
Total	87	72	69	61	32	38	22
Urban	73	63	43	50	11	21	13
Rural	89	73	73	62	36	41	25

Years

Distribution of Under-five mortality by place of residence



	1988-89	1995	2000-01	2006	2009*	2011	2016
Total	177	147	151	128	86	90	64
Urban	163	129	93	114	72	64	52
Rural	178	150	159	129	88	94	68

Years

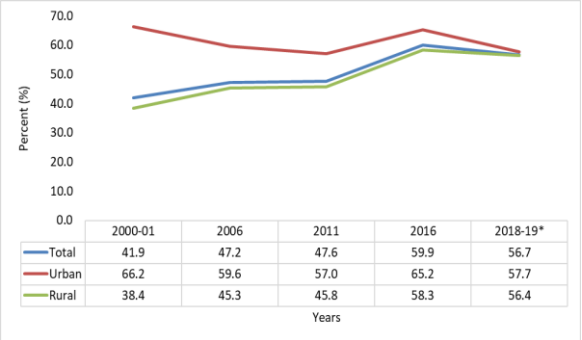
Source: *Generated using Demographic Health Survey STATCompiler*

1.2.2. Access to maternal and child health care services

The current estimates in antenatal care, health facility delivery and treatment for sick children indicate a challenge in attaining universal health coverage and henceforth meeting the SDGs and national targets of reducing under-five and neonatal mortality. Though we observe an increase in access to obstetric health interventions such as antenatal care, delivery, and caesarean sections (Figure 1.3), the increase in the coverage of these interventions does not match neonatal mortality changes as one would expect. Yet, these are high impact interventions that have been shown to significantly reduce maternal and new-born mortality. Besides, access to the caesarean section is estimated at 6%, accessed mainly by urban residents (Figure 1.3).

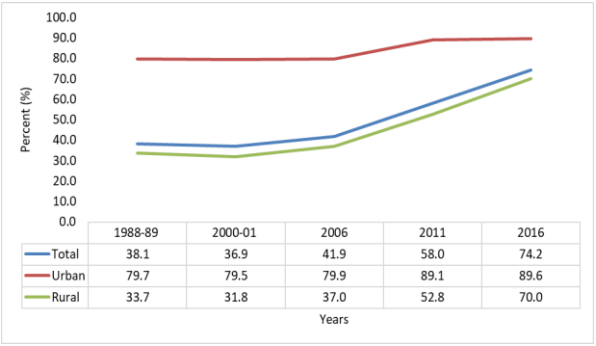
Figure 1.3: Changes in health service access indicators in Uganda (1998-2016)

ANC 4 times attendance



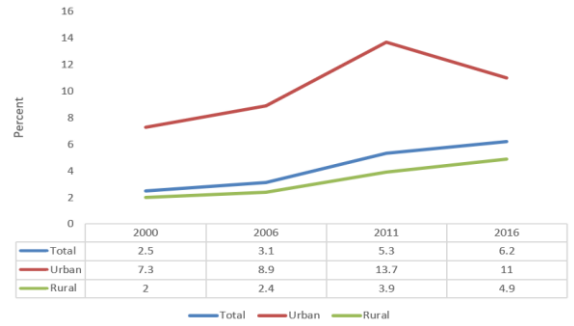
	2000-01	2006	2011	2016	2018-19*
Total	41.9	47.2	47.6	59.9	56.7
Urban	66.2	59.6	57.0	65.2	57.7
Rural	38.4	45.3	45.8	58.3	56.4

Assisted delivery



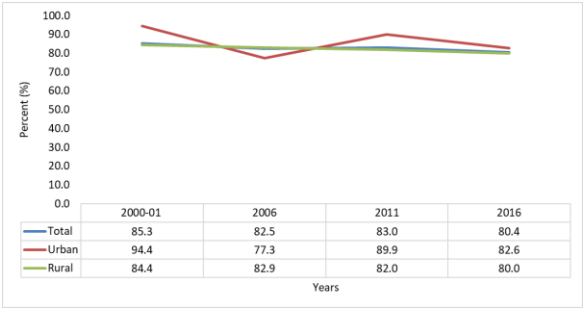
	1988-89	2000-01	2006	2011	2016
Total	38.1	36.9	41.9	58.0	74.2
Urban	79.7	79.5	79.9	89.1	89.6
Rural	33.7	31.8	37.0	52.8	70.0

C-section



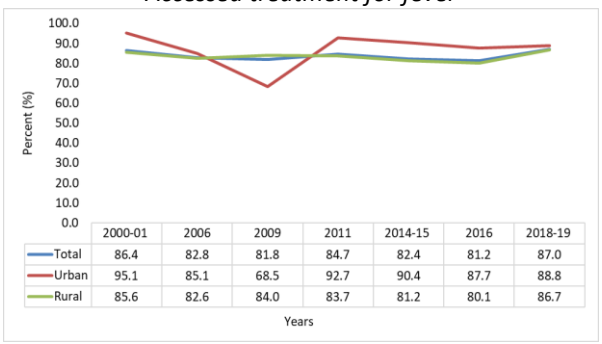
	2000	2006	2011	2016
Total	2.5	3.1	5.3	6.2
Urban	7.3	8.9	13.7	11
Rural	2	2.4	3.9	4.9

Accessed treatment for ARI



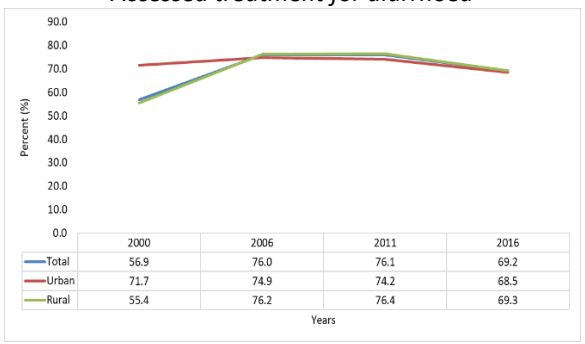
	2000-01	2006	2011	2016
Total	85.3	82.5	83.0	80.4
Urban	94.4	77.3	89.9	82.6
Rural	84.4	82.9	82.0	80.0

Accessed treatment for fever



	2000-01	2006	2009	2011	2014-15	2016	2018-19
Total	86.4	82.8	81.8	84.7	82.4	81.2	87.0
Urban	95.1	85.1	68.5	92.7	90.4	87.7	88.8
Rural	85.6	82.6	84.0	83.7	81.2	80.1	86.7

Accessed treatment for diarrhoea



	2000	2006	2011	2016
Total	56.9	76.0	76.1	69.2
Urban	71.7	74.9	74.2	68.5
Rural	55.4	76.2	76.4	69.3

Source: Generated using Demographic Health Surveys STATCompiler

Furthermore, while access to treatment for sick children with pneumonia and diarrhoea seems to be higher, the estimates have remained stagnant for the last two decades (Figure 1.3). Moreover, the UDHS 2016 data reanalysis reveals that only 39% and 48% of children with suspected pneumonia and fever sought care within 24 hours, respectively (Uganda Bureau of Statistics and ICF International, 2018).

1.2.3. Current health policies and health structure in Uganda

To improve access to health services, Uganda has implemented various policies. For instance, since 2001, the user fee was abolished in all public health facilities except for private "wings" within the public hospitals (Nabyonga-Orem et al., 2011). While this attracted high demand for services, the health facilities have struggled to match the demand because of various health services system factors: persistent stockout of drugs, inadequate health workers, underfunding, and corruption (Kiwanuka et al., 2008; Uganda National Population Council, 2018). Furthermore, while close to 72% of the population live within a 5 Km radius of the

health facilities[5], due to the construction of new health facilities, 25% of health facilities provide maternal labour services at lower levels. Only 4% (hospitals and health centre IVs) provide comprehensive services (Table 1.4). Overall there are 6,138 health facilities (Table 1.4) serving a population of 37.7 million (Uganda Bureau of Statistics, 2017), of which 50% are private health facilities (Table 1.4). These facts show that access to obstetric services and advanced services for sick children could be far from the community, which could be worse in a rural setting. With unavailable estimates on informal providers such as drug shops, clinics and traditional healers[6], the majority of the country's population seek care from the informal providers (WHO, 2017).

Table 1.4: Health facility by ownership in Uganda

Health facility categories	Government	Private-for-profit	Private-not-for-profit	Total
Blood collection and distribution points	6	-	-	6
Clinic	-	245	15	260
General Hospital	51	36	66	153
Health Centre II	1834	1854	520	4208
Health Centre III	992	219	299	1510
Health Centre IV	175	19	21	215
National Blood Bank	1	-	-	1
National Referral Hospital	2	-	-	2
Regional Blood Bank	7	-	-	7
Regional Referral Hospital	16	-	-	16
Special clinics	-	-	26	26
Total	3078	2128	932	6138

Source: 2018 *Health facility inventory report, Ministry of Health*

Like other national priorities, the national maternal and child health priorities are aligned with global sustainable development goals. For example, reducing infant and under-five mortalities are among the National Development Plan (Uganda Ministry of Health, 2015; Uganda National Planning Authority, 2020). As such, there is a strategic investment plan known as "the Reproductive, Maternal, New-born, Child and Adolescent Health Sharpened Plan 2015/2020" that aims at reducing under-five and neonatal mortality rates to less than 47 and 12 per 1,000 live births by 2020, respectively (Uganda Ministry of Health, 2016). In addition, the Ministry of Gender, Labour, and Social Development has a strategic plan known as "the National Integrated Early Childhood Development Policy Action Plan 2015/2020" with the vision of *"all children in Uganda from conception to 8 years of age grow and develop to their full potential"* (Uganda Ministry of Gender Labour and Social Development, 2016). While

[5] **Health centre IIs**- based at parish level and largely providing only outpatient with an Enrolled Comprehensive Nurse running the facility; **Health Centre IIIs**-based at sub-county level and offer basic preventive and curative outpatient services and inpatient care (largely through general and maternity wards) and laboratory services. **Health centre IVs** – based at county or district level providing Preventive, Promotive Outpatient Curative, Maternity, inpatient Health Services, Emergency surgery and Blood transfusion and Laboratory services; **Hospitals**- based at district or regional or national level as teaching, research institutions in addition to handling emergences.

[6] Though not documented, usually not regulated, and supervised, many people seek care from these services providers as the first entry point.

these policies emphasise the need to address multi-dimensional needs of improving child health through multisectoral approaches in the implementation of child health interventions, the lack of information analysed to show the areas of focus makes the implementation unclear. A holistic approach that shows the mortality and morbidity pathways and how the different age groups are affected may guide the mechanism through which the multisectoral approach can be applied.

Therefore, the national and global policy priorities and the current evidence on child health justify the need for approaches that seek to understand how mortality and access to health care are distributed across different segments of the population. Consistent with the global call of *"leaving no one behind",* we need to go beyond the national and regional estimates to unmask the most vulnerable to the risk of mortality, morbidity, and inappropriate health care access. However, the current national survey may limit such discovery. Like other sub-Saharan African countries, Uganda's child health monitoring and planning are majorly dependent on demographic health surveys (DHS) that are often conducted every five years. Yet, there are at least five independent Health and Demographic Surveillance (HDS) sites, some of which have existed for at least 20 years collecting data on most health indicators through households' registration and follow-up. However, these data have been inadequately used to measure most health indicators changes (Baiden, 2006). Yet, in the current situation of poor civil and vital registration systems, these data would provide national estimates on mortality estimates and patterns (Waiswa et al., 2019; Ye et al., 2012).

Applying life-course and systemic approaches, I use multiple data sources (collected in Uganda) and multiple analysis techniques to examine the child's health and survival within the life span of 0-10 years of age. The research focus is based on the global and national need for applying the life-course in the design and implementation of child health interventions and the need for clearer child health and survival life-course frameworks. It is also aligned with the recent call of redesigning child health (Requejo & Strong, 2021). In section 1.3, I discuss the importance of the life-course approach in child health research and implementation and subsequently explain the child health and survival life-course framework in relation to available literature in section 1.4.

1.3. Why the life-course and systemic framework

The life course approach involves studying life transition and trajectories, which contributes to understanding mechanisms of health inequalities over a lifetime as it incorporates critical health and well-being determinants e.g.; material, behavioural, institution, and social (Cable, 2014). Additionally, life course emphasises time as an important element in shaping the health and well-being of the population (Cable, 2014). Relatedly, from a systemic perspective, child health and development are composed of complex variables that include multiple factors with their multiple agents, which requires multiple agencies and groups to improve their health and well-being (Midgley, 2006).

For successful initiation modification and sustainability of programs for improving population health, including maternal and child health, there must be a thorough understanding of social systems and the responsiveness of the health service system in which populations live (Kroelinger et al., 2015). From the life-course perspective, individuals' health and well-being are shaped by a wider health determinant throughout their life span (Aagaard-Hansen et al., 2019; WHO, 2015a). The determinants are categorised as behavioural, biological, psychological, social and health service systems. The effect at any stage of development within the life cycle may affect the health and well-being in a later stage of development (Aagaard-Hansen et al., 2019; WHO, 2015a). Unlike the disease and age-specific approaches to health that often target a specific condition and groups, usually at a single life stage, a life-course approach involves all stages, particularly focusing on the transitional mechanisms (Kuruvilla et al., 2018). Thus, highlighting major gaps that may lead to the quest of understanding the differences in the determinants as well as specific health and well-being interventions. I discuss these determinants' effects based on the five principles (Burton-Jeangros et al., 2015; Halfon et al., 2014): life span development, the timing of outcomes, agency, linked lives, and time and place. The five principles steer research away from age and diseases specific studies by promoting the holistic understanding of lives over time and across changing social contexts (Halfon et al., 2014).

Life span development

Under this principle, an individual's current health and well-being can be affected by previous events – indicating that the current events can also affect future individuals' well-being and health (Burton-Jeangros et al., 2015; Halfon et al., 2014; Jeylan & Michael, 2003). This also means that early experienced advantages or disadvantages can lead to a series of cascading health events that have consequences across different domains in later life (Burton-Jeangros et al., 2015). Under this PhD project, I study how initial maternal socioeconomic, environmental, and demographic factors affect children's survival over the life span in Chapter 3. In Chapter 3, I study how the socioeconomic status, maternal characteristics and child characteristics at birth continued to affect children's survival to their 10th birthday.

Timing of outcomes

Under this principle, the health events' patterns, such as morbidity and death; and the magnitude of the effect of the risk factors change with an individual's age (Burton-Jeangros et al., 2015; Halfon et al., 2014; Jeylan & Michael, 2003) and therefore lead to *critical or sensitive period*. Exposure to the risk factors may lead to the *intrinsic capacity* that may affect the *individual's functional ability* throughout the life-course if moderating interventions are not appropriately provided. I consider the intrinsic capacity as internal attributes that children are born with, such as preterm and low birth weight, that affect their life span functional ability. The lives (functional ability) of such categories of children can be improved through a better environment in which they live and appropriate social and healthcare support. Nonetheless, all children's functional ability depends on continued

exposure to a better environment and health care from conception and throughout all stages of development. From a systems perspective, the functional ability considers the complex interplay of individual, social, and environmental determinants of health; and the individual agency and collective actions required to ensure health and well-being throughout their life. The social and environmental determinant of health involves health systems, essential public health functions, multisectoral factors and cross-sectoral actions (Kuruvilla et al., 2018). Thus, the functional ability can be enhanced throughout life by a supportive environment, altering society norms and policies, and addressing the inequalities that affect the life-course trajectory. Under this PhD study, the principle of timing outcome is studied by examining the mortality and risk exposure patterns (age-specific mortality and age-cause-specific mortality) in Chapter 3 and Chapter 4. In addition, under this principle, I assess the timing of access to healthcare services (delivery and treatment for sick children) known to avert mortality in Chapter 3 and study how institutional delivery modifies the effect of intrinsic capacity on child survival in Chapter 4.

Agency and linked lives

The principle of agency stresses how the interaction between individual action and the social structure shapes the health and well-being of the population (Burton-Jeangros et al., 2015; Halfon et al., 2014; Jeylan and Michael, 2003). The individuals' actions and choices are dependent on the available opportunities and constraints within the families and communities in which they live (Burton-Jeangros et al., 2015). At a family level, available evidence indicates how women's agency who are primary caretakers depend on their husbands and other influential family networks (Colvin et al., 2013; Morgan et al., 2016) – this also applies to the linked lives principle. The individuals' actions and decisions are shaped by the community structure at the community level: transport system and neighbourhood. From the linked lives perspective, the individual's health and well-being are interdependent within a network of shared relationships (Burton-Jeangros et al., 2015; Halfon et al., 2014; Jeylan and Michael, 2003). For instance, a woman's exposure to poor health in the preconception or pregnancy stage may lead to adverse birth outcomes. Under this PhD work, I apply the agency and linked lives principles by examining and interpreting how the social network ties, the structure of the community, and the organisation of health services shape children's health in Chapter 6.

Time and place

The time and place principle highlights that an individual's health and well-being are embedded in and shaped by the historical context (Burton-Jeangros et al., 2015; Halfon et al., 2014; Jeylan and Michael, 2003). A place is composed of time variant characterised by infrastructure (both public and private), culture, leadership, family composition and individuals' socioeconomic position. Thus, the principle of time and place considers how changes in the institutional, community and family factors affect individual development. For instance, institutional policy changes or changes in the family's socioeconomic status may affect behavioural changes. Chapter 3 and Chapter 4 of this thesis present the differentials in

rural-urban residents' mortality patterns and risk exposures, while Chapter 5 presents rural-urban morbidity patterns.

There is a growing interest in the application of the life-course approach in the design and implementation of health interventions (Aagaard-Hansen et al., 2019; Alfvén et al., 2019; Bundy et al., 2018; Chan, Lake, and Hansen, 2016; Kuruvilla et al. 2018; Requejo et al. 2020; Richter et al. 2017; R. Sharma et al., 2017; United Nations, 2016; WHO, 2015a; WHO, 2015b). The 2030 sustainable development goal 3 is to *"Ensure healthy lives and promote well-being for all, at all ages"* (WHO, 2015a). SDG 3 indicates the need for holistic, people-centred, and multisectoral approaches to human health and development, which align with the life-course approach to health (WHO, 2015a). Further, the 2016-2030 global strategy for women's, children's and adolescents' health with its slogan *"survive, thrive and transform"* (United Nations, 2016) emphasises the life-course approach in designing and implementing the intervention. Nevertheless, despite the emphasis on its application, the approach has not been extensively applied in the studies and policy implementation of maternal and child health (Kuruvilla et al., 2018). Most studies that have applied the life-course approach are in non-communicable diseases and ageing, primarily in high-income countries (Lynch & Smith, 2005; B. Mikkelsen et al., 2019). A search strategy *"(((Child[MeSH Terms]) AND (Health[MeSH Terms])) AND ("life-course")) AND (Africa[Text Word])* in PubMed as of 17th/February/2021 revealed only three articles (Clark & Hamplová, 2013; Lule et al., 2019; Requejo et al., 2020) that applied the life-course approach to child health and survival in Africa. Aligned with the global interest, I apply life-course and systemic approaches to child health to comprehensively understand the distribution of morbidities and mortality across different groups and the mechanism of the events' occurrences.

1.4. A life-course and systemic approach to child health and survival

The current frameworks on child health and survival, including obstetric health (Marsh et al., 2002; Mosley and Chen, 1984; Thaddeus and Maine, 1994), overlook how multiple factors throughout the development affect child health and survival. While Marsh et al. (2002) framework indicate the importance of health facility delivery, identification and care for risk groups, including mothers with danger signs, LBW babies, and new-borns with asphyxia and other infections, it is limited to obstetric and new-born health care services. Moreover, the framework ignores how the social, environmental, and health service systems affect access to such important suggested interventions. Further, while the framework by Mosley & Chen (1984) has contributed much to the understanding of child health and survival in developing countries, the framework shows a linear relationship between the socioeconomic determinants and child health events (sickness and death) that is out of touch with the reality of multidimensional factors. The interplay within the socioeconomic determinants and how the health service system contributes to children's survival may be overlooked in studies that apply or have applied Mosley & Chen (1984) model.

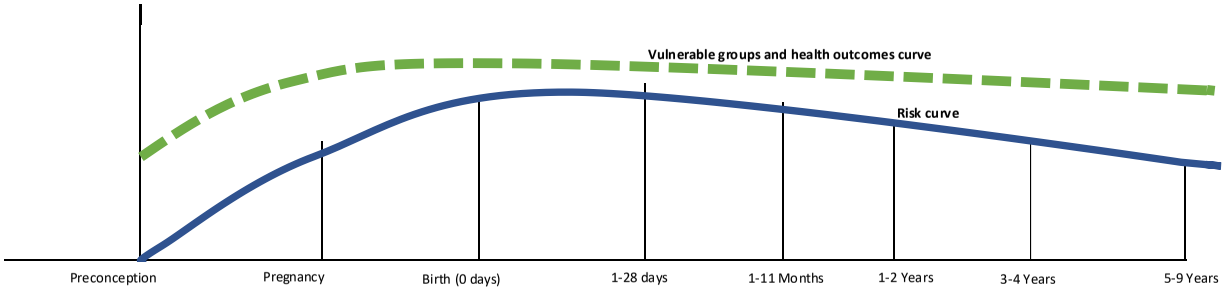
Further, accessing appropriate health facility services is well known as the most effective intervention in reducing new-born and child mortality. For instance, available studies indicate that accessing appropriate obstetric services at the time of delivery could avert at least 40% of new-born death (Darmstadt et al., 2005; Haws et al., 2007; Rutherford et al., 2010). However, various impediments usually interact to affect appropriate access in resource-poor settings. Although the delay model has been extensively applied to understand the barriers to obstetric health care access and child health care access, the model abandons how the interplay within the factors or barriers generates various categories of vulnerability (Thaddeus and Maine, 1994).

Building on these frameworks, I generate a life-course and systems framework for child health and survival that highlights the levels of risk and vulnerability from the preconception to the childhood stage (Figure 1.4). This framework is the foundation of this PhD work. The framework (Figure 1.4) illustrates that the risk of occurrences of the events that affect the functional ability and mortality increases with child age from preconception to infancy, beyond which the risk starts reducing. Similarly, the risk increases with the level of vulnerability. Consistent with (R. Sharma et al., 2017), the framework highlights the vulnerability of children at different stages of development and how the vulnerability is linked to various outcomes over the life course, which showcases the importance of life-course interventions in improving the health and survival of children. From the systems perspective, the framework also shows the need for addressing the social and environmental determinants of health, particularly using social justice approaches. The changes and differences in vulnerability and risk suggest specific point interventions are elaborated on in the subsequent sub-sections.

1.4.1. Preconception and pregnancy health interventions

WHO emphasises the importance of antenatal care (ANC) in identifying and managing pregnancy that may result in labour complications (WHO, 2016). Access to ANC may expose the mother-foetus dyad to preventive and care interventions that may improve their health by reducing the occurrences of maternal morbidities (Darmstadt, Oot, & Lawn, 2012; Dickson et al., 2014; Engmann et al., 2013; Lincetto et al., 2013; Vesel et al., 2015; WHO and UNICEF, 2014; WHO, 2016). This might explain why some studies (Bailey et al., 2017; Lincetto et al., 2013; Momeni et al., 2017) have reported a significant reduction in LBW and neonatal mortality among women who accessed ANC. Additionally, ANC attendance provides an opportunity for increased, skilled birth attendance and other healthy behaviours such as breastfeeding, early postnatal care, and planning for optimal pregnancy spacing (Lincetto et al., 2013; WHO, 2016). Nevertheless, the global gap in early ANC attendance is still low – estimated at 59%, as reported by Moller et al. (2017); moreover, with a wider disparity between the LMICs (24%) and HICs (82%) (Moller et al., 2017). Additionally, in the sub-Saharan context, even those who reach health facilities may inappropriately and inadequately receive the service (Benova et al., 2018; Heredia-Pi et al., 2016; Kyei et al., 2012).

Figure 1.4: Life-course and systems framework for child health and survival



	Preconception	Pregnancy	Birth	New-born and children
Vulnerable group	Adolescents	Adolescents	Adolescents	Adolescents
	Newly delivered mothers	Newly delivered mothers	Newly delivered mothers	Unmarried mother
	Advanced age	Advanced age	Advanced age	Limited maternity leave
	Multiparous	Multiparous	Multiparous	Living in community with poor infrastructures
		Mothers with non-communicable diseases	Mothers with non-communicable diseases	Preterm birth
		Mothers with infections	Mothers with infections	Low birth weight
		Unmarried mother	Unmarried mother	Born as macrosomia
		Limited maternity leave	Limited maternity leave	
		Living in community with poor infrastructures	Living in community with poor infrastructures	
Outcome	Unplannned & unwanted pregnacies	Maternal mortality	Preterm birth	Infections
		Miscarriage	Low birth weight	Growth retardation
		Abortion	Stillbirth	Mortality
			Shoulder dystocia	
			Maternal mortality	

Social and enviromental determinants of health
1) Families and community, 2) health services and systems, and 3) multisectoral factors related to sociocultural norms, economics, politics, physical environment

Social justice approaches for the realiszation of rights
Apply human right based, gender-responsive, and equity driven approaches

Source: Author

Furthermore, access to modern contraceptives, particularly birth control methods, is an important preconception intervention. Family planning access during preconception is the most effective intervention that reduces the unwanted pregnancies among women of adolescent and advanced age and short interval between birth (Blumenthal and Voedisch 2011; Dean et al. 2013; Kopp 2016; Norton, Chandra-Mouli, and Lane 2017; Tsui, Mcdonald-mosley, and Burke 2010). Unwanted pregnancies among women of adolescent and advanced age and short intervals between birth are associated with adverse birth outcomes, including mortality, birth defects and low birth weight (Khalil et al., 2013; Oakley et al., 2016; Vaughan & Cleary, 2013).

While this thesis does not comprehensively study how access to preconception and pregnancy interventions may reduce child mortality, studying mortality and morbidity risk factors such as low birth weight, adolescent births, and births in advanced age groups in Chapter 3, Chapter 4, and Chapter 5 gives us an insight into the preconception and pregnancy interventions that should target women.

1.4.2. Birth and neonatal health interventions

Most child deaths occur during labour/delivery and within 28 days after birth; hence, the labour period is critical and sensitive for child survival. Therefore, access to quality care within the labour period and early postnatal period may be crucial in averting neonatal deaths. It is well known that during labour, women should be attended to by skilled health workers, who should be able to assess the labour complications such as obstructed labour conditions that may need emergency services such as caesarean-section (Campbell, 2014; Darmstadt et al., 2013; Salam et al., 2014; Wall et al., 2010). After delivery, the new-borns should access specific recommended postnatal care services such as immunisation and other special care for high-risk children. For instance, in the presence of LBW and preterm birth, sepsis, and asphyxia, interventions such as resuscitation, corticosteroid treatment administration, and kangaroo mother care should be provided (Berkley et al., 2014; Darmstadt et al., 2005; Dickson et al., 2014; Salam et al., 2014).

This thesis comprehensively analyses how access to labour interventions affects new-borns. By presenting the causes of stillbirths and new-born deaths in Chapter 3 and showing the trends in stillbirths and deaths within the first day of life in Chapter 4, the thesis gives insight into access to the quality of health care services. Similarly, by showing how institutional delivery is associated with neonatal death and its role in moderating the association between low birth weight and new-born deaths in Chapter 4, the thesis provides an insight into how access to health interventions benefits the most at-risk new-borns.

1.4.3. Other postnatal and childhood health interventions

Access to health interventions throughout childhood is essential (Were et al., 2015). However, the interventions need to be implemented at scale and with quality. The interventions include both preventive and protective services such as immunisation, proper hygiene and sanitation, use of mosquito nets, and access to healthcare services for sick children (Bhutta et al., 2013; Lassi et al., 2015, 2014; Leung et al., 2017; Were et al., 2015). In addition, WHO recommends exclusive

breastfeeding for at least 6 months and henceforth breastfeeding with supplements up to 2 years of age and beyond (Lassi et al., 2015, 2014; Were et al., 2015). Further, injuries and accidents are common incidences among children aged 5+ years (Were et al., 2015) and as Kendrick et al. (2013) indicate, prevention interventions targeting families are needed (Kendrick et al., 2013). The other emerging non-communicable diseases, such as diabetes, need policy interventions on, for instance, the marketing of unhealthy food and beverages targeting children (Were et al., 2015).

Understanding the age-specific causes of death and mortality risk factors in Chapter 3 and Chapter 4 and morbidity predictors in Chapter 5 helps us understand which age-specific interventions should be designed and implemented.

1.4.4. Challenges to access prevention and care services

The known cost-effective interventions that have been mentioned earlier have not been replicated in most resource-limited setting communities (Hatt et al., 2017; Haws et al., 2007). For instance, 30% of women and sick children in LMICs do not access health services from skilled professionals (Källander et al., 2008; Rutebemberwa et al., 2009; Van der Stuyft et al., 2007), and sometimes, care is first sought from informal providers such as drug shops and traditional providers (Kalyango et al., 2013; Kiwanuka et al., 2008). Challenges to prevention and care services access arise from the supply and demand side. The supply-side challenges include recurrent inadequate life-saving supplies and skilled health professionals[7] (Ackers, Ioannou, & Ackers-Johnson, 2016; Barros et al., 2011; Kiwanuka et al., 2008; Van der Stuyft et al., 2007; Wall et al., 2010). Indeed, in LMICs, there are inadequate midwives to conduct deliveries and doctors to provide comprehensive services to mothers and children with complications (Kiwanuka et al., 2008; Wall et al., 2010).

The demand side challenges include behavioural, maternal, and community factors (Donnell, 2007; Upadhyay et al., 2017; Waiswa et al., 2010). Details of how demand factors could affect health access and child survival are in Section 1.6 of this Chapter. Such challenges may lead to failure or delays in receiving appropriate care, thus predisposing the mother and child to mortality risk factors. Such complexity suggests that reducing neonatal mortality needs interventions that tackle both demand and supply-side bottlenecks simultaneously (Darmstadt et al., 2013) and interventions that influence those in charge to take action.

In this thesis, Chapter 3 describes the delays or failures in accessing obstetric and child health care services. Chapter 6 comprehensively examines how various barriers concurrently affect access to appropriate obstetric and child health care services. The findings in Chapter 6 showcase how multiple barriers concurrently affect different categories of people differently based on their economic position, age, marital status, and place of residence, thus creating different groups of vulnerability. The vulnerability resulting from exposure to multidimensional factors is twofold. First, these factors are associated with morbidities, access to appropriate health care services, and mortality. Secondly, most of these factors interrelate and make some other individuals more vulnerable. Section 1.5 of this Chapter discusses the mechanisms through which these factors affect

[7] Health workers who can provide services as required.

child survival in four themes: socio-economic, maternal demographic, behavioural, place of residence, and health systems factors.

1.5. Factors that affect health care access, child health and survival

In this section, I discuss the mechanisms through which various factors affect child survival (Figure 1.5). Socioeconomic and demographic factors may affect child survival directly or indirectly through birth weight, morbidity, and health facility intervention access. In addition, birth weight and morbidity may be affected directly or indirectly by access to prenatal health interventions. Moreover, as presented under Section 1.5.1, socioeconomic factors are sometimes interrelated and may affect maternal factors. In line with the available literature, I discuss how these factors affect child health and survival in subsequent subsections and provide how their association was studied in this thesis.

1.5.1. Socioeconomic factors

The socioeconomic variables considered in this thesis were household wealth position, maternal education level and maternal occupation (Figure 1.5).

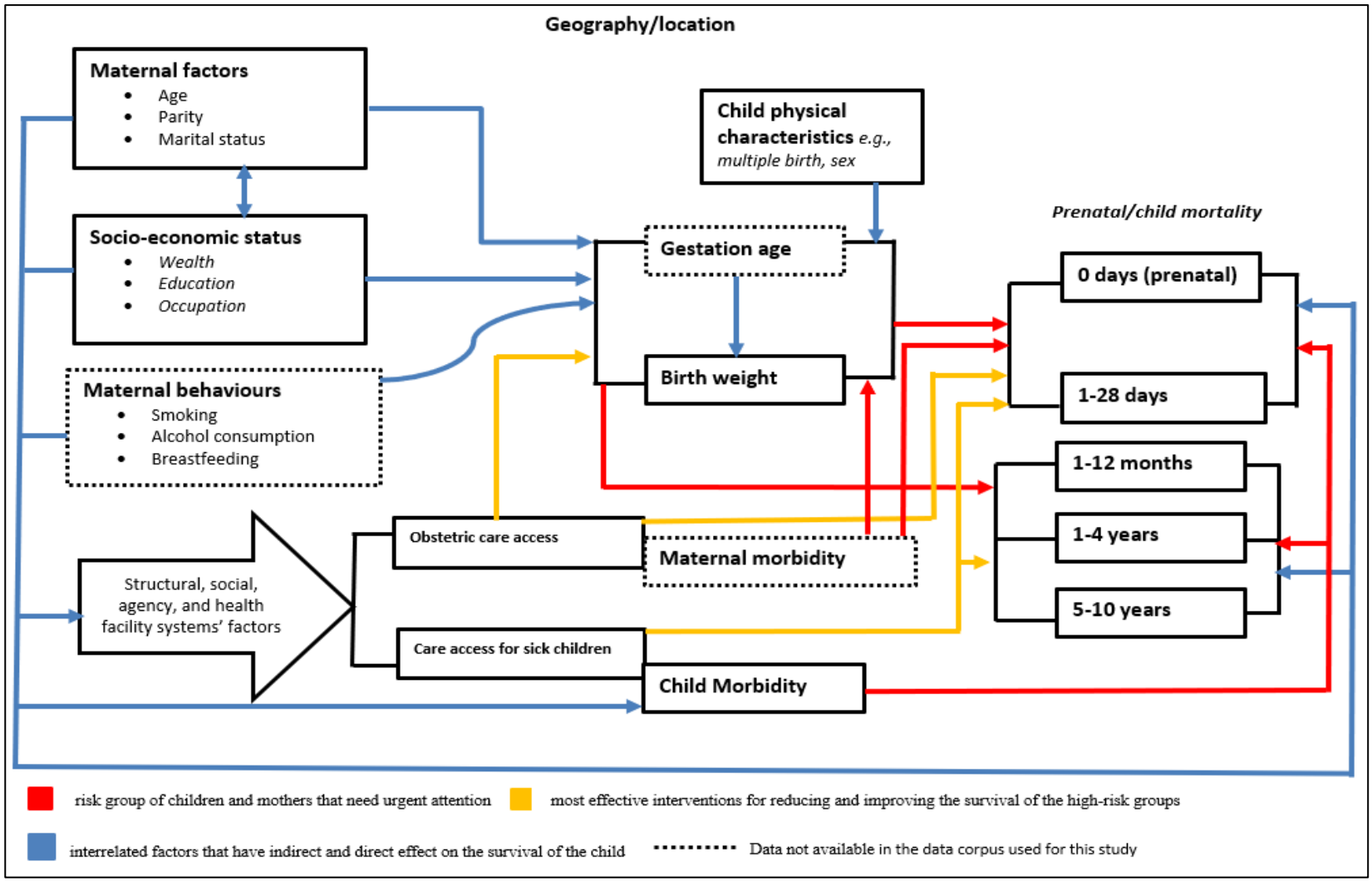
Wealth position

Wealth may be an important factor that may directly or indirectly affect the general population's health and survival and is usually considered a proxy indicator of poverty. Indeed, poor groups[8] , including high-income countries, are always at high risk of several morbidities and mortality (Victora et al., 2003). In the context of SSA communities, wealth may act as a "central point player" as it may directly affect most of the maternal factors such as education, access to income/finances, early pregnancies, high fertility rate, and access to health interventions (Victora et al., 2003). In addition, the poorer groups sometimes lack access to quality health services resulting from their limited decision-making power over healthcare choices. While the user fees were abolished in several sub-Saharan African countries'[9] public health facilities, usually, such facilities persistently experience scarce life-saving commodities (Kananura et al., 2017; Nabyonga-Orem et al., 2011). Thus, the poor may not be able to incur an extra bill aside from what government provides (Ntenda et al., 2014; Kayode, Adekanmbi, & Uthman, 2012). Such may expose women and children to poor health services that could lead to poor birth outcomes, increase children's morbidity and deaths (Manyeh et al., 2016), or lead to catastrophic expenses (Leone et al., 2013).

The association of a family's wealth position with child survival is studied extensively in all the sub-studies. In Chapter 3, I study how the family's wealth position is associated with under-10 mortality and how this association changes with the child's age. In Chapter 4, I study how the wealth position is associated with intrinsic capacity and new-born mortality. In Chapter 6, I identify family wealth or financial position as one of the key factors that contribute to women's agency in accessing obstetric and child health care services.

[8] These may include individuals, households/families and communities.
[9] Some of the countries include Uganda, Ethiopia, India, Zambia, Ghana, and Kenya,

Figure 1.5: conceptual framework illustrating the mechanisms through which various factors affect child survival.



Source: Author

Education level

As Nattey et al. (2013) indicate, child mortality is likely to be higher among mothers with no education level than at primary and higher levels (Nattey et al., 2013). As mentioned earlier, the effect of education, particularly in SSA may be linked to wealth. Sometimes, women from poor groups are less educated or may not attain a higher level beyond the free public level or become pregnant during adolescence. In fact, in conformity with Prakash et al. (2017) and Sekine & Hodgkin (2017), girls from the poorest families sometimes drop out of school to complement the household's income if not forced to marry (Prakash et al., 2017; Sekine & Hodgkin, 2017) and such are common in LMICs (Snilstveit et al., 2016). Besides, the pathway could be childcare practices' knowledge and healthcare access. Several studies have indicated the contribution of maternal education toward better health behaviours' practices such as nutrition, childhood immunisation and better sanitation (Ehrenstein et al., 2014; Grépin & Bharadwaj, 2015; Makoka & Masibo, 2015; Semba et al., 2008). Furthermore, as Semba et al. (2008) heed, education may lead to delayed age at marriage, sexual debut, first birth and better economic opportunities for women (Ehrenstein et al., 2014). The association between child mortality and education level is studied in Chapters 3 and 4. The pathway in the association of new-born mortality with education is further studied in Chapter 4, with a focus on how such could be mediated by low birth weight.

Occupation

Women's engagement in productive work contributes to financial autonomy and agency. However, in LMICs, most women are not engaged in productive work and have limited access to income-generating resources. Yet, access to finance may influence access to health prevention and care interventions (Darmstadt et al., 2005; Hatt et al., 2017; Kananura et al., 2017; Kiwanuka et al., 2008). Besides, it is important to note that the type of work may predispose the woman-foetus dyad and infants to adverse risks and with the existing poor maternal employment policies in LMICs, such may be worse. For instance, Nandi et al. (2016), Rossin (2012) and Ruhm (2000) indicate that maternal employment with inadequate maternal leave may increase the risk of child mortality (Nandi et al., 2016; Rossin, 2012; Ruhm, 2000). This could be due to the little time, if not none; the employed receive to access prenatal services in addition to a few maternal and postnatal[10] leave days needed for the delivery preparations and new-borns care, respectively. Additionally, as several studies conducted in HICs indicate, women who are involved in manual work involving heavy carrying or exposure to other health risk hazards such as pollution are more likely to experience poor birth outcomes (Ahmed & Jaakkola, 2007; Althabe et al., 2015; Chen et al., 2007; Demelash et al., 2015; Dhaded et al., 2015; Mahumud, Sultana, & Sarker, 2017; Manyeh et al., 2016; Momeni et al., 2017; Ronda et al., 2009). However, such information on the type of work and exposure to occupational hazards appears to be inadequately collected in several LMICs surveys and studies, yet this would help draft maternal employment policies.

Assessing the effect of maternal occupation on child mortality in Chapter 3 and Chapter 4 could not be possible as this was based on the data collected from rural communities whose main

[10] The inadequate postnatal leave days predisposes new-born to poor care practices that may lead to morbidities such as infection.

occupation was the peasantry. Although the occupation levels were considered as variables under Chapter 6, I did not examine how this could be associated with child morbidity as the focus was mainly on identifying the topmost predictors of suspected pneumonia and diarrhoea among under-five aged.

1.5.2. Maternal demographic factors

The maternal or demographic factors are marital status, age, and parity/gravida (Figure 1.5). The complex effect of maternal age on child survival needs to be analysed with care. In their studies, Blomberg et al. (2014) and Sinha et al. (2017) note the age-related mortality risk U-shaped curve (Blomberg, Tyrberg, and Kjølhede 2014; Sinha et al 2016), which could indicate the high mortality risk among younger and older aged mothers. Pregnancy in adolescents and women aged above 35 years is associated with increased risks of preterm births and LBW, which are the major causes of new-born death (Khalil et al., 2013; Oakley et al., 2016; Vaughan & Cleary, 2013). Additionally, pregnancy in adolescents and women aged above 35 years is associated with increased risks of preeclampsia and obstructed labour, which are the major causes of stillbirths, including maternal death (Khalil et al., 2013; Oakley et al., 2016; Shah et al., 2011; Vaughan & Cleary, 2013).

Adolescent women are usually isolated in the communities, not engaged in any income activity, and unmarried/single, thus having inadequate support for appropriate care-seeking while pregnant, during, and after labour. Studies on the effect of marital status on birth outcome indicate how unmarried, cohabiting, and single women are more likely to experience LBW/preterm births (Kayode, Adekanmbi, & Uthman, 2012) and under-five death (Bado & Susuman, 2016; Hale, Davanzo, & Razzaque, 2009; Huq & Tasnim, 2008; Kanmiki et al., 2014; Lartey, Khanam, & Takahashi, 2016; Makate & Makate, 2016; Quamruzzaman et al., 2014; Singh-manoux et al., 2008). Therefore, one would argue that marital status affects child mortality via access to income and decision-making power, which usually influences healthcare access. Usually, married women have support from their spouse in the form of joint income and joint care (Kaiser et al., 2018), which may contribute to their birth preparedness, child nutrition and general health of the household.

Further, studies have indicated how first pregnancies and pregnancies of fourth-order and above are more likely to result in preterm, LBW and stillbirth (Aliyu et al., 2005; J. Bai et al., 2002; Lisonkova et al., 2010; Shah, 2010). Further, as Oakley et al. (2016) indicate, the first pregnancy conceived at 35 years and above may lead to stillbirth (Oakley et al., 2016). This may result from the fact that the nulliparity and grand parity women may acquire pregnancy and labour complications that could lead to the death of either the dyad or one of them if care received is inappropriate. Therefore, the association of maternal demographic factors with child health and survival is extensively studied in this thesis.

In Chapter 3, I study how maternal age and marital status are associated with the under 10 mortalities, while in Chapter 4 I study how maternal age and marital status are associated with new-born mortality and low birth weight. In Chapter 5, maternal factors were among the set of variables included in identifying the most important factors that predict child morbidity: suspected pneumonia and diarrhoea.

1.5.6. Behavioural risk factors

Common maternal behaviours that affect child health are drug abuse (smoking, drug consumption, and traditional medicine) and exclusive breastfeeding (Figure 1.5). However, exposure to these categories of behaviours varies by context and country. For example, the use of harmful substances such as tobacco, alcohol, and traditional medicines while pregnant that affect the pregnancy outcome seems to vary between and within regions and countries, resulting from differences in societal norms. Caleyachetty et al. (2014) estimated 2.2% tobacco use among pregnant women in Uganda compared to 15% in Turkey and 6% in Namibia (Caleyachetty et al., 2014). Popova et al. (2016) estimated 20% of alcohol use among pregnant women in Uganda compared to 13% in Cameroon and 4% in Algeria (Popova et al., 2016). Additionally, Kayom et al. (2015) indicate that at least 60% of women in Uganda use traditional drugs to induce labour and treat their new-borns morbidities before seeking formal healthcare (Kayom et al., 2015). Important to acknowledge is the limited research on the use of harmful substances in pregnancy and inadequate data in LMICs.

While I did not study the effect of behavioural risk factors on child health and mortality in this thesis comprehensively, the identification of various ways applied in caring for pregnancies and sick children gives us an idea of community practices. However, studies on understanding various behaviours and how the practices vary across contexts would provide better results are needed. For instance, to my knowledge, the use of alcohol may be common in slum settings, while tobacco use and traditional medicine may be common in rural settings, and these could be associated with the household and community socioeconomic status.

1.5.7. Child physical characteristics

Child physical characteristics such as sex, birth order and birth category (multiple and singleton births) are associated with adverse birth outcomes and survival (Figure 1.5). Studies have indicated how multiple births and sex are associated with birth weight (Tamirat et al., 2021). Multiple births are usually associated with preterm births (Tamirat et al., 2021), while the variation between sexes has been identified to be associated with foetal growth, size and risk for adverse pregnancy outcomes. Studies have indicated a slower growth in female foetuses as compared to their male counterparts, where the second-trimester head circumference (HC) is usually smaller in females than in male foetuses (Melamed et al., 2013; Wainstock et al., 2015). The association of child sexes with intra-uterine growth retardation is inconsistent. Some studies have shown that it is more prevalent in female foetuses (Engel et al., 2008; Melamed et al., 2013; Wainstock et al., 2015) and others otherwise (Tamirat et al., 2021). Studies have also indicated the high-risk gestation diabetes and stillbirth among male foetus relative to female counterparts (Engel et al., 2008; Khalil & Alzahra, 2013; Melamed et al., 2013; Wainstock et al., 2015). In this thesis, I study the association of child sexes, birth order and birth category with child mortality and low birth weight in Chapters 3 and 4.

1.5.8. Place of residence

The socioeconomic, maternal factors and health interventions mentioned earlier may vary across and within the countries/communities, possibly explaining the mortality variations. This appears to be consistent with Halonen et al. (2013) and Martikainen et al. (2003), who indicate the

significant contribution of the area's context to health and mortality (Halonen et al., 2013; Martikainen et al., 2003). The place of residence is characterised by community behaviours such as alcohol use, geographic characteristics such as calamities, and facility proximity, all of which may contribute to the child's health and survival. For instance, while studies have indicated how rural women residents are more likely to experience LBW/preterm and infant deaths than urban residents (Dahlui et al., 2016; He et al., 2018), the urban settings include deprived communities that are also characterised by the undesirable community and geographical factors (X. Bai et al., 2012; Fotso, 2007; Van de Poel et al., 2007). National surveys such as the DHS are sometimes insufficiently collected and analysed to articulate child health and mortality variations between districts within countries. Yet, such information would direct the specific design of the interventions targeting the underserved populations.

Because of the limitations of the data used in this thesis, I could not study how child mortality and health vary across the geography beyond the rural-urban residence. Analysing the national surveys by population segmentation in the form of topography such as mountainous, island, low-land, and drought areas, gross domestic product, and economic activities could have provided a better picture, though this was not the focus of this thesis. Nonetheless, by indicating the rural-urban mortality and morbidity differentials in Chapters 3, 4 and 6, the thesis gives us an idea of how the place of residence affects child health and survival. However, moving beyond urban-rural disaggregation would provide better ideas. For instance, to my knowledge of Uganda's context, there are many emerging urban or town centres, and most of them share the same characteristics as slum areas in big cities. Therefore, grading such areas as urban areas as could be done in the DHS is an "injustice" as this provides unrealistic evidence.

1.5.9. Health service systems factors

Often, like other health services such as immunisation and HIV/AIDs, the health facility services for maternal and child health in low and middle-income countries do not match the demand because of numerous constraints: shortage and distribution of appropriately qualified staff; weak technical guidance, programme management and supervision; inadequate drugs and medical supplies; and lack of equipment and infrastructure, including poor accessibility of health services (Bohren et al., 2015; Colvin et al., 2014; Jacobs et al., 2012; Kananura et al., 2017; Oliveira-Cruz et al., 2003).

Studies on health services access are fragmented and thus do not provide a comprehensive package of interventions that should improve access to appropriate health care services. Yet, these factors usually happen concurrently and affect access to appropriate or quality health services and, ultimately, mortality and long-term consequences. Most studies applying quantitative analysis approaches usually consider maternal socioeconomic and demographic variables such as gender, age, education, wealth position and religion but leave out the mechanisms through which these factors are associated with health services access. Analysis through regression models or stratifying by these variables may not provide the complexity of health care access. Going beyond the "hardware" factors that inhibit service delivery, there are other health services systems' "software" factors that affect access to appropriate services, which include power, trust, leadership and management skills, institutional culture and norms, and (unclear) policy

implementation and governance processes (Campos & Reich, 2019; Gilson et al., 2017; Hay et al., 2019; Jacobs et al., 2012; Kabir et al., 2011; Mukuru et al., 2021). There is an interaction between the hardware and software factors and across two domains; however, this complexity is usually overlooked. As such, few studies have studied such health systems' complexity (Bigdeli et al., 2013). Besides, these may be difficult to study quantitatively.

In Chapter 6 of this thesis, I challenge the available frameworks and approaches to the health system by understanding how multiple factors concurrently affect access to appropriate services. For example, I consider how health facilities and community social systems affect obstetric and child health care access. The aim is not to "rubbish" the existing frameworks but to build on them to generate realistic frameworks that contribute to having a clear package or set of interventions.

1.6. Aim and objectives of the thesis.

In previous sections of this chapter, I have discussed how social and health care systems significantly shape child morbidities and mortality patterns, asserting the need to understand how the environment and the operation of the social and health systems impact children's health and survival. However, the inadequacies in applying the social system approach in health research make the exploration and explanation of health systems difficult, leading to flaws in designing and implementing realistic interventions. This PhD thesis is based on a series of four interlinked research studies that were written to understand how social and health systems elements shape children's health in their life-course of development in a poor-resource setting. The thesis specific objectives are:

I. To examine the under-10 mortality age-specific estimates, mortality risk factors and causes of death
II. To assess the role of birth weight in mediating new-born mortality and the role of institutional delivery in their association
III. To identify rural-urban differentials in the predictors of children's suspected pneumonia and diarrhoea
IV. To examine how the interaction within the social contextual and the health institutional systems' factors influence children's healthcare access in resource-poor settings

Table 1.5 shows research questions for each of the objectives. Using multiple analytical methods and data sources, the four studies illustrate several aspects that affect healthcare access and children's survival. Additionally, the analytical approaches are applied to illustrate the need for a much broader range of methodologies that are typically combined to guide a comprehensive interpretation of how a combination of human, societal and health facility system problems affect children's health. Thus, the combined papers help us build a more robust life-course framework on child health and survival in resource-poor settings.

Table 1.5: Research questions

Study objectives	Sub research questions	Data Sources
Objective I	What are under-10 age-specific mortality estimates, causes, mechanisms, and risk factors? *i. What are under-10 age-specific mortality estimates?* *ii. How are the causes of mortality among the under-10 differ by the age group?* *iii. How do intrinsic factors at birth, such as low birth weight, associated with children's survival within 10 years after birth?* *iv. How do socioeconomic and maternal characteristics at birth shape children's survival within 10 years after birth?*	2005-2015 Iganga-Mayuge Health and Demographic Surveillance Site
Objective II	What is the role of birth weight in mediating new-born mortality and the role of institutional delivery in their association? *i. Does institutional delivery affect inversely affect the association between LBW and new-born mortality?* ii. *What are some of the new-born mortality factors mediated by low birth weight?* *iii. Are the perinatal and late neonatal mortality factors the same?*	2011-2015 Iganga-Mayuge Health and Demographic Surveillance Site
Study objectives	Sub research questions	Data Sources
Objective III	What are the key household and individual-level predictors of suspected pneumonia and diarrhoea in Uganda? i. *Do the identified predictors differ by place of residence (rural Vs. Urban)?*	2006-2016 Uganda Health Demographic Surveys
Objective IV	What are social contextual and the health institutional systems' factors that influence children's healthcare access in resource-poor settings of eastern Uganda? *i. How do social constraints and opportunities shape appropriate healthcare access?* *ii. How do social network ties, the structure of the community, and the health services' organisation shape access to the appropriate services?*	Primary data collection was collected through in-depth interviews, key informant interviews and focus group discussions.

1.7. The structure of the thesis

In addition to the Introduction (Chapter 1), Data and Methods (Chapter 2) and Conclusions (Chapter 7), the thesis consists of four interlinked sub-studies. The first study, which I report in Chapter 3, addresses objective I, where I applied a life-course and systemic perspectives in analysing and interpreting the data to understand the under-10 mortality age-specific estimates, mortality risk factors and causes of death. I analysed a decade (2005-2015) of event histories data

on 22385 and 1815 verbal autopsies data collected by Iganga-Mayuge HDSS in eastern Uganda. I used the lifetable for mortality estimates and patterns and the Royston-Parmar survival analysis approach for the assessment of mortality risk factors. I follow the international classification of diseases (ICD-11) to analyse causes of death patterns. In the same chapter, I present descriptive statics on the timing of access to obstetric care access and health care services for sick children and morbidity in pregnancy. Such a holistic approach guides the generation of prevention and healthcare interventions that not only improve the children's survival but also being able to thrive and transform. These results have been published in a peer-reviewed journal (https://doi.org/10.1371/journal.pone.0234573)

The second study, which I report in Chapter 4, addresses objective II and builds on the results of the first paper, where preterm and LBW are identified as the major cause of mortality. In this chapter, I used the 2011-2015 event histories health demographic data collected by Iganga-Mayuge HDSS to examine how birth weight mediates new-born mortality and the role of institutional delivery in their association. The dataset consisted of 10,758 registered women whose birth occurred at least 22 weeks of the gestation period and records of new-borns living status within 28 days after birth. The motive arises from Uganda's unchanged neonatal mortality rates for the last 2 decades, despite the remarkable increase in health facility delivery. Yet, health facility delivery has been indicated as the most effective intervention in averting neonatal mortality. The "puzzle" is if the designed interventions properly address the challenges. Specifically, the chapter presents the groups of new-borns at high risk of mortality and critical time of death. The study results provide an insight into new-born survival life-course and health systems interventions, particularly targeting the prevention of LBW occurrences and management of or care for LBW new-borns. These results have been published in a peer-reviewed journal (https://doi.org/10.1136/bmjopen-2020-046322).

The third study, which I report in Chapter 5 responds to objective III and builds on the results of the first paper that indicated pneumonia and diarrhoea as the top five causes of child mortality. In this chapter, I applied machine learning (ML) techniques to 2006-2016 Uganda DHS data to identify rural-urban differentials in the predictors of child's diarrhoea and ARI. To the best of my knowledge, this study is the first to apply an algorithmic modelling approach to identify the household and individual predictors of pneumonia and diarrhoea in LMICs settings based on cross-sectional surveys. The analysis approach contributes to the knowledge of the application of ML in the population health and social science field. Additionally, the results inform the decision-makers in public health work on which variables or measurements should be used while reaching those in need of services. Further, understanding the priority risk factors by place of residence help in developing and implementing area-specific interventions. The study manuscript has been accepted for publication in the journal of PLOS Global Public Health (https://doi.org/10.1371/journal.pgph.0000430).

The fourth study, which I report in Chapter 6, responds to objective IV and builds on the first and second studies' results on new-born mortality causes and access to obstetric and child health care. In this chapter, I used qualitative data to examine how the interaction within the social contextual

and the health institutional systems factors influence children's healthcare access in resource-poor settings of eastern Uganda. The findings are based on in-depth interviews with mothers who experienced pregnancy or new-born death, focus group discussions with mothers and fathers' children aged 0-59 years of age, and key informant interviews with public health workers. The study goes beyond examining individual factors such as biological, socioeconomic status, sex, gender, and race to understand how relationships and interactions between such factors and across multiple levels of society shape a particular population group's health. The findings unmask the differences within population groups that are often viewed as homogenous, thus providing a detailed understanding of differences in vulnerabilities and the complex nature of health inequalities. Additionally, the findings illustrate how differences in the populations' well-being are shaped by the interaction of different social identities such as marital status, family networks, age, geography, and family socioeconomic position. The study manuscript will be submitted to the Social Science and Medicine or BMJ Global Health.

CHAPTER TWO
DATA AND METHODS

2.1. Study setting

This thesis is based on the Iganga-Mayuge HDSS event histories data, the qualitative data collected in Iganga and Mayuge districts, and the Uganda demographic and health surveys data.

Iganga and Mayuge districts are located in central-eastern Uganda, and like other districts in the country, the largest population (80%) live in rural communities (Uganda National Population Council, 2018). Iganga and Mayuge districts have 49 and 55 Health Centres (HC), respectively (Uganda Ministry of Health, 2018b), serving an average population of 500,000 in each district (Uganda Bureau of Statistics, 2016). Close to 18% and 15% of the HC in Mayuge district are clinics (private for profit) and private not for profit, respectively (Uganda Ministry of Health, 2018b). Additionally, close to 20% and 24% of the HC in Iganga district are clinics (private for profit) and private not for profit, respectively (Uganda Ministry of Health, 2018b). An estimate of 27% and 15% are government or private-not-for-profit facilities that can provide maternal deliveries (HC III and HC IV) in Iganga and Muyuge, respectively. One referral public hospital serves the two districts and the other four neighbouring districts (Luuka, Bugiri, Namutumba and Kaliro). The health staffing level in the eastern region is 71%, close to the national average of 73% (Uganda Ministry of Health, 2018b).

In Uganda, and as Chapter 3 of the thesis reports, malaria, malnutrition, pneumonia, and diarrhoea are among the top causes of child mortality. Because of pluralism in child health care providers, there are various therapeutic services for treating child morbidities. Before accessing formal health care services, the children's caretakers usually try traditional therapies provided by caretakers, family members, or traditional herbalists – and these are common in rural and urban slums. The formal health institutions also have levels: clinics or drug shops, lower public health facilities, middle level public and private health facilities, and higher-level public and private health facilities. Normally, access to each of these levels of services depends on the family's wealth position and place of residence. The clinics or drug shops are the lowest private level facilities that are usually close to the community and in a rural and urban slum setting and are unregulated (WHO 2017).

According to Uganda's health structure flow (WHO, 2017), the HC IIs are based at the parish level and largely provide only outpatient services with an Enrolled Comprehensive Nurse running the facility. The HC IIIs are based at the sub-county level and offer basic preventive and curative outpatient services, inpatient care (largely through general and maternity wards), and laboratory services. HC IVs are based at the county or district level providing preventive, promotive and curative outpatient, maternity, inpatient health services, emergency surgery and blood transfusion and laboratory services; Hospitals are based at the district or regional or national level as teaching, research institutions in addition to handling emergencies. With unavailable estimates on informal providers such as drug shops, clinics and traditional healers, most of the country's population seek

care from informal providers (WHO, 2017). Additionally, almost 30% of the health facilities are not within the 5 km recommended distance (Government of Ministry of Health 2015). Similarly, nearly 30% of the required health workers' posts are not filled (Uganda Ministry of Health, 2018b), and 44.7% is an estimate of health workers' absenteeism (Uganda National Population Council, 2018). Section 1.2 of Chapter 1 summarises Uganda's health context regarding child health indicators.

Figure 2.1: Map of Uganda showing regions and districts boundaries

Source: https://reliefweb.int/sites/reliefweb.int/files/resources/76380.pdf

2.1.1. Study area setting field observation case

This field observation case was documented during the collection of qualitative interviews in August 2019. In one of the villages in Kityerera Subcounty (Mayuge district), where my Research Assistant and I conducted interviews with women, we were transported by an old taxi [van used for public transport] from Mayuge town council to Kityerera trading centre. We were told to wake up very early in the morning as there was only one taxi that usually leaves early in the morning to Kityerera at the time of the study. The other means of transport that we could have used in case we missed is a *boda-boda*[11]. The road is murram and bumpy, and the distance from Mayuge town council to Kityerera trading centre is about 30 km. The distance from Kiteyera to the place where

[11] Two tyred motorcycle that is commercially used for the transportation of people in Uganda.

we went is about 5 km, and the means of transport is the *boda-boda* or bicycle. Because of the many *boda-bodas* associated with the increasing demand for fuel, some "petrol stations" are in the form of stalls/kiosks where the fuel is kept in a jerrycan, and fuel is measured in a 300ml bottle at 3,000 Ugx.

The place has poor roads, and during the rainy season, movements by *boda-boda* may be difficult. For instance, while we were travelling to the village, we witnessed a woman travelling with her child (aged about five years) on a boda-boda getting into an accident because it had rained, and the road was bumpy and slippery. The falling resulted in injuries for all three: the rider, woman, and child. On asking the woman where she was going, she said she was taking her child to the health facility for fever treatment. The distance from the place where the accident occurred to the health facility was about 4 km. The public health centre IV is located 30 Km away from the interview venue. The HC IV is also located 30 km away from Iganga and Jinja general hospitals[12]. This means that accessing advanced services that are only provided in these health facilities may be difficult. Returning to the place of residence in the evening, we could not get any vehicle, and the only transport option was a boda-boda, yet it was raining. This scenario indicates how poor access to transport means and roads may make health services access hard even if the health facility is within the recommended 5 km distance. Chapter 6 of the thesis presents how the transport system was a major barrier to health services access in these communities.

Figure 2.2: Field photos illustrating the community transport system

Left – the situation of Iganga and Mayuge districts' rural roads after the rain; right – fuel stall station in a rural setting

2.1.2. Health facility's setting field observation case

This fieldwork observation case was documented in September 2019 while conducting interviews with the health workers at one of the facilities. While interviewing the health workers, later (after

[12] Mayuge district is between Iganga and Jinja district

30 minutes into the interview), we had someone calling [non-medical health worker] – *"Musawo*[13] *Jesca, there is a woman in labour that has arrived. She seems to be in critical condition",* she said. Immediately "Musawo Jesca" left to attend to her, and we remained around observing[14]. The patient had travelled with a female caretaker who was her family relative. I verbally asked the caretaker to tell me how the labour had started. *"The labour started in the morning at around 11:00 pm, but we delayed coming to the health facility because it was at night, and we did not have any means of transport",* she said. *"Even then, we did not have enough money for transport bec ause our village is quite a distance away from this facility, so we had to walk, and when you are in labour, you have to walk slowly",* she added. They reached the health facility at around 11:00 am.

Figure 2.3: Field photo illustration boda-boda as the major means of transport for referral at lower-level facilities

A woman who had come for delivery is being helped to sit on a boda-boda. Because of post-haemorrhage, she was referred to the hospital for further management.

Indeed, the midwife did her work to ensure that the woman delivered well. Unfortunately, the mother got a post-haemorrhage that necessitated her to be referred to the district hospital. The facility had no means of referral transport. The caretaker started mobilising the family members to look for money (I heard her talking on the phone, communicating with different people). She spent at least 30 minutes at the health facility with the caretaker making calls to the relative before being transported. They were later transported using the *boda-boda* that was owned by the VHT attached to the health facility. With nurse's and VHT's, the patient was lifted onto the *boda-boda* to be transported to the district hospital. She sat in the middle holding the rider (and looking at her face, she was in so much pain that she could not let her eyes open or talk to someone), and the caretaker sat behind carrying the baby.

The distance from the facility to the hospital is about 15 Km. We returned to the health facility for some additional research work, and we followed up on this case with the health worker and the

[13] Meaning health worker
[14] We suspended the interview since the health worker became engaged with the patient.

VHT who transported her. We were told that there was no blood when they reached the hospital, and the decision was to refer her to the regional hospital. However, the family had to first look for money by selling some items, which contributed to the delays. Tragically, this woman died and left her new-born baby behind. This case presents multiple barriers that affected appropriate access to health care services. I present in-depth how such multiple barriers affect obstetric and child health care access in Chapter 6 of this thesis.

2.3. Health and demographic surveillance data

Chapter 3 and Chapter 4 findings are based on 2005-2015 anonymised Iganga-Mayuge Health and Demographic Surveillance Site (HDSS) event histories and Verbal Social Autopsy (VSA) data. The HDSS is located in central-eastern Uganda, covering at least 185[15] villages in seven sub-counties within the districts of Iganga and Mayuge, with at least 100,000 registered population, of which 59% live in rural areas (Kajungu et al., 2020). The HDSS is managed by Makerere University Center for Health and Population Research (MUCHAP)—a not-for-profit, semi-autonomous organ of Makerere University. The site is an active member of the International Network for the Demographic Evaluation of Populations and Their Health (INDEPTH) (www.indepth-network.org).

The HDSS routinely collects data on core demographic events of births, deaths and migrations. Each household within the HDSS is geo-referenced, and every household member has a unique identifier. The main data collection tools are household registration, pregnancy registration, pregnancy outcome, and verbal autopsy forms. The household registration form is used to capture household assets, individual socioeconomic and demographic status, and residence status (migration). These data are collected twice a year. The HDSS employs community health workers known as the village health team to register pregnancy registration and pregnancy outcome using registers. The variables collected in these registers include expected date of delivery, maternal age, marital status, birth outcome and date, place of birth and child's gender. In addition, the HDSS employs Field Assistants responsible for verifying the pregnancy and birth outcome registers. The Verbal Social Autopsy information is collected using WHO/INDEPTH Network tools (INDEPTH Network, n.d.). These tools capture VA data for different age groups: Neonates (0-28 days), children (29 days to 14 years), and Adults (15 years and above). The verbal autopsy is usually conducted after mourning days – usually 3-4 weeks after the event.

The data elements under stillbirth and new-born mortality verbal autopsy tool include places of birth, maternal morbidity's experience, childbirth status (live or stillbirth), time the baby died after birth, birth weight, gestation period and causes of death. The data elements for the 29 days-15 years mortality's verbal autopsy tool include treatment before death, the time it takes to receive treatment in days, and death causes. A responsible team of trained physicians assign death causes using the international classification of diseases (WHO, 2012). For all pregnancies, births, and deaths events, a community health worker in each village is responsible for notifying the HDSS within two weeks. Thereafter, the reported events are verified by the HDSS Field Assistants to check for residential status and henceforth use a structured respective standard tool for actual

[15] New villages/cells within the traditional 65 HDSS villages were created.

data collection. The HDSS has standard operating procedures for administering each tool, training, and data management. Refresher training is conducted before the actual days of data collection. In the field, each team of 4 Field Assistants is assigned to a supervisor whose role is to ensure that the data collection standards are adhered to. The forms that only have the supervisor's signature are then submitted to the Field Manager, who later submits them to the data management office. The data is managed by a data scientist team that includes two statisticians, two computer scientists, one data entry supervisor and four data entrants who ensure that the data is well entered and cleaned.

2.4. Uganda demographic and health survey data

In Chapter 5, I used the Uganda Demographic and Health Survey (UDHS) data to determine the community and household predictors of suspected pneumonia and diarrhoea. To have a sufficient dataset for identifying the predictors of this study's outcomes, I pooled the UDHS data collected between 2006 and 2016 and publicly accessed as of March 2020. The DHS uses a multistage, stratified sampling design with households as the sampling unit. The age and sex of each household member are obtained in the household questionnaire used to identify women, men, and children eligible for individual interviews, anthropometry measurement, and anaemia testing. The household questionnaire also collects information on the household's dwelling unit's characteristics, including water source, toilet facilities, materials used for the dwelling unit floor, and ownership of various household items.

The data were pooled using the IPUMS-DHS online system (Boyle, King & Sobek, 2020), by choosing children under five and their related records. This included only children aged 0-59 months born in the five years preceding the survey. During data cleaning, I excluded children who were not staying with the mothers on the interview day for better estimates, which is not in line with the DHS analysis (ICF, 2018) and may lead to differences in the reported estimates of suspected pneumonia and diarrhoea. The premise was that including children that were not living with their parents at the time of data collection may lead to underestimation as mothers may not be sure of their health status in recent days when they were not home. The total sample size for the pooled dataset is 27687 after leaving out children who were not staying with their parents at the time of the interview. Table 2.1 shows the distribution of unweighted sample size across years of data collection.

Table 2.1: Distribution of unweighted sample size across years of data collection

	Sample size of all children				Sample size that only includes children residing with their parents at the time of interview			
Place of residence	2006	2011	2016	Total sample	2006	2011	2016	Total sample
	0-59 months							
Rural	6,746 (88.9%)	5,772 (78.4%)	12,037 (81.8%)	24,555 (82.8%)	6,436 (89.4%)	5,492 (79.6%)	11,222 (82.5%)	23,150 (83.6%)
Urban	847 (11.1%)	1,583 (21.6%)	2,673 (18.2%)	5,103 (17.2%)	763 (10.6%)	1,407 (20.4%)	2,367 (17.5%)	4,537 (16.4%)
Total	7,593	7,355	14,710	29,658	7,199	6,899	13,589	27,687
	6-59 months							
Rural	6035 (89%)	5171 (78.9%)	10824 (81.6%)	22030 (82.7%)	5726 (89.6%)	4894 (80.1%)	10023 (82.4%)	20643 (83.7%)
Urban	747 (11%)	1387 (21.2%)	2445 (18.4%)	4579 (17.2%)	664 (10.4%)	1213 (19.9%)	2142 (17.6%)	4019 (16.3%)
Total	6782	6558	13269	26609	6390	6107	12165	24662

2.5. Qualitative data

2.5.1. Selection of study area and participants

Chapter 6 findings are based on the qualitative data that I collected between June-November 2019 in Iganga and Mayuge districts. The main aim was to examine how multiple barriers concurrently affect access to obstetric and child health care services. The study participants were eligible if they lived or worked within the area for at least six months before the data collection. The qualitative methods included 29 in-depth interviews, 8 focus group discussions and 6 key informant interviews with public health facility workers. Before the actual data collection, I reviewed documents on the distribution of the health facilities across the sub-counties to guide the interview allocation. Based on the distribution list, I made sure that the interviews were conducted in both areas with easy access or hardships in accessing maternal and child health services. The villages were randomly selected from a list of the sub-counties. The in-depth interviews were purposively conducted with women who delivered in the last four months in four villages. The in-depth interviews involved women who had experienced new-born death (death within the first month of delivery, including stillbirths) in the last four months preceding the month of the data collection. The focus group discussions were conducted with women and men whose households had children aged 0-5.

2.5.2. Ethics

Ethical approval

The LSE Research Ethics Committee approved the study (REC ref. 000731). The protocol was also approved by the Makerere University School of Public Health institutional review board (HDREC 674) and Uganda National Science for Technology (HS395ES).

Recruitment and training of research assistants

During data collection, I worked with three Research Assistants (Ras) who understood the study area's context and had experience in collecting verbal autopsy data and conducting FGDs. In addition, two research assistants were assigned to conduct in-depth interviews, while the other was assigned to work with me on conducting focus group discussions and key informant interviews.

Before the actual days of data collection, the research assistants were trained on data ethics, collection and management protocols. The main ethical concern was the collection of data from bereaved mothers and health providers, as I expected emotional risk during the interview process. During the training and fieldwork, I emphasised the importance of providing enough time to the in-depth research participants before and during the interview. Before the interview, the study was explained to the research participants five days before the data collection, and they were later contacted about their decision to participate. In addition, the training of RAs included a session on how to conduct interviews with bereaved participants and the ethics involved. For any emotional distress that arose during interviews, the research participants would be asked if she (respondent) could first take a break or stop the interview. I did not experience any participation denial and consistent with other studies (Dyregrov, 2004; Kalter et al., 2011). Most participants, including those who wept, embraced their interaction with the RAs as one of the women narrates.

> *"I am very happy that someone has reached me to ask for the reasons why my baby died. No one in this community has ever sat with me to ask me why my child died. I now feel relieved, and I hope what I have shared with you will help to improve the health of the community".*

Participants' consent and data confidentiality.

The consent forms were prepared to protect and ensure the dignity and positions of all participants and those who may be affected by the research results. The forms had the contacts of the lead researcher and those of the research authorising institutions. All participants were asked to sign a consent form and were informed about their participation. The consent forms for the health facility workers were in English, while those of community participants were translated into Lusoga Language and were read for those who could not read. In acquiring the participants' consent, we emphasised how the participants could withdraw at any point of the study without giving a reason and how they were free not to respond to the questions that could make them uncomfortable. The consent form was read to those who could not read and later asked to append their thumbprint to approve their participation. The research participants took one copy of the consent form and another retained in the research files (Appendix 8.1.1). We emphasised how we were not interested in the participants' names and asked them to choose a preferred pseudo name for both interviews. In reporting results, I use identification numbers for vignettes, and where photos are used, I ensure that the participants' faces are unidentified.

The women's in-depth interviews were conducted in their homes, while the FGDs were conducted at VHTs homes but in the absence of the VHTs. At the end of the interview, each participant, including the health worker, received a bar of soap equivalent to one pound. All the interviews were audio-recorded and subsequently verbatim transcribed.

2.6. Data Analysis

2.6.1. Analysis of event histories data

I used the HDSS event history data to estimate the age-specific mortality patterns and risk factors presented in Chapters 3 and 4 of this thesis. The HDSS data manager provided the dataset with the variables indicated in Table 2.2.

The residents' live births, migration out of the HDSS for less than 6 months and in-migration for at least 6 months were considered for analysis. The HDSS in-migrants are considered residents if they stayed within HDSS for at least 6 months, and out-migrated are considered residents for fewer than 6 months before returning to the HDSS. The study's primary outcome is an event (death) that is experienced after "alive" birth by time t (10^{th} birthday). The cleaning and analysis of data were done in STATA version 15. Details of how the data was analysed and the variables considered are explained in the following subsections.

Table 2.2: HDSS variables and description

Variables	Description of variables
mother id	HDSS family member unique identification number
child identification	
Birth outcome,	Birth outcomes recoded as LBR-live birth and STB-stillbirth
Status of child	Assessment of if the registered child is alive or dead at follow-up. This is recorded as OBE-still under observation, DTH- Death, OMG – out-migration, LBR – live birth, STB – stillbirth
end date of the individual's episode	Date the event occurred
Delivery place	Place where the child delivery was coded as private health facility, public health facility, traditional birth attendance's home, home, and en-route to the place of delivery.
Mother religion	The religion of the mother
District	Residence – district
Parish	Residence – parish
Village	Residence – village
Sub-county	Residence – sub-county
Childbirth weight	Weight of the child at birth. This is captured from the child's immunization certificate
Gender	sex of the child
Birth category	Number of children born at birth was recorded in numbers
Marital status	The mother's marital status was coded as married, single, cohabiting, widowed, and separated.
Mother date of birth	Mother's date of birth was recorded in complete dates.
Wealth	Household wealth index calculated based on the households' assets using principal component analysis
education level	The mother's education level was recorded as none, primary level, secondary level, advanced level, and tertiary level.
Childbirth order	Child pregnancy position was recorded in numbers

2.6.2. Estimation of under 10 mortality patterns

I applied a life table approach to assess child age-specific mortality estimates reported in Chapter 3 of this thesis. For the life table computation, let t be the interval time $x, x-n, I_t$– be the number of participants who are at risk during interval t, D_t– number of participants who die during interval t, $C_{\frac{t}{2}}$ – number of participants who are censored during interval t, N_t^* - the average number of participants at risk during interval t, q_t– proportion dying during interval t, p_t– proportion surviving interval t, S_t– the proportion surviving past interval t (cumulative survival probability).

$$q_t = \frac{D_t}{N_t^*} \qquad (2.1)$$

$$p_t = \quad 1 - q_t \qquad (2.2)$$

$$N_t^* = I_t - C_{\frac{t}{2}} \qquad (2.3)$$

$$S_t = P_{t+1} * S_{t-1} \qquad (2.4)$$

$$F_t = 1 - S_t \qquad (2.5)$$

Note that the calculation of N_t^*assumed the occurrence of events of interest at the end of the interval, and the censored events are assumed to occur uniformly or evenly throughout the interval. Therefore, an adjustment on the initial number of participants for each time interval (I_t) was made to reflect the average number of participants at risk during the interval t.

2.6.3. Assessing the under-10 mortality risk factors' patterns

To assess the under-10 mortality risk factors reported in Chapter 3 of this thesis, Royston-Parmar (RP) flexible parametric model for survival analysis was performed using *stpm2* user-written STATA command (Royston & Lambert, 2011) with individual-level clustering while controlling for all covariates after multiple imputations. The approach was used because of its flexibility as compared to other survival parametric models such as the exponential and Weibull models(Royston & Lambert, 2011). Further, death among children has a monotone hazard rate that reduces with time, which is suitable for the RP method. Give the cumulative hazard function linked to the survival function as;

$$H_t = -ln(S_t) \qquad (2.6)$$

$$H_t = H_{0t}\, e^{x\boldsymbol{\beta}} \qquad (2.7)$$

$$ln(-ln\,(S_t) = ln(-ln\,(S_{0t}) + x\beta \qquad (2.8$$

Equation 2.8 may be generalised as;

$$g_\theta(S_t) = g_\theta(S_{0t}) + x\beta \qquad (2.9)$$

Where $g_\theta(.)$ is a monotonic increasing function, depending on the parameter θ. This was considered as Aranda-Ordaz's (Aranda-Ordaz, J., 1981) function.

$$g_\theta(x) = ln\left(\frac{x^{-\theta} - 1}{\theta}\right) \qquad (2.10)$$

Where $\theta > 0$. As θ tends to 0, $g_0(x) = \ln(-lnx)$ so that if $\theta = 0$, we get a proportional-hazard model (2.8).

When $\theta = 1$, then $g_1(x) = \ln(x^{-1} - 1) = \ln\left\{\frac{(1-x)}{x}\right\}$. Writing $x = S_t$ yields equation 2.11.

$$g_1(S_t) = \ln\left\{\frac{(1 - S_t)}{S_t}\right\} \qquad 2.11$$

From the standard survival model, $F_t = 1 - S_t$ and $S_t = 1 - F_t$ as a cumulative distribution function {probability of failure or survival in an interval (0, t)}

$$g_1(S_t) = \ln\left\{\frac{(F_t)}{1 - F_t}\right\} \qquad 2.12$$

Thus $g_1(S_t)$ is the logit of the cumulative distribution function and the covariates effects are proportionated on the scale of the cumulative odds of an event. Equation 2.8 presents the survival model under RP family and the transformed survival function $g_1(S_t)$ can be estimated by a restricted cubic spline. However, since the focus was on the hazard rates, the transformed hazard function was;

$$g_1(F_t) = \ln\left\{\frac{(1 - F_t)}{F_t}\right\} = \ln\left\{\frac{(S_t)}{1 - S_t}\right\} = -\ln\left\{\frac{(1 - S_t)}{S_t}\right\} \qquad 2.13$$

Therefore, in the analysis using $stpm2$ user-written STATA command, the *scale* category considered was a hazard at 3 degrees of freedom. The 3 degree of freedom is the same as a spline with 2 interior knots (Royston & Lambert, 2011), which provides better estimates(Royston & Lambert, 2011). Further, the hazard probability graphs were generated to assess how the mortality varies across the child's age for each risk factor. The censoring was done at 120 months (10 years), and the analysis was restricted to children born alive. The study covariates are LBW (<2.5 Kgs), maternal age, marital status, household wealth index, maternal education level, child sex, place of residence, and birth category (multiple or singleton).

2.6.4. Assessing Mediation role of low birth weight in the association of new-born mortality risk factors

To assess the mediation role of LBW on the factors associated with new-born health and the role of institutional delivery moderating the association between LBW and new-born mortality reported in Chapter 4 of the thesis, I analysed a cohort of births registered between 2011-2015. The outcome variables (LBW, prenatal mortality, late neonatal mortality) were in the form of binary, with 1 – indicating the presence of outcome exposure and 0 – the absence of outcome exposure. Considering new-born mortality as a rare event, I ran a model for rare events known as

the firth logistic model (Coveney, 2008) to assess the sample size bias for perinatal mortality, late neonatal mortality, and LBW coefficient estimates. Comparing the firth logit model results with the logistic regression model, I found consistent results (Table 2.3).

Because of the consistencies in results generated through logistic and firth logit models, I later decided to use logistic modelling because of the lower computing time while running imputed data as compared to the firth logit model. I, therefore, used a generalised linear modelling approach with a logit link function. To examine the new-born mortality pathway, several analysis steps were applied. First, bivariate model(s) with all covariates on the perinatal, late mortality and LBW as outcome variables were performed to identify the variables that would significantly affect these outcomes of interest in the adjusted models.

Let y_i represents the outcome of interest as a binary variable (i) that takes the probability of the presence of the outcome's exposure as P and the probability of absence of the outcome's exposure as 1-P. The bivariate regression model would be of the form as in Eq. 2.14

$$ln\left(\frac{P_j}{1-P_j}\right) = \alpha_i + \beta_i x_i \qquad (2.14)$$

Table 2.3: Logistic and firth logit bivariate analysis using 2011-2015 Iganga-Mayuge event history data.

	Perinatal mortality				Late neonatal mortality			
	Logit		Firth logit		Logit		Firth logit	
	OR	P-value	OR	P-value	OR	P-value	OR	P-value
Annual birth quarters								
1	1.00	-	1.00	-	1.00	-	1.00	-
2	1.08	0.63	1.08	0.63	1.55	0.41	1.51	0.42
3	1.26	0.14	1.26	0.14	1.63	0.35	1.58	0.36
4	1.20	0.27	1.20	0.27	1.43	0.51	1.40	0.52
Childbirth weight								
<2.5 Kgs	2.52	<0.001	2.53	<0.001	2.37	0.05	2.45	0.04
25 Kgs+								
Maternal education level								
None	1.69	<0.001	1.70	<0.001	1.37	0.49	1.46	0.39
Primary+	1.00	-	1.00	-	1.00	-	1.00	-
Place of delivery								
Health facility	1.01	0.91	1.01	0.93	1.22	0.61	1.18	0.67
Community	1.00	-	1.00	-	1.00	-	1.00	-
Maternal age (years)								
<20	1.12	0.46	1.13	0.42	0.88	0.80	0.97	0.95
20—29	1.00	-	1.00	-	1.00	-	1.00	-
30+	1.48	<0.001	1.48	<0.001	1.73	0.12	1.74	0.11
Childbirth order								
1	0.80	0.07	0.80	0.07	0.70	0.32	0.71	0.33
2—4	1.00	-	1.00	-	1.00	-	1.00	-
5th+	0.46	0.06	0.49	0.07	2.20	0.20	2.52	0.10

OR – Odds Ratio

Table 2.3 continued

	Perinatal mortality				Late neonatal mortality			
	Logit		Firth logit		Logit		Firth logit	
	OR	P-value	OR	P-value	OR	P-value	OR	P-value
Place of residence								
Urban	1.00	-	1.00	-	1.00	-	1.00	-
Rural	1.40	0.01	1.39	0.01	0.77	0.45	0.76	0.43
Marital status								
No partner	1.00	-	1.00	-	1.00	-	1.00	-
Has a partner	0.74	0.07	0.74	0.07	0.63	0.31	0.60	0.24
Experienced neonatal or pregnancy loss previously								
No								
Yes	4.18	0.00	4.20	<0.001	3.60	0.01	3.89	0.00
Birth category								
Singleton	1.00	-	1.00	-	1.00	-	1.00	-
Multiple	1.02	0.96	1.08	0.83	7.70	<0.001	8.31	0.00
Child sex								
Male	1.00	-	1.00	-	1.00	-	1.00	-
Female	1.06	0.68	1.06	0.68	0.57	0.12	0.58	0.12
Household Wealth								
Poor(er) (1-2)	1.10	0.43	1.10	0.43	0.73	0.39	0.75	0.41
Less poor (3-5)	1.00	-	1.00	-	1.00	-	1.00	-

OR – Odds Ratio

Where j represents categories of perinatal, late neonatal mortality, and LBW, x_i covariates of choice for each of the outcomes and β_i their respective coefficients.

To assess the moderation effect of health facility delivery on the effect of LBW on perinatal mortality (*pm*), an interaction term between the LBW and institutional delivery (*hf*) was introduced as indicated in Eq. 2.15.

$$ln\left(\frac{P_{pm}}{1-P_{pm}}\right) = \alpha_i + \beta_{lbw}x_{lbw} + \beta_{hf}x_{hf} + \beta_{lbw*hf}(x_{lbw} * x_{hf}) \qquad (2.15)$$

Subsequently, a multivariable regression model controlling for other factors added on eq. 2.17 was run (Eq. 2.16). In this model, I also assessed how the intersection between birth order and maternal age would affect perinatal mortality.

$$\begin{aligned} ln\left(\frac{P_{pm}}{1-P_{pm}}\right) = {} & \alpha_i + \beta_{lbw}x_{lbw} + \beta_{hf}x_{hf} + \beta_{Age}x_{Age} + \beta_{educ}x_{educ} + \beta_{birth\ order}x_{birth\ order} \\ & + \beta_{multiple\ birth}x_{multiple\ birth} + \beta_{wealth}x_{wealth} \\ & + \beta_{nm\ expreinced\ preiviously}x_{nm\ expreinced\ preiviously} + \beta_{sex}x_{sex} \\ & + \beta_{birth\ quarter}x_{birth\ quarter} + \beta_{marital\ status}x_{marital\ \ status} \end{aligned} \qquad (2.16)$$

The independent variables that were included under the multivariate regression model for the late neonatal mortality (*nm*) are as indicated in Eq. 2.17

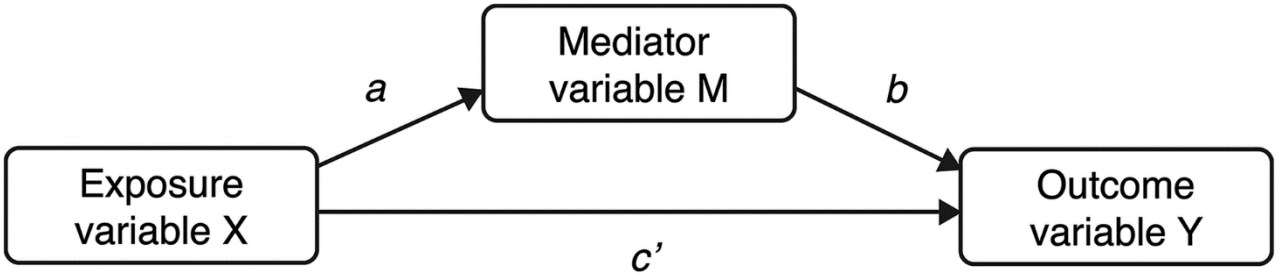
$$ln\left(\frac{P_{nm}}{1-P_{nm}}\right) = \alpha_i + \beta_{lbw}x_{lbw} + \beta_{Age}x_{Age} + \beta_{educ}x_{educ} + \beta_{birth\ order}x_{birth\ order} + \beta_{multiple\ birth}x_{multiple\ birth} + \beta_{wealth}x_{wealth} + \beta_{nm\ expreinced\ preiviously}x_{nm\ expreinced\ preiviously} + \beta_{sex}x_{sex} + \beta_{birth\ quarter}x_{birth\ quarter} + \beta_{marital\ status}x_{marital\ \ status} \quad (2.17)$$

The mediating variable was selected if the predetermined endogenous – in this case, LBW was strongly associated with the primary outcome variable in the multivariate model. The effect of selected covariates on LBW was determined using a multivariate regression model as indicated in Eq. 2.18

$$ln\left(\frac{P_{lbw}}{1-P_{lbw}}\right) = \alpha_i + \beta_{age}x_{age} + \beta_{educ}x_{educ} + \beta_{birth\ order}x_{birth\ order} + \beta_{multiple\ birth}x_{multiple\ birth} + \beta_{wealth}x_{wealth} + \beta_{nm\ expreinced\ preiviously}x_{nm\ expreinced\ preiviously} + \beta_{sex}x_{sex} + \beta_{birth\ quarter}x_{birth\ quarter} + \beta_{marital\ status}x_{marital\ \ status} \quad (2.18)$$

The total and indirect effects were estimated based on (Rijnhart et al., 2019) recommendation for binary outcomes and mediators, where given a mediation model (Figure xx), indirect effect is estimated as *ab* and proportion mediated based on multiple regression estimated as *ab*/(*ab* + *c'*).

Figure 2.4: Path diagram of a relatively simple mediation model



Source: (Rijnhart et al., 2019)

For instance, using Eq. 2.16 and Eq. 2.18, the indirect effects were calculated as indicated in Eq. 2.19.

$$indirect\ \ effect_i = \beta_{lbw\ i} * \beta_{lbw}x_{lbw} \quad (2.19)$$

Total effects were calculated as

$$total\ effect = \frac{\beta_{lbw\ i} * \beta_{lbw}x_{lbw}}{\beta_{lbw\ i} * \beta_{lbw}x_{lbw} + \beta_{pm\ i}} \quad (2.20)$$

Where, $\beta_{lbw}x_{lbw}$ represents LBW coefficient in the PM model, $\beta_{lbw\ i}$ represents variable coefficient in the LBW model and $+\beta_{pm\ i}$ represents variable coefficient in the PM model that matches $\beta_{lbw\ i}$.

2.6.5. Missing data and multiple imputations for event histories data

The HDSS data that was used under Chapters 3 and 4 had issues with the missing field in some data variables. Birth weight, wealth index, and Marital status records were missing among 64%, 22.3%, and 29% of registered birth records, respectively (Table 2.4). For all other variables, data were missing for <1% of the study participants (Table 2.4).

To check if the missingness status was missing completely at random or missing at random, I ran a model of missing dummies (0: not missing and 1: missing), controlling for variables that I expected to increase the probability of missingness.

$$ln\left(\frac{P_{ij}}{1-P_{ij}}\right) = \alpha_i + \beta_{1i}x_{i1} + \ \ldots\ldots\ldots + \ \beta_{ki}x_{ik} \qquad (2.21)$$

where P_{yi} is a proportion of missingness i for outcome j.

Table 2.4: Distribution of individual characteristics for completed and imputed data using the 2005-2015 birth registration dataset.

	Complete		Missing		% Imputed
	Freq.	%	Freq.	%	
Overall total	*22,385*	*100.0*	-	-	-
Sex					
Male	11,192	50.0	-	-	-
Female	11,193	50.0	-	-	-
Total	*22,385*	*100.0*	*0*	*0.0*	-
Birth Category					
Singleton	21,599	97.5	-	-	97.5
Multiple	564	2.5	-	-	2.5
Total	*22,163*	*100.0*	*222*	*1.0*	*100.0*
Birth weight					
>=2.5 Kg	7004	86.9	-	-	85.5
Low birth weight	1059	13.1	-	-	14.5
Total	*8063*	*100.0*	*14,322*	*64.0*	*100.0*
Place of residence					
Urban	7461	33.3	-	-	-
Rural	14,924	66.7	-	-	-
Total	*22,385*	*100.0*	*0*	*0.0*	-
Maternal age [16]					
<20	993	4.4	-	-	-
20-29	9737	43.5	-	-	-
30+	11,655	52.1	-	-	-
Total	*22385*	*100.0*	*0*	*0.0*	-
Marital status [17]					
Not married	2113	11.7	-	-	12.8
Married	15,902	88.3	-	-	87.2
Total	*18,015*	*100.0*	*4,370*	*19.5*	*100.0*

[16] – *because of the possibility of non-linearity between age and childhood mortality a restricted cubic splines analysis was used to determine the age-group, from which the childhood mortality was a u-shaped with mortality being higher among those aged below 20 and 30+ years.*

[17] – *the married women included those who were both officially married and cohabiting, while the unmarried women included those staying alone, widowed and divorced or separated.*

Table 2.4 continued

	Complete		Missing		% Imputed
	Freq.	%	Freq.	%	
Overall total	*22,385*	*100.0*	-	-	-
Education level					
None	5931	26.5	-	-	-
Primary	10,856	48.5	-	-	-
Post-primary	5598	25.0	-	-	-
Total	*22,385*	*100.0*	*0*	*0.0*	-
Wealth index [18]					
Index 1-2	8650	49.8	-	-	47.2
Index 3	3758	21.6	-	-	21.0
Index 4-5	4974	28.6	-	-	31.8
Total	*17,382*	*100.0*	*5003*	*22.3*	*100.0*

Table 2.5: Determinants of birth weight, wealth, and marital status missingness in birth registration dataset

	Low birth weight missing		Wealth status missing		Marital status missing	
	OR	P-value	OR	P-value	OR	P-value
Place of birth						
Public health facilities	1.00					
Community delivery	2.28	<0.001	-	-	-	-
Private Clinics	2.10	<0.001	-	-	-	-
Place of residence						
Urban	1.00		1.00		1.00	
Rural	1.35	<0.001	0.45	<0.001	0.66	<0.001
Time of child death						
Child died after day one			-	-	-	-
First day or stillbirth	2.05	<0.001	-	-	-	-
Education level						
None	1.00	-	1.00	-	-	-
Primary	0.30	<0.001	0.83	0.018	-	-
	Low birth weight missing		Wealth status missing		Marital status missing	
	OR	P-value	OR	P-value	OR	P-value
Post-primary	0.20	<0.001	1.01	0.918	-	-
Age group (in years)						
<20	1.00	-	1.00	-	1.00	
20-29 years	1.17	0.032	0.80	0.036	0.51	<0.001
30 and above	2.01	<0.001	0.42	<0.001	0.20	<0.001
Marital status						
Not married	-	-	1.00		-	-
Married	-	-	1.57	<0.001	-	-

[18] – *household wealth index was calculated through principal component analysis, and the items included were electricity, cassette, radio, fan, television, telephone, bicycle, fridge, television, generator, bicycle, fridge, motor vehicle and motorcycle ownership, household floor structure, household wall and roof structures, type of fuel used for cooking*

For birth weight, I found that the likelihood of missing was highly associated with those who did not deliver in the health facilities and those born as stillbirths or died immediately after birth (Table 2.6) – indicating a possibility of birth weight missing at random. Similarly, the likelihood of wealth index was highly associated with the maternal age of less than 20 years (Supplement Table 1) – indicating a possibility of the wealth index missing at random. The consideration of missing at random is based on the assumption that the missingness of variables' fields depends on some of the observable variables (Carpenter & Kenward, 2013; Pampaka et al., 2016). Given the determinants of missingness, I ran multiple imputations (m=100), controlling for identified factors that contribute to the likelihood of missingness and all other variables (as auxiliary) in the dataset. The multiple imputation method has been indicated as an essential approach for minimising the missingness bias (Graham et al., 2007). This does not depend on the magnitude of missingness (Lee & Huber, 2011; Madley-Dowd et al., 2019). After imputation, LBW was found to be underestimated for completed cases data (Figure 2.4), while the household's poor status was found to be overestimated for completed cases data (Figgure 2.5).

Figure 2.5: Comparing the LBW and household poor status for imputed and completed cases

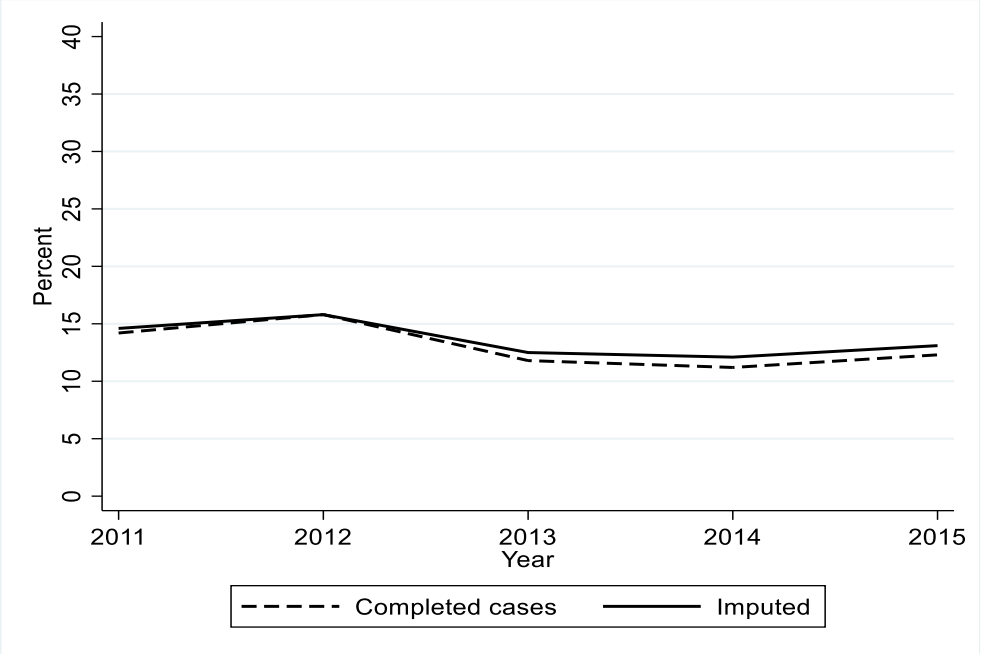
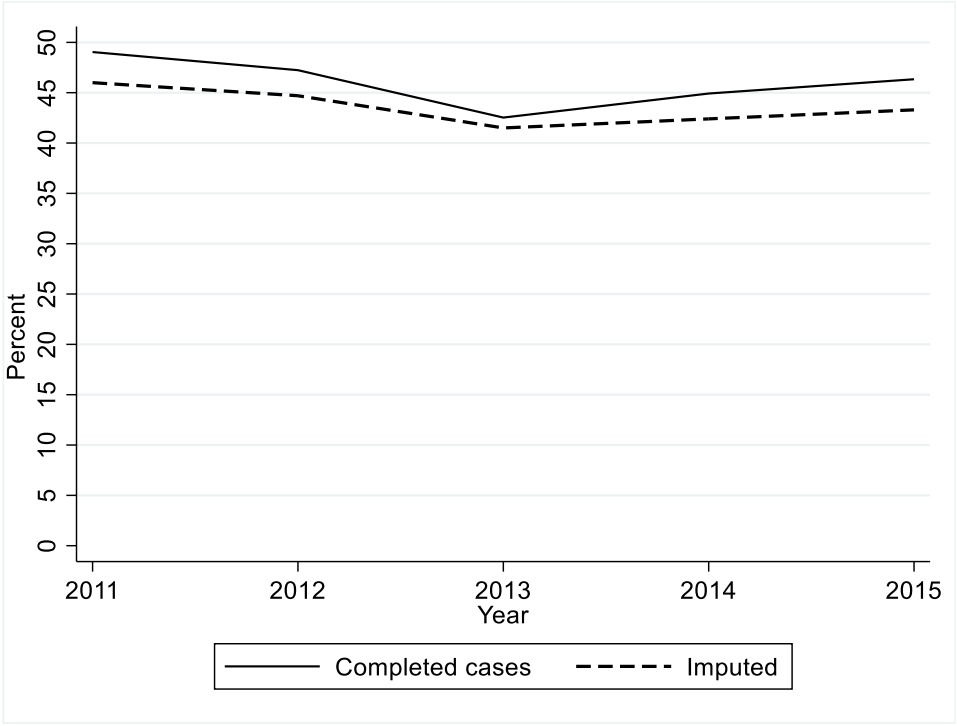


Figure 2.6: Comparing wealth index (1 and 2) imputed and complete case analysis estimates



2.6.6. Causes of death.

The causes of death results reported in Chapter 3 of this thesis were based on the VSA data on 844 neonatal deaths, including stillbirths and 986 children (1 month-10 years). The VSA data were provided as a separate file, and one of the limitations was that the data could not be linked to the event histories dataset. Based on the HDSS data manager's explanation, this limitation arises from the fact that during the collection of verbal autopsy data, the data collectors were not assigning the VSA form with the standard HDSS household and individual identifiers, which makes it hard to merge the two. Because of the limitation of linking the VSA data to the event histories data, the cause-specific mortality probabilities and rates cannot be estimated directly. Additionally, the dataset did not include all the variables that could be used to assign the causes of death using the available software algorithm such as InSilicoVA (McCormick et al., 2016) or SmartVA (Serina et al., 2015) or InterVA (Byass et al., 2019). Thus, the results only depend on the causes of death that the Physicians assigned. The Physicians follow the international classification of diseases (ICD-11).

2.6.7. HDSS birth registration data quality issues

While I never comprehensively assessed the quality of HDSS data, the limitations of HDSS, including stillbirth and newborn underestimation resulting, birth weight heaping, and causes of death missclassificantion are well known (Akuze et al., 2020; Amek et al., 2018; Anker, 1997; Biks et al., 2021; Blencowe et al., 2021; Chandramohan et al., 2001; Channon et al., 2011; Herrera et al., 2017; Kadobera et al., 2017; Nareeba et al., 2021). In this thesis, the inconsistencies in the proportion of births and deaths registered by Iganga-Mayuge HDSS over the years highlight the quality issues with birth and death registration data (Table 2.6). Moreover, the migration that could have affected such inconsistencies was insignificant. I used the birth concertation index or birth displacement (Eq. 2.24)) to measure the quality of birth registration data.

$$Birth\ concetration\ index\ (Bi) = 100 * \frac{2 * B_t}{B_{t-1} + B_{t+1}} \qquad (2.22)$$

where B_{t-1}, B_t, and B_{t+1} are the number of births in the t−1, t, and t+1 calendar years. The index Bi should be close to 100. A value of less than 100 implies fewer births than expected for year t. Table 2.8 shows the annual birth and death registration and birth concentration index.

Table 2.6: Assessing the number of registered births in Iganga-Mayuge HDSS between 2005-2015

Year of HDSS entry	Total birth registration	Outmigration after registration	Death among registered at birth	B_{t+1}	B_{t-1}	$100 * \frac{2 * B_t}{B_{t-1} + B_{t+1}}$
2005	1179	2	95	2154		
2006	2154	4	155	2038	1179	133.9
2007	2038	5	134	2174	2154	94.2
2008	2174	2	194	2143	2038	104.0
2009	2143	5	182	2309	2174	95.6
2010	2309	2	158	2356	2143	102.6
2011	2356	2	164	2328	2309	101.6
2012	2328	1	157	2208	2356	102.2
2013	2208	0	124	1932	2328	103.7
2014	1932	2	104	1939	2208	93.2
2015	1939	0	81			
Total	22760	25	1548			

Using the cut off as Bi >=95 for No under registration 90< Bi<95 – little under registration problem and Bi<90 – Serious under registration, there were little under documentation of birth problem in 2014 and 2007 (Table 2.8).

Table 2.7: Comparing the number of deaths reported in verbal autopsy and birth registration datasets

	Stillbirth			**New-born mortality**		
Year of event	*Verbal autopsy*	*Birth registration and follow-up*	*% Point difference*	*Verbal autopsy*	*Birth registration and follow-up*	*% Point difference*
2011	37	29	21.6	74	51	31.1
2012	33	23	30.3	52	54	-3.8
2013	42	25	40.5	72	49	31.9
2014	29	20	31.0	65	47	27.7
2015	44	31	29.5	45	36	20.0
Total	**185**	**128**	**30.8**	**308**	**237**	**23.1**

In terms of data systems interoperability or linkage, the number of children reported in the causes of death data did not to match the number reported in the birth registration and follow-up dataset (Table 2.7). For instance, considering the data collected between 2011 and 2010, the total number of deaths in the verbal autopsy dataset is 26% points higher than the number of deaths reported in the birth registration and follow-up dataset. In addition, stillbirth and new-born death reported in the verbal autopsy data are higher than the number registered in the birth registration and

follow-up dataset. Nonetheless, this is expected as the causes of death data captures death outside the HDSS but buried in the HDSS catchment.

2.6.8. Predicting community and household factors for suspected pneumonia and diarrhoea

To identify the community and household predictors of suspected pneumonia and diarrhoea, I used two models based on ML techniques and a traditional logistic regression model to select the best model that predicts the probability of ARI and diarrhoea prevalence. The ML models were lasso logistic and gradient boosting machine. Based on the theoretical framework, including available literature (Kamal et al., 2015; Kandala et al., 2008; Mosley & Chen, 1984), the predictor variables (Supplement 2) that could be associated with the occurrence of diarrhoea and ARI were entered in all the ML models. Instead of generating a latent variable or index that is normally done through principal component or factor analysis, for instance assent index (a measure of wealth) that is based on the list of household assets and environmental index that is based on the household environmental characteristics, all the variables (Appendix 5.9) were included in the models to determine those that were substantial in predicting the occurrence of diarrhoea and ARI. Furthermore, in Uganda, the vaccines included in this manuscript are administered to children at the of 6 months. As such, the modelling only considered children aged 6-59 months. However, before the modelling, I first assessed the association of diarrhoea and ARI with child age, which showed a steep curve in diarrhoea and pneumonia at 6 – indicating how quickly child health can worsen within this period (**Figure 2.6**).

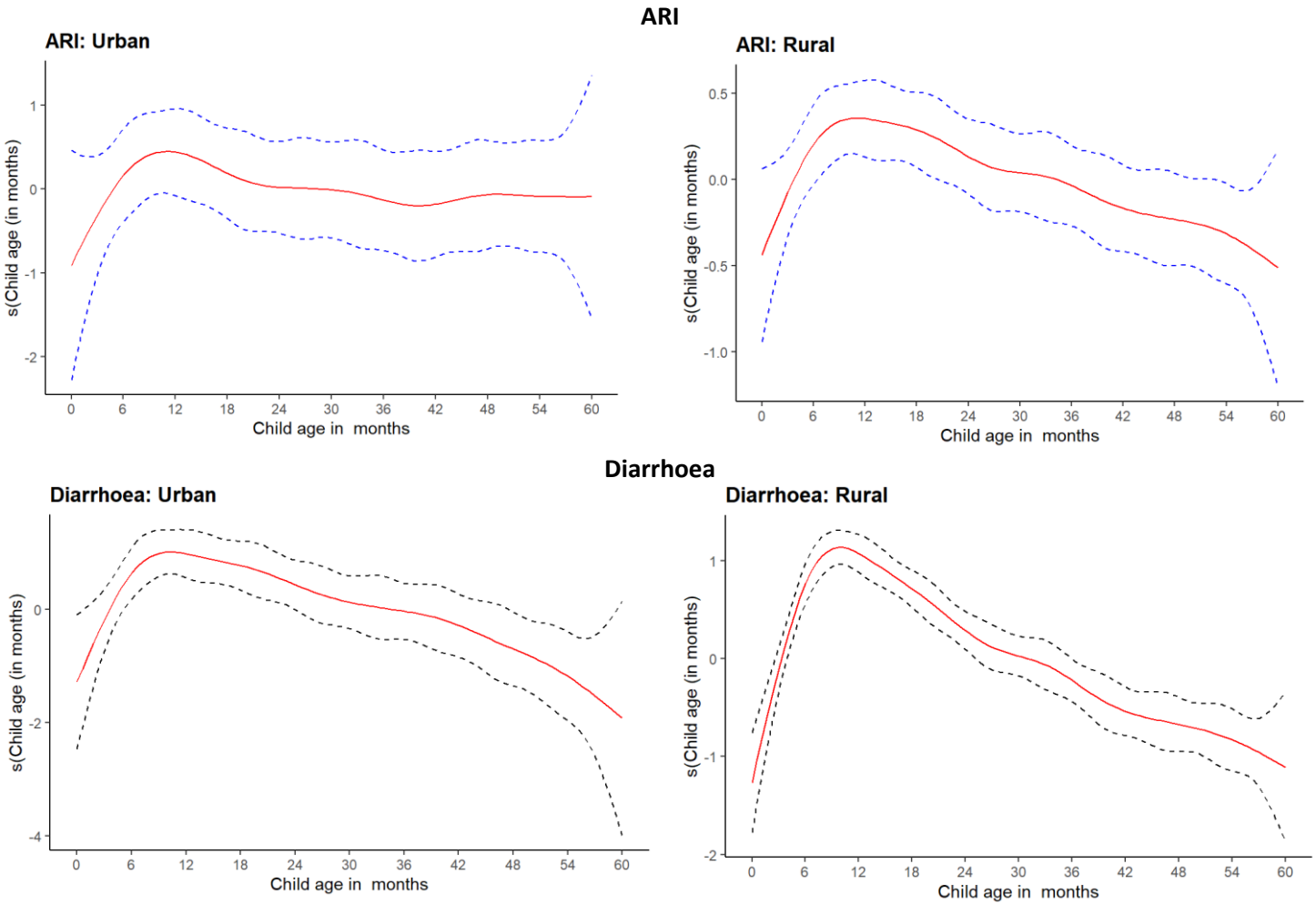
Logistic regression

For each of the outcomes and place of residence, I ran the logistic regression model with all the independent variables included (Supplement 2). The modelling was done on the full dataset (training set) and also on the sample of the two datasets (testing or validation set). Both stepwise and backwards were considered in the selection of important variables.

Lasso regularization

When faced with many predictors (p), Lasso regularization – an extended standard regression model- is superior in selecting important predictors (feature selection) that are more interpretable and more useful than the standard logistic regression. Unlike the standard logistic regression model, the lasso approach shrinks logistics regression coefficients towards zero, thus performing variable selection (James et al., 2013). Shrinking of coefficients helps to reduce the model complexity and multi-collinearity. However, with high dimensional data, it may be hard to select the important variables with respect to the model. Through shrinkage, parameters with low coefficients are shrunk to zero, thereby reducing the number of parameters. Reducing the number of parameters reduces variance and increases the bias (variance-bias trade-off). In this study, I performed Lasso with binomial link function using the *glmnet* package (James et al., 2013) implemented in R.

Figure 2.7: Assessment of the association of ARI and Diarrhoea with child age



Decision tree classification

The decision tree classifications are tree bagging, Random Forest (RF), and Gradient-Boosted Machine (GBM) (James et al., 2013). Bagging as a technique of aggregating bootstraps (James et al., 2013) is used to reduce the variance in the decision tree predictions. It is done by combining the result of multiple classifiers modelled on different random sub-samples of the same training dataset (James et al., 2013). A separate prediction model for each sub-training set is generated and later the overall result mean prediction is generated. However, RF provides an improvement over the bagged tree by decorrelating the trees (James et al., 2013) and generating better predictions of the response variable by recursively splitting the data into more homogenous units (nodes) independent of the other. Furthermore, GBM is another ensemble approach applied to improve the predictions of the decision tree. Like the RF, boosting involves creating multiple copies of the original training dataset using the bootstrap, fitting a separate decision tree to each copy, dependent on each other, unlike the RF. Each tree is built on a bootstrapped dataset, dependent on the other trees, but in boosting the trees are grown sequentially – each tree is grown using information from previously grown trees (James et al., 2013). A mean prediction is later generated by combining all the trees (James et al., 2013). Therefore, GBM is usually considered the best ML model approach. In this study, GBM was the decision tree classification ML model that I applied. To get the best results, the model was tuned with the number of trees (500, 1000, 1500, and 2000) in an interval of 500, hyperparameter (1, 2, 3, 4, 5) and the training rate (shrinkage) (0.1, 0.01,

0.001) and the tuning parameters selected best on the combination of parameters that provider better (higher) accuracy and kappa.

For each area of residence (urban and rural), the data was partitioned into three sets: testing set (10%), validation set (30%) and training set (60%). The training set is used in running the model(s), the testing set is used for validating the performance of the model(s) in other new datasets with the same parameters (Fuller et al., 2017), and the validation set is used to assess the consistence of the model on new datasets. For both models, the measure of prediction was based on 10-fold cross-validation. After running the best model for the selection of the most important variables, predictive probabilities were generated to assess the actual direction of the selected variables in affecting their respective outcomes.

2.6.7. Model evaluation

Four measures were used to select the best model: sensitivity, specificity, accuracy, and area under the roc curve.

Sensitivity

The sensitivity of a test is its ability to determine the patient cases correctly (Baratloo et al., 2015). Sensitivity is the proportion of real positive cases that were predicted as positive. This implies that there could be another proportion of real positive cases that could be predicted as negative (false negative). This can also be presented in the form of a false negative rate (Eqn. 2.23).

$$\frac{True\ Positives}{True\ Positives + False\ Negative} \qquad (2.23)$$

Specificity

The specificity of a test is its ability to determine the healthy cases correctly (Baratloo et al., 2015). It is the proportion of real negative cases that were predicted as negative. This implies that there could be another proportion of real negative cases that could be predicted as positive (false positives). This can also be presented in the form of a false positive rate (Eqn. 2.24).

$$\frac{True\ Negative}{True\ Negative + False\ Positive} \qquad (2.24)$$

Accuracy

The accuracy of a test is its ability to differentiate the patient and healthy cases correctly (Baratloo et al., 2015). It is calculated as the true positive and true negative proportion in all evaluated cases (Eqn. 2.25).

$$\frac{True\ Positives + True\ Negative}{True\ Positives + False\ Negative + True\ Negative + False\ Positive} \qquad (2.25)$$

The area under the roc curve

I measured the prediction performance of each model by computing the ROC, and the model with the highest ROC curve estimates was considered the best model.

Identification of the influential variables

The variable importance for the best model was also computed relative to the highest. The variable importance is a scaled measure to have a maximum value of 100.

2.7. Data management and analysis of qualitative data

As mentioned earlier, the qualitive findings reported in Chapter 6 included 29 in-depth interviews, 8 focus group discussions and 6 key informant interviews with public health facility workers. Audio recordings were done upon the formal consent of the study participants. Each day, all recordings were uploaded onto the LSE OneDrive server. The recordings were transcribed verbatim and then translated into English. Ten per cent of the transcripts were reviewed against audio recordings to check for consistency. The transcripts were then managed and analysed in R using RQDA package and SQLite. I applied a combined approach to analysis for generating themes through inductive coding on research participants' accounts and deductive coding from existing literature. The codes were generated and indexed to each transcript and then grouped into categories, forming a working analytical framework. The categories were then used to generate the study themes. **Table 2.7** indicates the codes for each of the themes and sub-themes.

Table 2.7: Codes that were generated through open coding using RQDA.

Themes	Categories	Codes
I. Role of family and community social support networks	1. Existing family support networks	1. Husband 2. Grandparents 3. Family friends or neighbours 4. Community transporters
	2. Ways of support	5. Therapeutic provision 6. Enforce Cultural values and practices. 7. Caretaking 8. Financial and material support 9. Information and experience sharing about health services, treatment options
II. Role of community systems' characteristics	3. Social infrastructures or services	10. Community roads 11. Health facilities (quality and proximity)
	4. Civil institutions	12. Voucher provision 13. Subsidised services at the community level 14. Outreaches 15. mobilization and sensitisation 16. Support community health workers
		17.
	5. Leadership or political will (**authority**)	18. Transport services (ambulances) 19. Enforce behavioural change
	6. Community diagnosis and therapeutic systems	20. Traditional birth attendants 21. Drug shops 22. Community health workers
III. Health services system factors	7. Health responsiveness 8. Community trust in health services	23. Respectful care 24. Service charges 25. Stock out of drugs 26. Health workers availability 27. Experience, and skills 28. Customer care 29. Patients' experience with health institutions or health workers

2.8. Reflexivity

2.8.1. Reflexivity in the thesis

The Critical Realistic perspective as a philosophy and systems thinking perspective indicates the agent-agent and agent-structure relations as the object of the study; hence, society is nothing but the sum of these interactions (Connelly, 2001). Some social system agents exist at different levels of social structure and have multiple roles that affect well-being. Because of the layered social structure within which multiple agents live, multi-method approaches are needed to understand the multilevel relationships between population well-being and social structures. This is the motivation of this PhD project, which seeks to understand the under-10 child survival mechanisms. Applying the multiple methods and the different data sources were based on the data access and methodological limitations. While the Iganga-Mayuge HDSS data provides us with information on under-10 child mortality estimates, mortality risk factors, and causes of death, the limitation of linking the individual causes of death data with the birth registration data provides an unclear picture of how the morbidity is distributed across various vulnerable groups. The use of UDHS addresses such limitations by providing the understanding of children at high risk of morbidities that were identified among the major causes of mortality.

Further, moving beyond the empirical results presented in Chapters 3-5, I found it important to understand why a segment of women in labour and sick children were not accessing appropriate health care services. Chapter 3 of the thesis found that 30% of deliveries and sick children did not access appropriate health facility services. Given the complexity of social and health systems factors that affect health care access, qualitative findings presented in Chapter 6 were important in understanding the communities' experiences in accessing health care services. Finally, with the notion of generating realistic frameworks that steer research and implementation of interventions, I identified how the child mortality mechanism provides an insight into how to address harmful effects or enhance beneficial effects. Overall, the thesis gives us a sense of rethinking and redefining the current obstetric and child health care frameworks, including the interventions' package.

2.8.2. Reflexivity in Qualitative data collection

In this section, I reflect on how the qualitative data collection procedures and the involvement of the participants contribute to the ethical consideration of future similar studies. While I was aware of the emotional concerns that could arise during the in-depth interviews with the bereaved women, I was not fully equipped to provide psychosocial support. Though most women did not weep during the interview, their faces showed that they were still grieving and needed more social support. Indeed, it was *weeping in silence,* as studies have indicated (Kiguli et al., 2015; Mills et al., 2021) (*see Box 2.1*). However, the interviews were conducted by RAs who had the experience of conducting verbal and social autopsies and had professional counselling training. Based on my prior experience of interviewing bereaved women and working with the RAs experienced in verbal and social autopsy data collection, listening, and feeling concerned without blaming was a critical approach to be employed (*see Box 2.1*).

Box 2.1: Qualitative vignette on bereavement during interview among women who experienced child loss.

> *"We would reach somewhere [in the course of the interview], and she would just keep quiet with her face down and her hands on her face",* ***research assistants said.***
>
> *"Whenever she would keep quiet, I would understand that she is grieving. So I would pose, give her time, and after 5-10 minutes, she would gain strength and start talking to me",* ***research assistants said.***
>
> *"I asked her what happened at the facility that could have led to the child's death. She kept silent for 5 minutes and later started crying. I started counselling her and asked her if we could stop the interview, but she said no, let us talk while shedding the tires. She said no one had ever asked her what could have led to the death of her new-born. She indicated how my coming [RA] was very important for her to tell why her baby died",* ***research assistants said****.*

Signalling the understanding of their position and feelings throughout the interaction was crucial. All women involved in the in-depth interviews, including a few who wept, indicated how important it was to talk to them as they felt neglected in the community (*see Box 2.1*). Whereas the RAs had some training in counselling, to my observation, the bereaved women needed more psychosocial support. Unfortunately, I could not find a formal organization that would provide psychosocial services. I suggest a post-natal psychosocial package that targets postpartum women who have experienced stillbirth and new-born death. Studies done in the same context have indicated a lack of support for bereaved families (Kiguli et al., 2015; Mills et al., 2021). However, more research is needed on how such a package can be delivered to reach the affected women and their partners.

All women who participated in the FGD interviews brought their children. Children would cry or want to play with their parents, obstructing the interview process, and increasing the time spent on the interviews. A few pieces of foodstuff, such as biscuits and juice, were beneficial in keeping children away from their parents, though this was not initially planned for. Bringing children along with them was understandable because 1) most of the children were still breastfeeding and could not be left home with other siblings or any other family member, 2) usually, when women are mobilised to attend meetings involving children's health, they assume that there is a sort of health camp that has been brought to the community, and 3) most women in rural settings do not have other people to leave children with at home since they are often the main children caregivers. Women considered the RAs, and I as medical health workers and some women would seek consultation on their children's health despite telling them that the work was a student's research. However, we told them that we had nothing to offer and advised them to take the children to the health facilities.

I identified power relations. During the FGD interviews, the younger women (adolescents) were not always active, and the older women would dominate and laugh whenever we asked the adolescents to talk. During training and our reflection meetings, we emphasised the need to pay attention to the silent participants and motivate them to speak. However, if I had considered splitting the FGDs in terms of ages (adolescents, youth and older), I would have understood issues that affect adolescents while pregnant. Similarly, as earlier mentioned, there were power relations between the interviewers and the researchers. The researchers were known as health workers and

were always referred to as health workers. However, the research assistants were experienced in how to engage the participants in the conversation, and so this encouraged more interactive and open discussions by creating a feeling of empathy that enabled people to talk about their lives' experiences openly.

Further, as presented in Chapter 6, men were reported as the main family authorities in decision-making. Even though the women were involved in farming, they [women] indicated having no authority to sell farming produces without their husbands' permission. Some women indicated how their men sell the farming produces and spend it on alcohol without leaving anything for the family, which usually results in gender-based violence whenever women ask how money was spent. Additionally, some women indicated how their husbands are usually drunk, which usually leads to fighting and forced sex. Cases of men forcing their women to have sex within a few weeks after birth were reported. RAs and I did not know how to handle gender-based violence as this was complex. Although we tried to establish the organisations or institutions that provide such services within the districts where such cases could be referred, we did not find any.

Further, social identity, position, ethnicity, and gender have been indicated to shape how research participants respond to the interview questions (Jacobson & Mustafa, 2019; Williams & Heikes, 1993). Throughout the data collection, I was aware of how these would affect interaction with the research participants. For instance, I knew that being a male could restrict women from talking about other reproductive health issues. Additionally, although I understood the local language, my local language speech accent could indicate that I was an outsider. While I tried to dress casually, my appearance remained urban. I, therefore, had to recruit three female RAs who were acquainted with the community setting. I also did not know the location of the sampled areas as I have never been to study villages. However, working with Iganga-Mayuge HDSS helped me generate a list of villages that I used to select the four study villages randomly. I also used the Iganga-Mayuge death registration register to identify women who had experienced pregnancy or new-born death in the last four months preceding the data collection. The death register had contacts for the community health workers who assisted with the mobilisation and rapport building. As mobilisation facilitation, the community health workers were paid 15,000 Ugandan shillings (Equivalent to 3 British pounds sterling as of June 2021).

Though the approval for conducting research went through multiple ethical reviews, and while this delayed the data collection, the Makerere University School of Public Health Institution Review Board provided critical comments that were beneficial for my study. For instance, they advised me to consider including men as respondents whom I had not initially included. They also advised me to consider how I would address the physical and emotional issues that would need psychosocial support. Although no organisations were providing such services, the feedback guided me on the training package and whom to consider as RAs. However, I acknowledge that this was not enough because of the lack of formal social support interventions that target bereaved families. Understanding the stillbirth and new-born death post-natal bereavement that targets bereaved women and men is an area that needs more research in such contexts.

Movements within the community were challenging because of poor transport systems. As shown in section 2.5 of this chapter, and as is the case for all rural communities in Uganda, the roads are always challenging during the rainy season, making movements difficult. As the data collection was done during the rainy season, there were difficulties in reaching rural communities. Moreover, the most common means of transport are motorcycles, which are usually not safe. Indeed, as earlier reported in section 2.5 of this chapter and Chapter 6, accidents happen while transporting women in labour and sick children. In addition, we experienced fuel outage challenges while travelling with motorcycles, which would take some time to refill as the rider walked to a nearby trading centre. The long-distance coupled with poor roads makes transportation expensive or even inaccessible. These issues were also reported in Chapter 6 as the main barriers to obstetric and child health care access.

2.8.3. Reflexivity in using HDSS data

The use of HDSS data was based on my understanding of and knowledge of the data collection tools within the INDEPTH network. Before enrolling for the PhD, I voluntarily did work with INDEPTH, which oriented me to the enormous valuable yet unexploited data that the network had. My participation in reviewing the HDSS tools for different sites and various INDEPTH review workshops helped me understand the potential of HDSS data in monitoring most health indicators. I then picked an interest in studying child health and survival. My initial PhD plan was to use data from all HDSS sites under INDEPTH network to study child health mortality in Asia and sub-Saharan Africa to compare countries and regions. However, accessing data that matched my PhD work objectives was not easy because of bureaucracies and data access fees.

While some of the data are freely accessed through the INDEPTH website after submitting the research plans, the available datasets are specific to death and birth outcome variables without other covariate variables (INDEPTH, n.d.). As presented by other researchers (Chandramohan et al., 2008), restricted access to HDSS data poses a challenge for interested researchers who want to do comprehensive analysis on regional and global issues. Yet, if pooled together, these data could be used to measure regional and national health and economic transitions. For instance, 38 HDSS under INDEPTH consortium – 26 in Africa, ten in Asia, one in Oceania, and one in Central America (Chandramohan et al., 2008). Moreover, within countries, there are multiple HDSS. Except for Agincourt (Agincourt, n.d.) and Nairobi HDSS under APHRC (APHRC, n.d.), most HDSS do not have clear guidelines on data accessibility. This observation was also highlighted by other researchers (Chandramohan et al., 2008). However, while Agincourt provides a sample of their datasets on their website, access was bureaucratic, and the authorising officer could not respond to the data access application request. Nairobi urban HDSS data is unique as the data is freely available through the APHRC website after formal application. There are available documents for each of the datasets on available variables, sample size, and collection procedures. Additionally, Nairobi urban HDSS has a person responsible for responding to the researcher's needs. Unfortunately, I could not use those datasets because they missed some of the key variables for my research question.

While I was able to access the Iganga-Mayuge HDSS data because of my affiliation with the site, there are no clear instructions on the site's website on how to access the data. There is a profile about the site presenting some of the data elements collected, including data collection approaches (Kajungu et al., 2020), but having links to the data collection tools would guide the interested researcher on what questions to answer. Nevertheless, the site has a responsible person (info@muchap.mak.ac.ug) for responding to the data request. The data is also not freely accessed as there is a fee levied – as a contribution to sustaining the site. Although the HDSS thought that being a student at a UK university makes me have research funding, my PhD studentship did not cater for research data collection and access.

In addition to the discussion and conclusion chapter (Chapter 7), I present the findings in Chapters 3, 4, 5 and 6 in a manuscript format. The versions of published papers may, to some extent, differ from what is presented in this thesis. Some parts of the text were not included in the published papers because of restrictions on the length of the paper. This relates particularly to the methods and results where certain tables and figures could be missing in the published papers.

CHAPTER THREE

UNDER 10 MORTALITY PATTERNS, RISK FACTORS, AND MECHANISMS

This paper has been published in PLOS ONE: Kananura RM, Leone T, Nareeba T, Kajungu D, Waiswa P, and Gjonca A (2020). Under 10 mortality patterns, risk factors, and mechanisms in low resource settings of Eastern Uganda: An analysis of event history demographic and verbal social autopsy data. https://doi.org/10.1371/journal.pone.0234573

Abstract

Globally, the under-10 years of age mortality has not been comprehensively studied. We applied the life-course perspective in analysing and interpreting the 22385 recodes of event history demographic and 1815 recodes of verbal autopsy data to examine when and why children die before their 10th birthday. These data were collected between 2005 and 2015 by the Iganga-Mayuge health and demographic surveillance site in eastern Uganda. The lifetable approach was used to estimate mortality patterns, while the Royston-Parmar survival analysis approach was used to assess mortality risk factors. The under-10 and 5-9 years of age mortality probabilities were 99 (95% Confidence Interval [CI]= 94-105) per 1000 live births and 11 (95% CI=7-26) per 1000 children aged 5-9 years, respectively. The top four causes of new-born mortality and stillbirth were antepartum maternal complications (31%), intrapartum-related causes including birth injury, asphyxia, and obstructed labour (25%), Low Birth Weight (LBW) and prematurity (20%), and other unidentified perinatal mortality causes (18%). Malaria, protein deficiency including anaemia, diarrhoea or gastrointestinal, and acute respiratory infections were the major causes of mortality among those aged 0–9 years – contributing 88%, 88% and 46% of all causes of mortality for the post-neonatal, child and 5-9 years of age respectively. 33% of all causes of mortality among those aged 5-9 years as a share of Injuries (22%) and gastrointestinal (11%).

Regarding the deterministic pattern, nearly 30% of the new-borns and sick children died without access to formal care. Access to the treatment for the top five morbidities was after 4 days of symptoms' recognition. The childhood mortality risk factors were LBW, multiple births, having no partner, adolescence age, rural residence, low education level and belonging to a poor household, but their association was stronger among infants. The analysis identified the vulnerable groups at risk of mortality: LBW children, multiple births, rural dwellers, those whose mothers are of low socioeconomic position, adolescents and unmarried. The differences in causes of mortalities between children aged 0-5 and 5-9 years were noted. These findings suggest a strong life-course approach to designing and implementing child health interventions that target pregnant women and children of all ages.

3.1. Introduction

Whilst there is enormous global evidence on the under-five mortality rate(UN IGME, 2018, 2019), very little on the level, patterns and mortality causes among 5-10 age group is known as the group is inadequately included in global reporting, yet in countries with high mortality rates, children aged 5-10 may remain at high risk of morbidity and mortality. The global 5-9 years of age mortality rate is estimated at 4 per 1000, and out of the 6.22 million children aged 0-14 years that died in 2018, 9% was a share of 5-9 years of age (UN IGME, 2019). Additionally, of the 5-14 years of age global annual deaths, 60% is a share of those aged 5-9 years (Masquelier et al., 2018; UN IGME, 2019). In countries with no or poor civil and vital registration systems, particularly those in the sub-Saharan Africa (SSA) region, very little is known about the level, patterns, and mortality causes among 5-9 years of age (Countdown to 2030, 2017). For instance, based on the recent literature search at the time of this study, there is a dearth of evidence on mortality estimates, causes and risk factors in SSA among those aged 5-9 years. Yet, given the high mortality rates in all age groups and many infectious morbidities in SSA, the 5-9 years of age remain susceptible to contracting infections that increase their likelihood of death. For instance, pneumonia, diarrhoea, and malaria that are major causes of under-five mortality recurrently occur among children aged 5-9 years in SSA (Liu, Oza, et al., 2016; Were et al., 2015) and thus contributing to prematurity mortality.

Building on the life-course framework presented in Chapter 1 (Section 1.4) of the thesis, children are always exposed to life-threatening events such as injuries, malnutrition, and non-communicable diseases that may inhibit them from thriving and transforming (H. Clark et al., 2020). The new-born individual risk factors such as Low Birth Weight (LBW) and preterm birth that are associated with the risks of contracting morbidities such as cardiovascular diseases, congenital anomalies, and chronic lung diseases (Kajantie et al., 2005; Li et al., 2003; Lindberg et al., 2012; Swamy et al., 2008; Zhang et al., 2013), may continue affecting their survival beyond infancy and childhood. However, in SSA, there is a dearth of evidence on how such new-born individual factors may affect their survival beyond infancy. Further, family structures such as socio-economic and maternal characteristics affect the birth outcomes and new-born survival at a later age. There is enormous evidence on how family structures and childbirth characteristics affect childhood and adolescence survival in high-income countries (HIC)(Anderson, 2014; Blakely et al., 2003; Remes et al., 2011), but very little is known for SSA countries. We also know that access to health care is crucial in preventing infection-related mortality causes. However, the community and health facility bottlenecks often lead to failures or delays in receiving the required healthcare services. The persistent healthcare access challenges in SSA have continued to predispose children to inappropriate services such as informal care and certainly, compromising the quality of care (Källander et al., 2008; Rutebemberwa et al., 2009; Waiswa et al., 2010) and assessing when children with morbidities or at high risk of mortality access treatment in such resources-limited settings is needed to understand the mortality mechanisms.

In settings with expected high childhood mortality, there is a need for information on how the overall system shapes children's health for them to be able to survive, thrive and transform. In line with the current global Sustainable Development Goal (SDG) theme of "leaving no one behind" (WHO, 2015a), United Nations Secretary-General's Health Global Strategy for Women, children and adolescents (United Nations, 2016), and the WHO–UNICEF–Lancet Commission on children (Clark et al., 2020), evidence that accounts for when and why do children die before their 10th birthday is an initial step for generating optimal solutions that may accelerate the SDG global and national commitments.

Therefore, using what is believed to be the largest and most recent event histories and verbal autopsies data in Uganda, we applied life-course and systemic perspectives in the analysis and interpretation of the data to understand how a combination of individual and family factors, morbidity and access to healthcare may be associated with under-10 child mortality. The study specifically provides evidence on the under-10 age-specific mortality estimates; under-10 age-specific mortality causes; mortality mechanisms in relation to health access to health services, and maternal morbidity; and how the socioeconomic, maternal, and child intrinsic factors continue to affect their survival. Such a holistic approach is essential in generating prevention and healthcare interventions that improve the children's survival and thrive and transform (Bhutta et al., 2019; H. Clark et al., 2020; Countdown to 2030, 2017; Kerber et al., 2007; Lassi et al., 2015).

3.2. Methods

Results in this chapter are based on the analysis of a cohort of children born between 2005 and 2015 in the Iganga-Mayuge HDSS dataset. From the life-course perspective, I study how the socioeconomic, maternal and individual (child) factors at birth shape children's survival within 10 years. Thus, the study's main outcome is an event (death) that is experienced after "alive" birth by time t (10th birthday). The study covariates are LBW (<2.5 Kgs), maternal age (grouped as <20 years, 20-29 years and 30 years and above), marital status (1 – having or staying with a partner and 0 – having no partner), household wealth index (least poor for indices 4-5, 3 middle poor and 1-2 poorer), maternal education level, child sex, place of residence, and birth category. Because of the missingness in some of the data variables, I performed multiple imputation for the imputation of missingness (*see section 2.6.5 of Chapter 2*). The life table approach was used to estimate age-specific mortality patterns (*see section 2.6.2 of Chapter 2*). At the same time, Royston-Parmar flexible parametric model for survival analysis was performed to assess under-10 mortality risk factors with individual-level clustering while controlling for all covariates after multiple imputations. The censoring was done at 120 months (10 years), and the analysis was restricted to children born alive (*see section 2.6.3 of Chapter 2)*. Additionally, we examined the epidemiological shift in the causes of death across child age groups using verbal autopsy data. Furthermore, from the systemic

perspective, the verbal autopsy[19] data were used to describe the timing of access to appropriate for sick children and women's labour and maternal morbidities experienced by the women who lost.

3.3. Results

3.3.1. Event histories study participants' information

A total of 22,385 birth were registered between 2005 and 2015, of which 14% were LBW and 3% multiple births (Appendix 3.1). By the end of the follow-up period, the mothers of 4% and 13% of children were still adolescents and unmarried, respectively. In addition, the mothers of 27% and 47% of children had no education and belonged to poor(er) households, respectively (Appendix 3.1).

3.3.2. Mortality estimates and patterns

Table 3.1 presents the age-specific mortality lifetable. The under-10 and 5-10 mortality probabilities were 99 per 1000 live births and 11 per 1000 children aged 5-9 years, respectively. Additionally, the likelihood of infant mortality and under-five mortality was 46 and 89 per 1000 live births, respectively.

[19] Verbal autopsy data included information on the time the sick child accessed health care services and the type of service provider. It also included information on the place of delivery.

Table 3.1: Under 10 mortality estimated-abridged life table using 2005-2015 birth registration dataset

Interval	Number of persons at risk (lt)	Deaths (d_t)	C_t	N_t*	Conditional hazard probability (q_t) (95% Confidence Interval)	Conditional survival probability (P_t)	Cumulative survival probability (S_t) (95% Confidence Interval)	Cumulative hazard probability (F_t) (95% Confidence Interval)
Age-specific mortality								
0-1 years	22385	946	3308	20731	0.046 (0.043-0.131)	0.954	0.954 (0.9514- 0.9571)	0.0456 (0.0429-0.0486)
1-5 years	18131	563	11205	12529	0.045 (0.041-0.126)	0.955	0.911 (0.907- 0.9158)	0.0885 (0.0842-0.093)
5-10 years	6363	38	6104	3311	0.011 (0.007-0.026)	0.989	0.901 (0.8954- 0.8954)	0.099 (0.0937-0.1046)
Male								
0-1 years	11192	474	1659	10363	0.046 (0.042-0.129)	0.954	0.954 (0.9501-0.9581)	0.0457 (0.0499-0.0419)
1-5 years	9058	296	5620	6248	0.047 (0.041-0.129)	0.953	0.909 (0.9025-0.9152)	0.0909 (0.0975-0.0848)
5-10 years	3145	22	3015	1637.5	0.013 (0.008-0.028)	0.987	0.897 (0.8885-0.9046)	0.1032 (0.1115-0.0954)
Female								
0-1 years	11193	472	1649	10369	0.046 (0.042-0.128)	0.954	0.954 (0.9503-0.9583)	0.0455 (0.0497-0.0417)
1-5 years	9073	267	5586	6280	0.043 (0.038-0.117)	0.957	0.914 (0.9076-0.9198)	0.0861 (0.0924-0.0802)
5-10 years	3218	16	3085	1675.5	0.01 (0.005-0.020)	0.99	0.905 (0.8975-0.9123)	0.0948 (0.1025-0.0877)

3.3.3. Causes of Mortality.

Stillbirth and new-born mortality causes

Of the 844 new-born deaths identified in VASA data, 32.2% were stillbirths. Antepartum and intrapartum complications contributed 56.3% of all mortality causes of stillbirth and new-born death – each contributing 31% and 25% respectively (Table 3.2). Prematurity and low birth weight had a share of almost 20% of all causes of stillbirth, and new-born mortality and 18% was a share of other unidentified perinatal causes (Table 3.2).

Table 3.2: Stillbirth and new-born mortality causes using 2005-2015 Iganga-Mayuge verbal autopsy data.

	Stillbirth		New-born		Total	
Stillbirth and new-born mortality causes	**Freq. (n=272)**	**%**	**Freq. (n=572)**	**%**	**Freq. (n=844)**	**%**
Antepartum maternal complications						
Hypertensive disorders	34	12.5	30	5.2	64	7.6
Other Antepartum Maternal diseases	186	68.4	-	-	186	22.0
Antepartum haemorrhage	12	4.4	-	-	12	1.4
Intrapartum-related causes						
Birth injury and or asphyxia	-	-	157	27.5	157	18.6
Obstructed labour	27	9.9	29	5.1	56	6.6
Prematurity and or low birth weight	13	4.8	155	27.1	168	19.9
All other unidentified perinatal causes	-	-	149	26.1	149	17.7
Other causes						
Febrile Infections	-	-	21	3.7	21	2.5
Sepsis or Tetanus	-	-	18	3.2	18	2.1
Abnormalies	-	-	9	1.6	9	1.1
Communicable diseases	-	-	2	0.4	2	0.2
Injuries or accidents	-	-	2	0.4	2	0.2

Child (0-10 years) mortality causes

Malaria, protein deficiency, diarrhoea or gastrointestinal, and acute respiratory infections were major causes of mortality among those aged 0–9 years – contributing 88%, 88% and 46% of all causes of mortality for the 1-12 months (post-neonatal), 1-4 years and 5-9 years of age respectively (Figure 3.1-3.3). Injuries and gastrointestinal had a share of 33% of all causes of mortality among those aged 5-9 years (Figure 3.3).

3.4. Drivers of death during the life-course

3.4.1.Maternal morbidity in pregnancy

80% of the mothers experienced morbidity in pregnancy (Table 3.3). These were febrile illness (44%), severe abdominal pain (31%), blurred vision (22%), smelly vaginal discharge (14%), vaginal bleeding (14%), pallor in the last trimester (13%), heart diseases (12%), puffy face (9%), high blood pressure (9%), and convulsion (5%).

Table 3.3: Maternal morbidities experienced in the last 3 months of pregnancy using 2005-2015 Iganga-Mayuge verbal autopsy data.

Maternal obstetric conditions	Percentage (n=844)
Overall	77.49
Febrile illness	44.08
Severe Abdominal pain in the last trimester	30.69
Blurred vision in the last trimester	21.68
Smelly vaginal discharge in the last trimester	14.45
Vaginal bleeding in the last trimester	13.86
Pallor in the last trimester	13.03
Heart diseases in the last trimester	12.68
Puffy face in the last trimester	9.24
Shortness of breath in the last trimester	8.53
High blood pressure in the last trimester	7.58
Convulsion during pregnancy	4.74
Epilepsy	1.30
Diabetes	0.47

3.4.2. Access to health services among children who died

Of the 844 stillbirth and neonatal deaths identified in the VASA data, 63% were delivered in the health facilities, and 10% (3.2/33.4%) of community deliveries occurred en-route to the health facilities (Figure 3.4).

Of the 986 children that died, 71% of the children accessed treatment from the health facility, of which 20% was a share of private health facilities (Figure 3.5). On average, access to the treatment for the top five morbidities was after 4 days of symptoms' recognition (3 days – Malaria, 3 days – malnutrition, 9 days – protein-energy deficiency, 11 days – Acute respiratory infections, and 3 days - diarrhoea) (Table 3.4)

Table 3.4: Average number of days before sick children accessed medical treatment after symptom recognition using 2005-2015 Iganga-Mayuge verbal autopsy data

Cause of death	Mean number of the before seeking hospital treatment after symptom recognition
Malaria	2.4
Malnutrition	2.7
Severe protein-energy malnutrition	8.9
Acute respiratory infection	11.1
Diarrhoea	3.0
Total	**3.9**

Figure 3.1: Infant (1-12 months) mortality causes

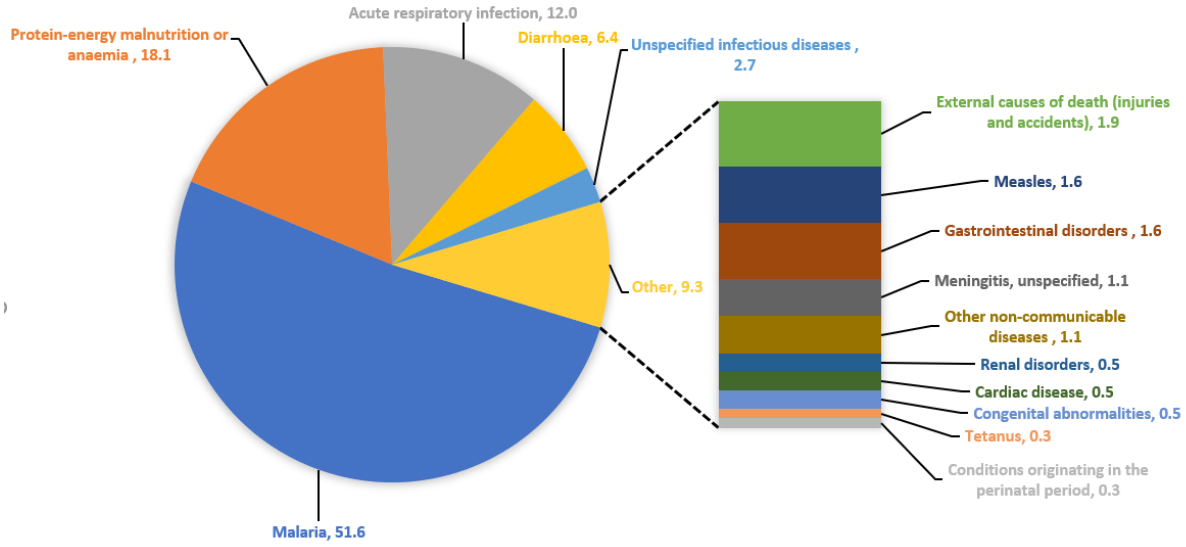


Figure 3.2: Child (1-5 years) mortality causes

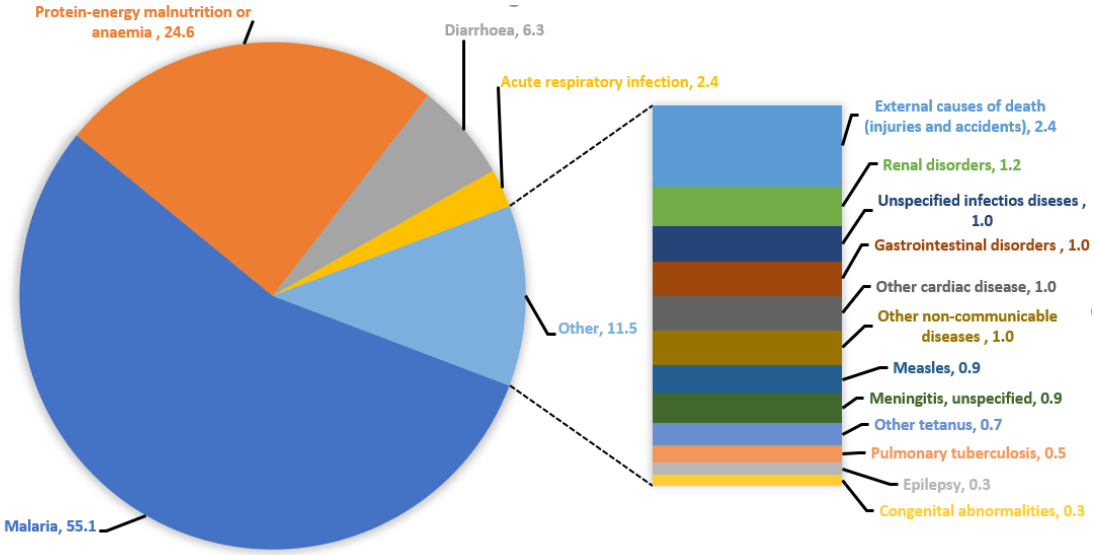


Figure 3.3: Childhood (5-10 years) mortality causes

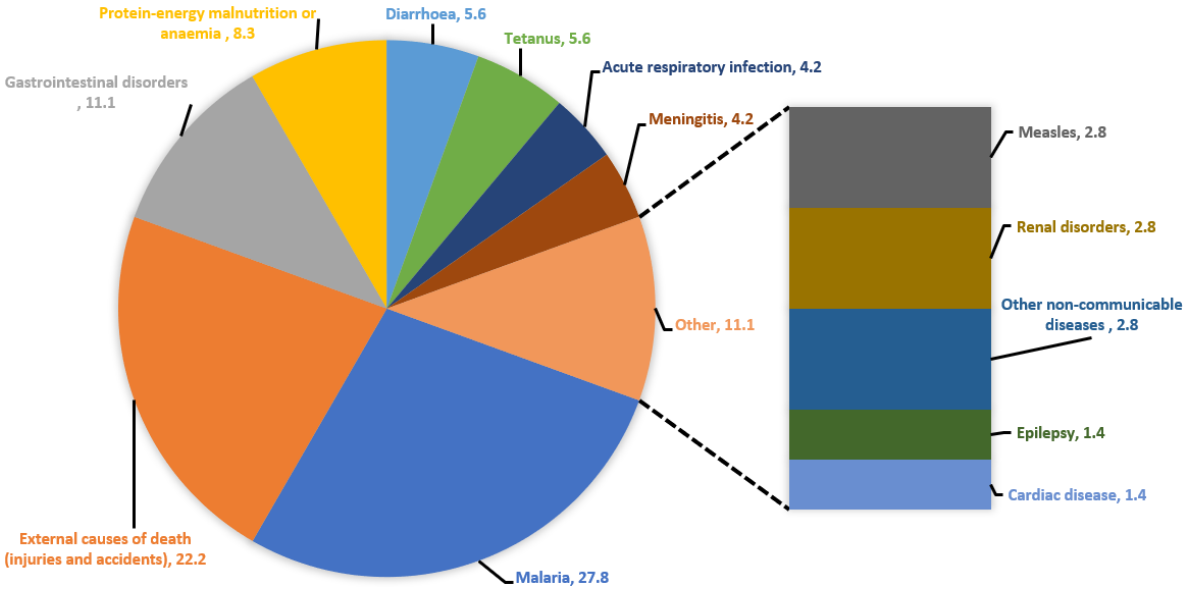
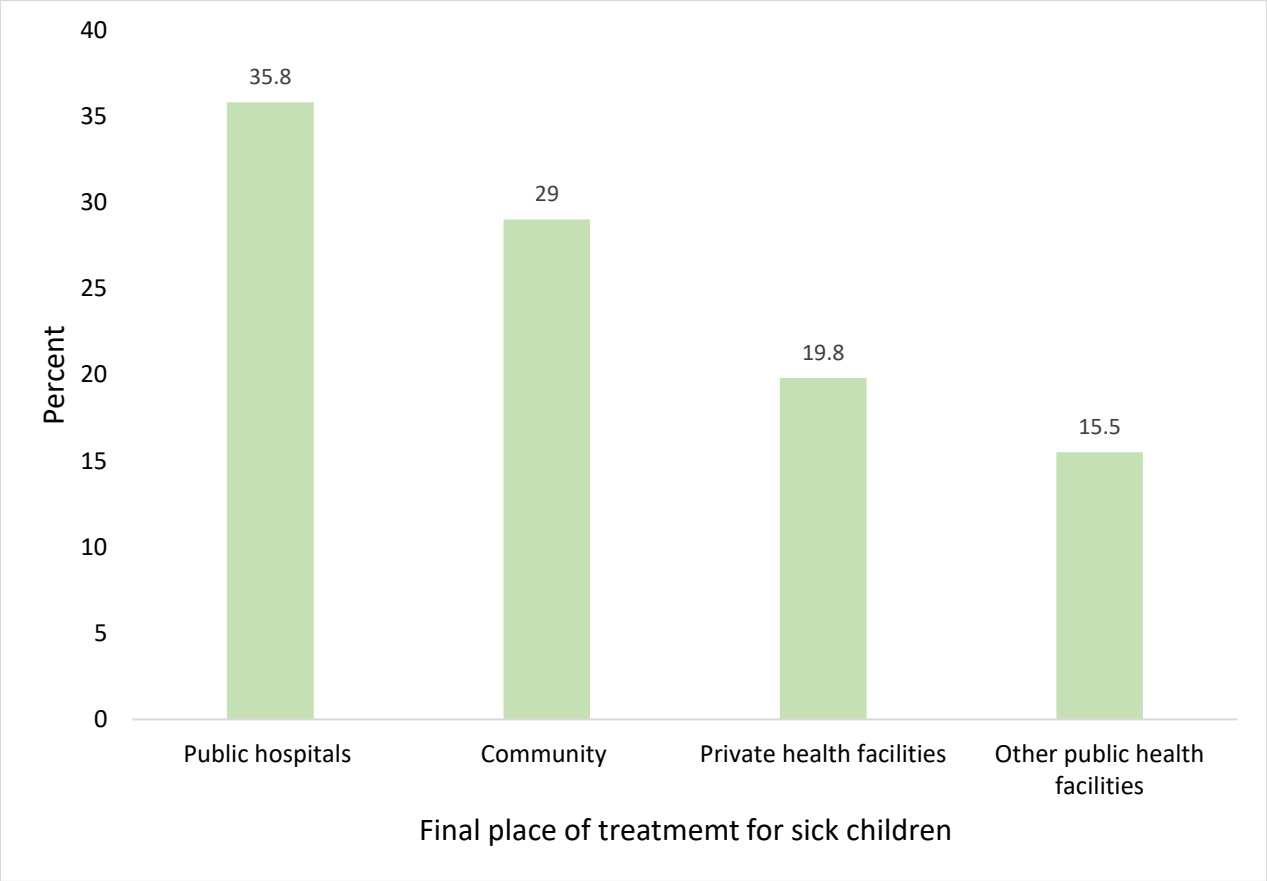


Figure 3.4: Access to health facility delivery

Figure 3.5: Access to treatment for sick children



3.4.3. Multivariate analysis for under-10 child mortality risk factors using event histories data

Association of birth weight and birth category with under-10 mortality

The under-10 likelihood of death was higher by 53% and 79% among LBW and multiple births, respectively (Table 3.5).

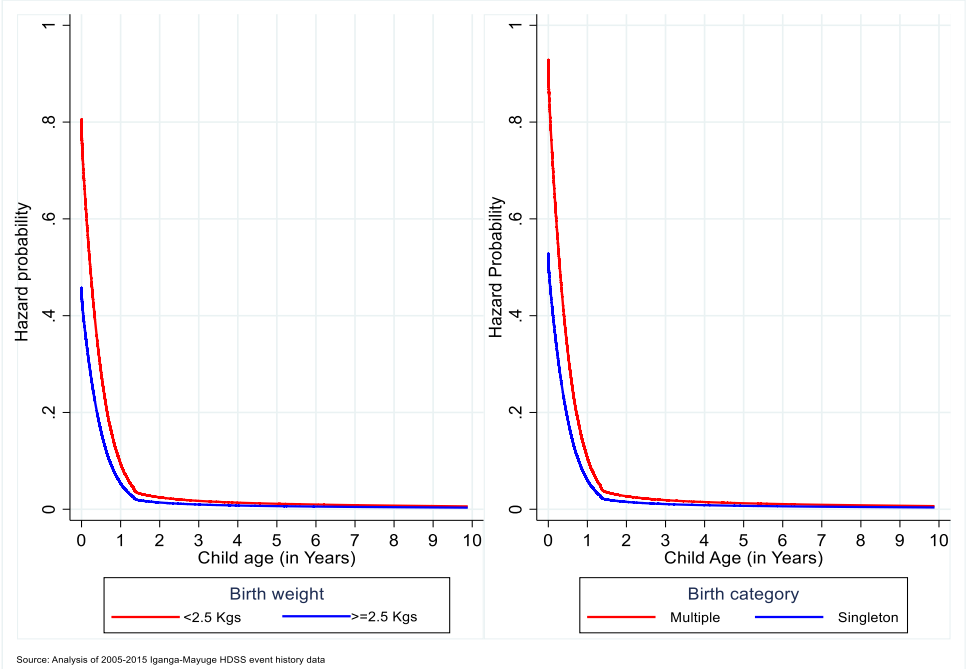
Table 3.5: Multivariate analysis of Child mortality risk factors using 2005-2015 Iganga-Mayuge HDSS event histories data

	Unadjusted		Adjusted	
	HR	**95% Confidence interval**	**HR**	**95% Confidence interval**
Birth category				
Singleton	1.00	-	1.00	-
Multiple	1.76	1.37-2.25***	1.76	1.31-2.35***
Birth weight				
>=2.5 Kg	1.00	-	1.00	-
<2.5 Kg	1.65	1.34-2.04***	1.75	1.33-2.32***
Child sex				
Male	1.00	-	1.00	-
Female	0.95	0.86-1.05	0.93	0.84-1.03
Place of birth				
Urban	1.00	-	1.00	-
Rural	1.68	1.49-1.90***	1.24	1.02-1.5*
Maternal Age				
Adolescent (<20 years)	4.36	3.7-5.14***	3.16	2.60-3.85
20-29 years	1.00	-	1.00	-
30 years+	0.47	0.42-0.52***	0.49	0.43-0.55***
Education level				
None	1.00	-	1.00	-
Primary	1.13	1.02-1.25**	0.98	0.87-1.11
Post primary	0.70	0.62-0.80	0.81	0.69-0.96**
Wealth index				
Index 1-2	1.00	-	1.00	-
Index 3	1.04	0.92-1.18	0.89	0.77-1.02
Index 4-5	0.58	0.51-0.66***	0.66	0.53-0.82***
Marital status				
Married	1.00	-	1.00	-
Unmarried	1.33	1.14-1.55***	1.22	1.01-1.48**

Note: H*R- Hazard Ratio, ***P<0.001, **P<0.01*

The probability of death among LBW was higher among children aged 0-1 years, after which the probability became parallel to that of the normal birth weight up to 3 years but remained higher among the LBW children (Figure 3.6). By 5 years, the mortality probability was close to zero (Figure 3.6). Similarly, the mortality probability was higher among multiple children aged 0-1 years, after which the probability became parallel to that of the singleton up to 5 years but remained higher for multiple birth children (Figure 3.6). By 6 years, the mortality probability curve flattened towards zero (Figure 3.6).

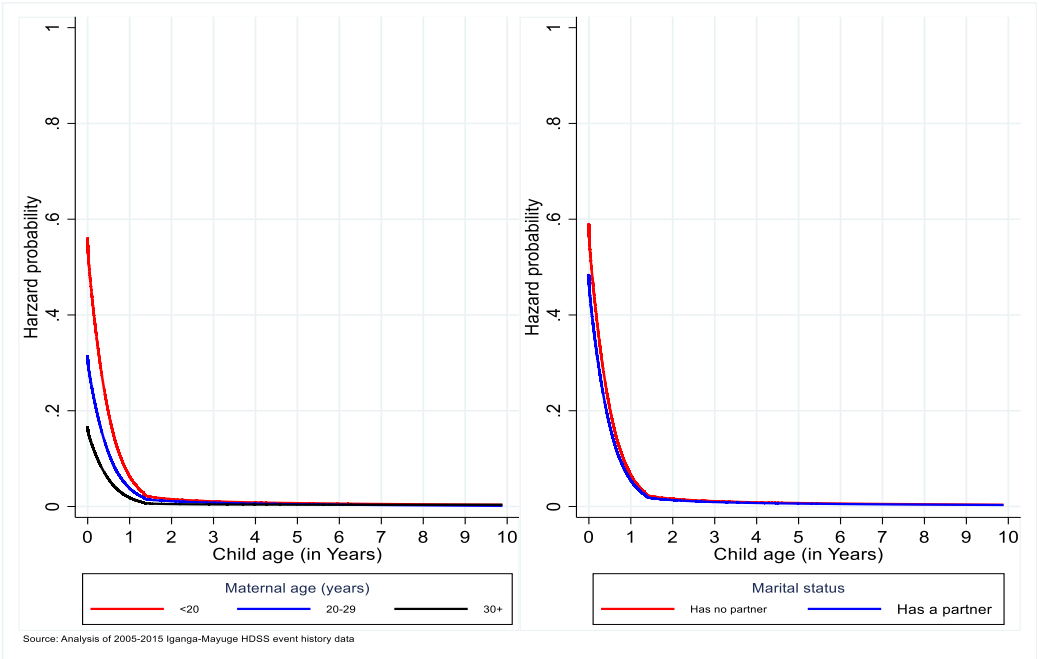
Figure 3.6: Association of birth weight and birth category with under-10 mortality



Association of maternal age and marital status with under-10 mortality

The under-10 mortality likelihood was lower by 32% and 16% among mothers aged 20-29 years and 30 years+ respectively, relative to those aged less than 20 years (Table 3.5). It remained parallel until 2 years, beyond which it became close to zero for the remaining 8 years (Figure 3.7). For infants, the child mortality likelihood among adolescent mothers (<20) was extremely high, and it remained slightly higher until 3 years (Figure 3.7). Unmarried women or those with no partners were 22% more likely to experience children mortality within 10 years after birth (Figure 3.7). The likelihood was higher for infant children beyond which it matched the married counterparts but remained high until the age of 2 years (Figure 3.7).

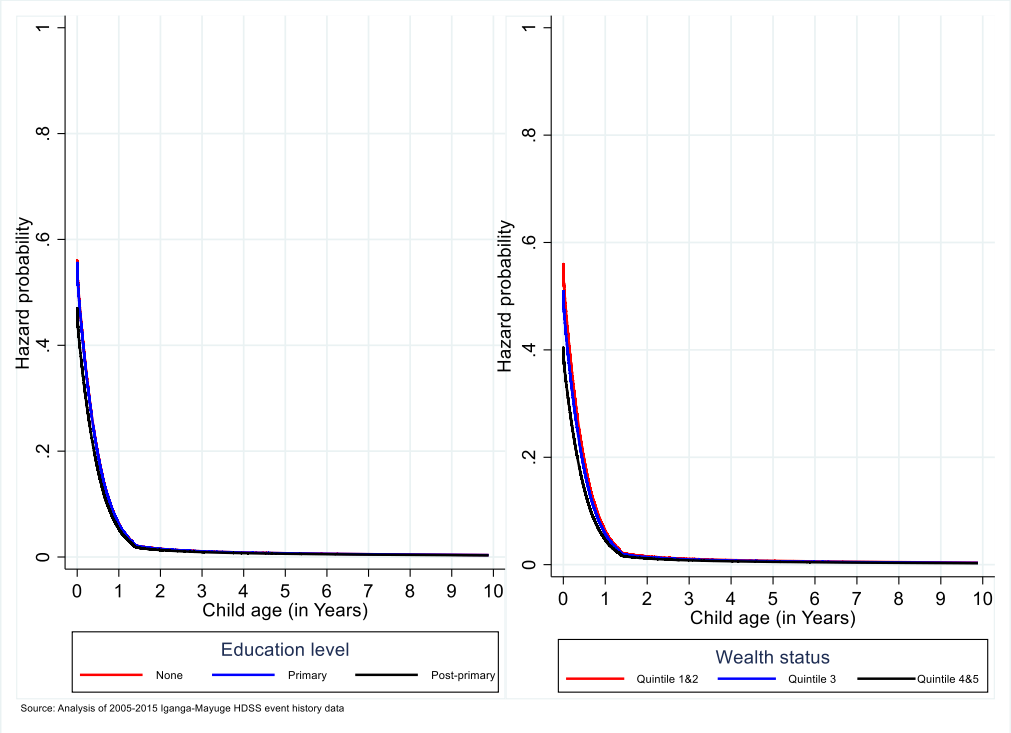
Figure 3.7: Association of maternal age and marital status with under-10 mortality



Association of maternal education and household wealth with under-10 mortality

The likelihood of under-10 mortality was 19% lower among women with post-primary education levels than those who had no education level (Table 3.5). However, the probability was only higher among infant children whose mother's education levels were lower than post-primary, beyond which the likelihood became close to each other but remained high until 2-years of age and thereafter became close to zero at nearly 6 years of age (Figure 3.8). Similarly, the likelihood of child mortality was 34% lower among the least poor women than those who were poor(er). However, the mortality likelihood was only higher for infants whose mothers were poor(er), beyond which it became parallel but remained lower among the least poor until 2-years of age and became close to zero at nearly 6 years of age (Figure 3.8).

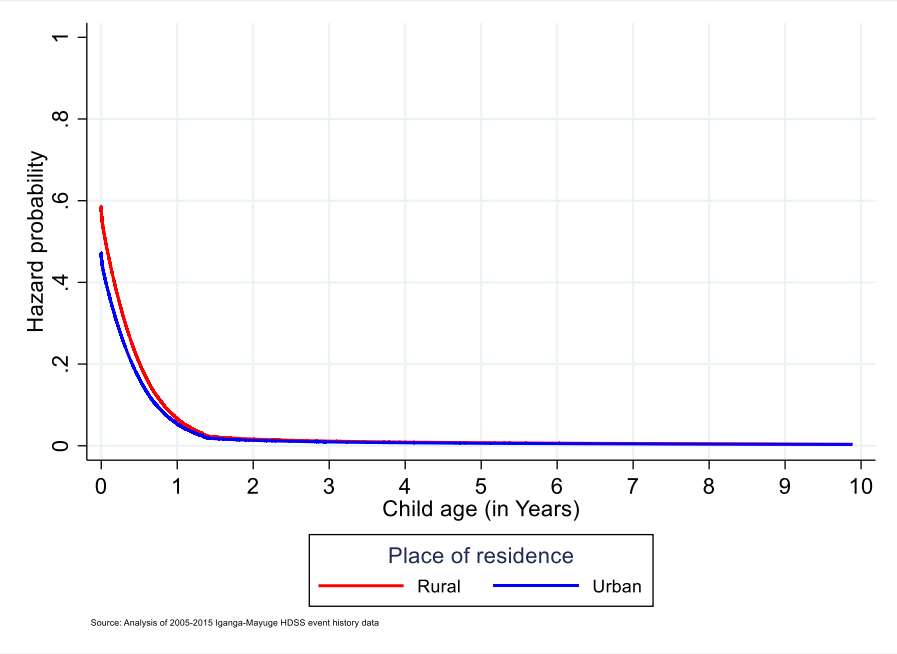
Figure 3.8: Association of maternal education and household wealth with under-10 mortality



Relationship between the place of residence and under-10 mortality

The likelihood of mortality was 24% higher among children who were residents of rural communities than urban residents (Table 3.5). However, the mortality likelihood was also high among urban infants, and it remained high in both areas up to the age of 2 years. The mortality probability curve flattened towards zero at the age of 6 years in both areas (Figure 3.9).

Figure 3.9: Relationship between the place of residence and under-10 mortality



3.5. Discussion

We have attempted to comprehensively provide an insight into when and why children die before their 10th birthday in a resource-limited setting using event history demographic and verbal social autopsy data that was collected by Iganga-Mayuge Demographic Surveillances Site in Eastern Uganda. The results are not entirely new but tend to reaffirm the key findings of previous reports on global and regional mortality. Particularly, our study provides the under-10 and 5-9 years mortality estimates and the importance of HDSS data in mortality estimates in areas with no or weak vital registration systems. Thus, our results contribute to the much-needed accountability of when and why children, particularly in a resource-limited context. In addition, we applied the life-course perspective in analysing and interpreting the data to understand how the child's individual, maternal, family, and community characteristics may be associated with childhood mortality. Similarly, we also assessed the mortality mechanism by analysing mortality causes and other associated determinants.

The mortality probabilities among under-10 and 5-9 years were 99 per 1000 live births and 11 per 1000 children aged 5-9 years, respectively. Our study's under-five and child mortality probabilities' estimates were slightly higher than the study's regional estimates on ten-year early childhood mortality rates reported in the recent national health survey report (Uganda Bureau of Statistics, 2017) and close to the global report on global, regional and national estimates (UN IGME, 2018, 2019). In this study, the mortality probability estimates among 5-9 years of age were close to the reported figures on SSA on the same age group in the global reports (Masquelier et al., 2018; UN IGME, 2019) – indicating a need for investing in Demographic Surveillance Sites for population health monitoring including mortality and death registrations, particularly, in countries with no or poor civil registration and vital data system. The difference in the mortality estimates between HDSS and other surveys based on

probability sampling such as DHS data are expected since the HDSS collected data on all registered households. Thus, HDSS data may provide accurate and reliable estimates of life events in their regional localities. However, from the analysis of this data, we identified a mismatch between birth registration and verbal autopsies data, where the two could not be linked as the birth registration unique identifier was missing in the verbal autopsy data. Yet matching the two datasets would provide direct estimates of cause-specific mortality rates. Our analysis, therefore, contributes to the identification of data gaps for data quality and system strengthening strategies for existing and emerging HDSS.

The high proportion of antepartum morbidities that this study identified indicates that the absence of adequate prevention, identification, and treatment interventions predisposes women to the increased risks of adverse birth outcomes (Vogel et al., 2014; Weiner et al., 2003). Additionally, health services' access failures or delays during labour contributes to the increased likelihood of new-born mortality or other injuries that may lead to long-term consequences. The substantial proportion of deliveries conducted outside the health facility (30%) confirms the existing challenges in accessing appropriate services since, in such low resources setting, the home deliveries are normally conducted under the assistance of unskilled health personnel. Indeed, the high proportion of stillbirth and birth asphyxia and injuries that this study has identified as major causes of mortality are related to the failures or delays in accessing appropriate healthcare services. In such context, the delays or failures in reaching the health facility are usually associated with transport challenges in accessing the health facility (Kananura et al., 2017). In fact, this study has indicated that 10% of the women who delivered in the community occurred while travelling to the health facility. Improved systems for prevention, identification and treatment of maternal morbidities at both community and health facility levels and improving access to required services are important in saving mothers with obstetric complications and new-bornsn with danger signs such as birth asphyxia and LBW. Furthermore, improving referral transport systems and women's birth preparedness practices could improve timely access to the required maternal and new-born health services.

The notable differences in causes of mortalities between children aged 0-5 and 5-9 years confirm an epidemiological shift of diseases between age bands. Malaria, protein deficiencies or malnutrition and acute respiratory infection (ARIs) were the major causes of mortality among children aged 0-5 years, but these were reduced by almost half among those aged 5-9 years. Gastrointestinal disorder and injuries were substantial emerging morbidities after 4 years of age. These emerging morbidities could be resulting from the transition of new behaviours and curiosity among children aged 5-9 years, and thus, their limited supervision may predispose them to unintended injuries such as poisoning, falls, drowning, burns and suffocation (Khatlani et al., 2017; Ruiz-Casares et al., 2018; WHO & UNICEF, 2008). Similarly, children aged 5-9 years may be exposed to ingestion of unhealthy items that may lead to gastrointestinal disorders such as worms and typhoid. The variation in some of the mortality causes across the age groups suggests age-specific interventions at different levels of growth.

Morbidities like malaria, protein deficiency, diarrhoea and ARIs identified in this study as some of the major causes of mortality among children aged 5-9 years indicate the need for prevention and treatment interventions that target all age groups.

However, access to treatment and preventive interventions is still a challenge in SSA. For instance, 46% and 90% of children in Uganda have no access to pneumococcal, and rotavirus vaccines, respectively (Uganda Bureau of Statistics and ICF International, 2018), and such could be worse in rural communities. Further, despite the recommendation of accessing treatment within 12 hours for children with suspected symptoms of fever, malaria, cough, and diarrhoea, this study revealed that on average, most children with these diseases were taken to the health facility after 4 days of symptom recognition and 30% never reached the health facility at all. Therefore, childcare integrated community prevention package targeting parents and caretakers as well as interventions for early identification and treatment of morbidities are needed. Community interventions that have been effective in such low resource settings include integrated community case management (Kalyango et al., 2013; Nanyonjo et al., 2013) and the use of community health workers for mobilisation, sensitisation and community-to-facility linkage (Aboubaker et al., 2014; Haver et al., 2015).

Adolescence age and unmarried or single motherhood status were associated with increased risk of child mortality, although the association was stronger among infants. Some of the worrying findings identified are that some girls become pregnant as early as 10 years, and 26% of the adolescent mothers were aged 17 years and lower. Such indicates that a mother whose first birth was between 10 and 17 years would have a 7-year-old child and many more children while still an adolescent or youth. Indeed, these mothers are characterised by other mortality risk factors such as LBW, low level of education, having no partner, and lack of access to resources. Adolescent women are normally isolated in the communities and not engaged in any income-generating activity and thus have inadequate support to cater to their children's health. The effect of marital status could also be via access to income and decision-making power, which normally shapes the choice of healthcare services. Married women may have collective decision-making and support, contributing to child health and wellbeing. These results suggest interventions that address issues of teenage pregnancy in such settings. Though still controversial in Uganda's setting because of culture and religion, one of the proposed interventions would be pushing for improved knowledge of and access to contraceptive methods, which could help reduce unwanted pregnancies. For teenagers that become pregnant or deliver, there is a need for interventions that help them produce and sustain healthy babies.

LBW and multiple births, which could be related, were important individual risk factors of child survival, particularly the infants. The LBW babies are always susceptible to infections and other risk factors such as proteins deficiency that may increase their risk of death (Ntenda & Chuang, 2018; Rahman et al., 2016). Similarly, multiple births may be susceptible to malnutrition and, ultimately, infections, which would increase their risk of mortality.

Interestingly, despite the importance of recording birth weight for the identification of LBW babies, many births had no birth weight taken, which has been indicated as a challenge in SSA countries(Cutland et al., 2017; UNICEF & WHO, 2004). Therefore, intervention targeting LBW risk factors such as maternal chronic illnesses, substance abuse, poor nutritional status, infections, maternal age under 20 and over 30, short birth intervals, and high parity should be designed and implemented to reach women and girls. For instance, improved access to family planning has multiple effects on reducing LBW risk factors such as deliveries among high parity women, pregnancies following short birth intervals, and adolescent pregnancies. The other low cost and effective interventions that contribute to the identification and survival of LBW babies in resource-limited settings are foot length measurements (Marchant et al., 2010, 2014) and Kangaroo Mother care (Colony, 2008; Suman et al., 2008; Vesel et al., 2015) respectively. As alluded to earlier, it is also recommended that mothers attend ANC as required if they are to benefit from the interventions that prevent or control the LBW effect and identify complications such as multiple births. Additionally, there is a need for guidelines on caring for LBW and multiple births at the facility and community level (Hanson et al., 2019). Further, the effect of LBW and multiple births on children's survival beyond the first month of life suggests strategies that improve the survival of such groups beyond infancy.

Higher levels of education and belonging to the least poor household were inversely associated with the increased likelihood of child mortality, but the association was higher among infants. Nattey et al., 2013 indicate that child mortality is likely to be higher among mothers with no education level than those with a primary level and higher (Nattey et al., 2013). Girls from the poorest families often drop out of school to complement the household's income and ultimately get exposed to early sex and pregnancy (Prakash et al., 2017; Sekine and Hodgkin, 2017). Such are common in LMICs (Snilstveit et al., 2016). Several studies have indicated the contribution of maternal education towards better health behaviours' practices such as nutrition, childhood immunization and better sanitation (Makoka & Masibo, 2015; Semba et al., 2008). Regarding the wealth effect, poor groups within the communities are always at high risks of several morbidities and mortality (Victora et al., 2003). Such groups often lack access to quality health services resulting from their limited decision-making power over the choice of healthcare.

The likelihood of mortality was also high among rural residents, but the association was higher among infants. Noteworthy is that the socio-economic, maternal factors and health interventions that affect the child's health may vary across and within regions, possibly explaining mortality variations (Halonen et al., 2013; Martikainen et al., 2003). The place of residence is characterised by community behaviours such as alcohol use, geographic characteristics such as calamities, and facility proximity, all of which are well known to affect the health and survival of the child. In Uganda's rural context, the high child mortality rates in rural communities are not surprising. Such communities are characterised by limited access to health facilities, poor transport systems, and poverty, each contributing to the delays or failure in accessing the required health services. As earlier mentioned, even the few health

facilities in such communities frequently experience inadequate amenities and qualified health workers to provide the required services.

3.6. Conclusion

The mortality causes such as LBW, premature, birth asphyxia injuries, diarrhoea, malaria, and pneumonia, as well as some of the identified risk factors such as adolescent pregnancy and LBW in this study, could be avoidable and amendable if pregnant women, women in labour and sick children received required prevention and treatment interventions. We note that proteins deficiency or malnutrition is, in most cases, not recognised as a direct cause of child mortality (Akombi et al., 2017; Bhutta et al., 2019) and has not gained global and national attention, yet in such a resource-limited context, the prevalence of malnutrition is high (Akombi et al., 2017). The epidemiological shifts in causes of death and the highest mortality in infancy and children aged 1-4 years, as well as the continued effect of risk factors among under-5 aged children, emphasize the need for a life course (Clark et al., 2020; Countdown to 2030, 2017; Kerber et al., 2007; Lassi et al., 2015; Tinker et al., 2005) approach in the design and implementation of child health interventions that include the pre-conception, pregnancy, birth or labour, and children of all age interventions. Some of the pre-conception and after delivery interventions include increased access to contraceptive use among adolescents and newly delivered women, which reduce adolescent pregnancy and short birth intervals. Pregnancy interventions may include strategies that mobilize women for antenatal care services, including sensitization on care for pregnancies, which may contribute to preventing LBW and identifying pregnancy complications and morbidities at an early stage. New-borns born with adverse outcomes such as LBW, preterm, and multiple births should be exposed to appropriate treatment and care interventions until 5 years of age. Such interventions should particularly target the uneducated, poor, and rural women dwellers. Other interventions on preventing accidents or injuries, hygiene-related infections and nutrition should target mothers, women, and other children's caretakers. In addition to under-10 protein deficiency research studies, we also recommend more evidence on how child morbidity and treatment access vary across different groups, which may guide the design of group-specific interventions.

3.7. Strengths and limitations

The main strength of the HDSS is that it comprehensively collects information on the same individuals that describe the changes in population over time. In particular, the capacity of the DHSS data in linking the health events' information with socio-economic, maternal demographic, structural and biological factors helps to assess how these factors shape the survival and wellbeing of the population over their life cycle. The limitations are that, first, the findings are generalisable to the two-district covered by HDSS and perhaps central-eastern Uganda. Nonetheless, since most of the communities not only in Uganda but also in other sub-Saharan Africa share the same community and health characteristics, the study's findings may contribute to the design of children's age-specific interventions that improve their survival and wellbeing. Second, as has been highlighted in other studies, the challenges

HDSS in reporting stillbirth and new-born mortality (Akuze et al., 2020; Kadobera et al., 2017; Nareeba et al., 2021) may affect the estimates. The problem of underreporting could be explained by the discrepancies in the death reported in verbal autopsy and birth registration data. Third, there was a considerate proportion of missingness for some variables, particularly birth weight, which was addressed through multiple imputation. Fourth, the limitation of linking the accessed verbal autopsy data with the birth registration dataset limited us from generating the cause-specific mortality rates. Lastly, the heaping of birth weight was observed in multiples of 1000g with high frequencies observed for 2000g (14%), 3000g (63%), 4000g (21%) and 5000g (3%), which affected the classification children birth weight categories. Section 7.3 (Chapter 7) of this thesis provides a comprehensive discussion on the strengths and limitations of HDSS.

CHAPTER FOUR
LOW BIRTH WEIGHT, INSTITUTIONAL DELIVERY, AND NEW-BORN MORTALITY

This paper has been published in BMJ Open Journal: Kananura RM, 2021: Mediation role of low birth weight on the factors associated with new-born mortality and the moderation role of institutional delivery in the association of low birth weight with new-born mortality in a resource-poor setting: https://doi.org/10.1136/bmjopen-2020-046322

Abstract

The study's objective was to assess Low Birth Weight (LBW)'s mediation role on the factors associated with New-born Mortality (NM), including stillbirth and the role of institutional delivery in the association between LBW and NM. I used the 2011-2015 event histories health demographic data collected by Iganga-Mayuge Health Demographic and Surveillance Site (HDSS). The dataset consisted of 10,758 registered women whose birth occurred at least 22 weeks of gestation and records of new-borns living status 28 days after delivery. The factors that were directly associated with PM were LBW (Odds Ratio(OR)=2.55, 95% confidence interval(95%CI) =1.15-5.67)), maternal age of 30+ (OR=1.68, 95%CI=1.21-2.33), rural residence(OR=1.38, 95%CI=1.02-1.85), mothers with previous experience of NM (OR=3.95, 95%CI=2.86-5.46), and mothers with no education level(OR=1.63, 95%CI=1.21-2.18). Multiple births and the mother's prior experience of NM were positively associated with NM at a later age. Institutional delivery had a modest inverse role in the association of LBW with PM. LBW mediated the association of PM with residence status, mothers' previous NM experience, multiple births, adolescent mothers, and mothers' marital status. Of the total effect attributable to each of these factors, LBW mediated +47%, +54%, +15%, 100%, and -45% of rural resident mothers, adolescent mothers, mothers with previous experience of new-born or pregnancy loss, multiple births, and mothers with partners, respectively. The findings demonstrate the need for a holistic life-course approach that gears the health systems to tackle NM.

4.1. Introduction

The evidence is clear that the availability of maternal and new-born life-saving technologies and effective interventions have worked towards reducing new-born mortality in developed countries and other developing countries (Darmstadt et al., 2005; Dickson et al., 2014; Zupan, 2005). However, new-born mortality continues to have the largest portion of under-five mortality (47%) and has remained unacceptably high in Sub-Saharan Africa (SSA) (UN IGME 2017, 2018, 2019, 2020). Of the 2.5 and 2.4 million new-born deaths in 2018 and 2019, respectively, 42% was a portion of SSA in both years of reporting (UN IGME 2018, 2020). The neonatal mortality rate (NMR) in SSA has persistently remained unacceptably high at an average of 27-28 per 1000 live births (UN IGME, 2017, 2018, 2019, 2020). At least 75% of new-born mortality occurs within the first week of life (Sankar et al., 2016), close to 55% within 24 hours (Sankar et al., 2016). These rates could be underestimated as stillbirths are normally misclassified because of weak documentation systems in SSA (Reinebrant et al., 2018).

The high proportion of new-born mortality has been attributed to Low Birth Weight (LBW) (Blencowe et al., 2012; Lawn et al., 2015) and their related consequences (Barros et al., 2011). The direct effect of the socio-economic and demographic factors such as wealth, education level, and maternal age on new-born mortality indicated in existing frameworks has been widely studied; however, evidence of how these could be mediated by LBW is elusive. For instance, a direct effect of adolescent age and advanced maternal age on neonatal mortality has been observed in some studies (Fawole et al., 2011; Kibria et al., 2018; V. Sharma et al., 2009; Sinha et al., 2017). However, maternal age extremes are associated with an increased risk of LBW and other adverse complications (Althabe et al., 2015; Blencowe et al., 2019; Blomberg et al., 2014; Grønvik & Sandøy, 2018; Lean et al., 2017; Manyeh et al., 2016; Weng, Yang, & Chiu 2014), ultimately leading to new-born mortality. Regarding socio-economic factors, educated and less poor women are more likely to access better maternal health prevention services that control LBW (Barros et al., 2012; Fenn et al., 2007; Lohela et al., 2019; Ronsmans et al., 2006) and can afford to incur an extra bill, aside from what is freely provided by the government (Ntenda et al., 2014; Kayode et al., 2012). Other LBW contributors include morbidity in pregnancy (syphilis and malaria), pre-pregnancy and pregnancy malnutrition exposure, and exposure to environmental factors, particularly indoor air pollution (Accrombessi et al., 2018; Blencowe et al., 2012, 2019), which are common among vulnerable populations. The scarcity of evidence on how LBW mediates new-born mortality limits the design of moderating interventions. Understanding the mediating role of LBW in the association of new-born mortality with socio-economic, demographic and other individual factors may generate clinical and community-based interventions that focus on women's health before and after pregnancy; and after delivery.

Further, access to health services is the most effective intervention in preventing maternal morbidities and controlling LBW and other complications' consequences (Darmstadt et al., 2005; Dickson et al., 2014). Attending the recommended number of antenatal care exposes

the mother to the interventions for identifying and managing pregnancies (WHO, 2016) that may lead to LBW. Additionally, access to ANC exposes the mother-foetus dyad to preventions and care interventions that reduce maternal morbidities associated with the increased likelihood of LBW and prematurity. The first day of life is vital for the survival of new-born, and thus, access to quality care within labour or delivery time is crucial. During childbirth, women should be attended to by skilled health workers, who should assess the labour complications, including obstructed labour conditions that may need emergency services such as caesarean section (Campbell, 2014; Darmstadt et al., 2013; Salam et al., 2014; Wall et al., 2010). After delivery, the new-borns should be screened for life-threatening signs, including LBW and asphyxia, to benefit from health interventions such as resuscitation for asphyxia and corticosteroid treatment administration/kangaroo mother care for LBW (Berkley et al., 2014; Darmstadt et al., 2005; Dickson et al., 2014; Salam et al., 2014). Notably, reaching the health facilities in the SSA context does not guarantee access to the required services (Benova et al., 2018; Lohela et al., 2019) because of multiple (concurrent) barriers that impede access to needed services. The health facility-based interventions could be performed inappropriately or too late, or women and new-borns may fail to access the necessary interventions because of inadequacies in supplies and skilled health workers (Goldenberg et al., 2018; Zupan, 2005). With the increasing rates of LBW and preterm birth vis-à-vis the stagnation of high neonatal mortality rates in SSA despite the increase in health facility delivery, evidence on how the health facility deliveries moderates the survival of LBW new-borns is warranted.

The above discussion highlights the role of LBW in mediating the association of some of the factors with new-born mortality and the role of institutional delivery in the relationship between LBW and new-born mortality. However, the pathways and mechanisms of the interactions are unclear, particularly in the sub-Saharan African context. In the light of life-course and systemic perspectives, I analyse the Iganga-Mayuge Health and Demographic Surveillance Site (HDSS) data to assess the LBW's mediation role on the factors associated with new-born mortality and the role of institutional delivery in the association between LBW and new-born mortality. Additionally, I study if identified perinatal mortality risk factors continue to affect the survival of new-borns in the later stage (late neonatal mortality).

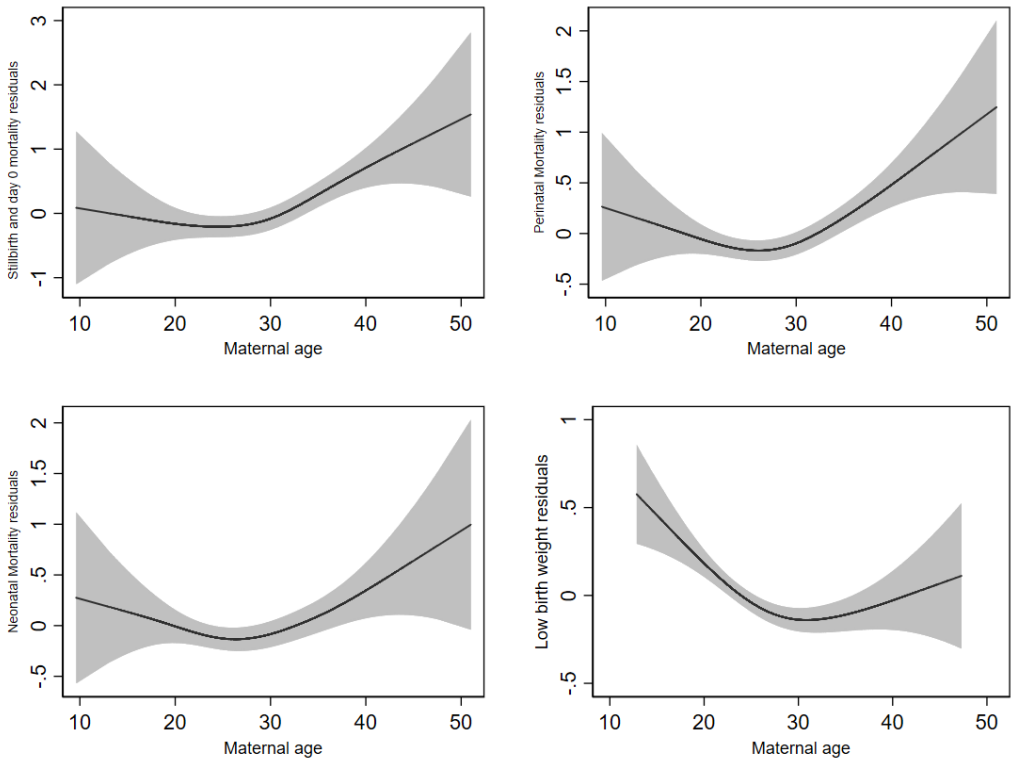
4.2. Methods

Results in this chapter are based on the 2011-2015 Iganga-Mayuge HDSS birth registration cohort. Details about Iganga-Mayuge HDSS have been presented in Chapter 2 of this thesis. The key outcomes or endogenous factors that were used to describe the perinatal and new-born mortality or survival system are perinatal mortality, late neonatal mortality and LBW (mediating factor). Perinatal mortality includes deaths within seven days after birth and all stillbirths, while late neonatal mortality is defined as death within 21 days after the first week of survival (7-28 days)(Da Silva et al., 2016; Pathirana et al., 2016) – describing the timing of death within the new-born survival system. LBW – defined as a birth weight that is less than

2.5 Kgs at birth (Cutland et al., 2017) explains how new-born survival could be indirectly affected by other factors through birth weight.

The new-born adverse outcomes' exogenous variables were categorised as maternal and household factors (having a partner, maternal education level, maternal age, household wealth index), child individual risk factors (childbirth order, birth category – multiple or singleton, child's sex), institutional delivery, mother's previous experience of new-born loss or stillbirth, place of residence (rural or urban), and birth season (in annual quarters). Having a partner was categorised as a dummy variable for 1 – having a partner (those who were either married or cohabiting) and 0 – having no partner (those who were single or widowed). The wealth indices 3-4 were considered less poor, and wealth indices1-2 were considered poorer. The wealth index was generated using principal component analysis, and the items were household assets, household roof structure, household floor structure, and household wall structure. Birth order was categorised as 1 – first order, 2 – 2nd to 4th order and 3 – 5th order. Education was categorised as no education attained, primary level attained, and the post-primary level attained; however, education level of at least primary was related to the reduced risks of perinatal and late neonatal mortality, so I later made it as a single dummy variable of no education (0 – at least primary level attained and 1 – no education level at all). Maternal age was grouped as <20 years, 20-29 years and 30 years and above based on the non-parametric analysis (Figure 4.1).

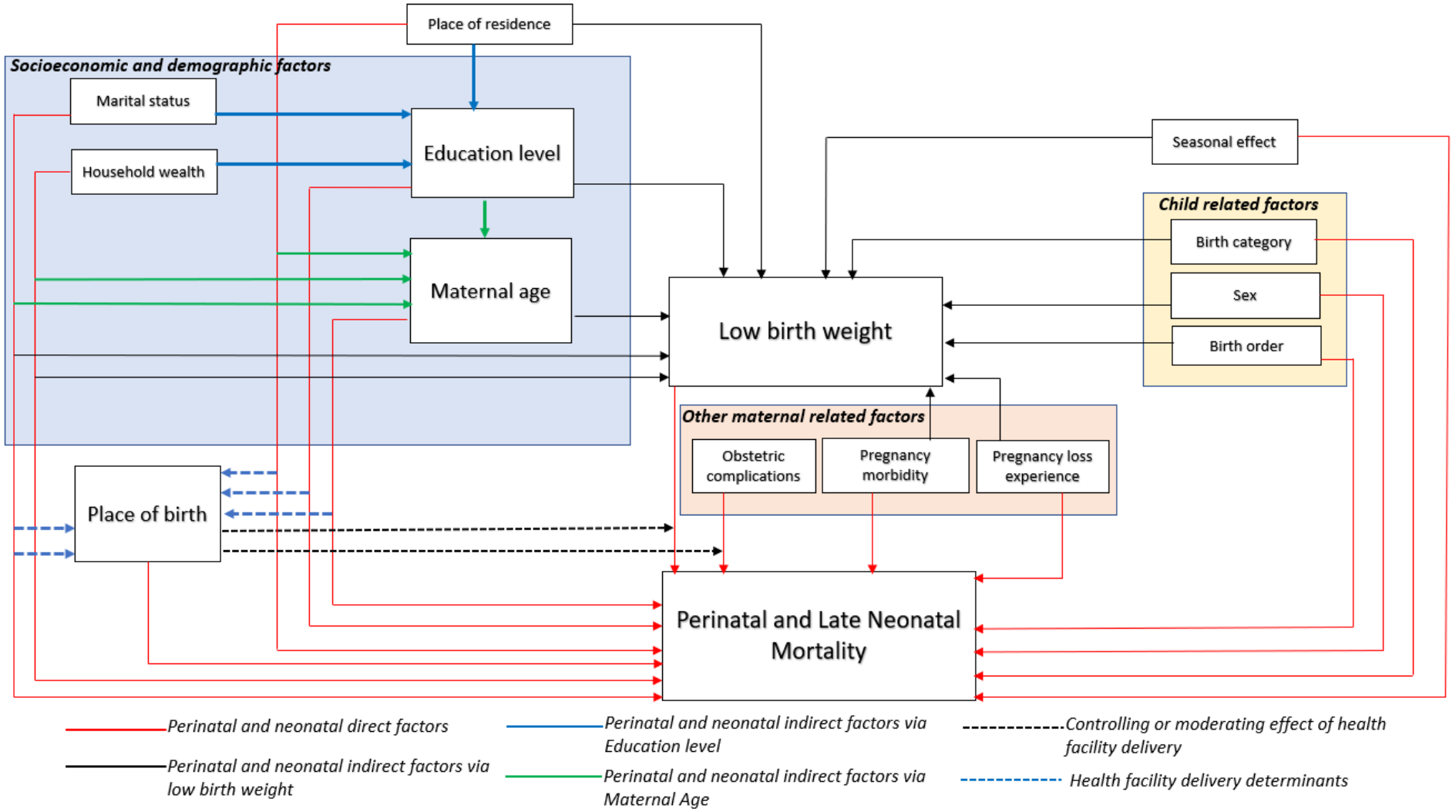
Figure 4.6: Relationship between age and birth outcomes for age categorization using event histories data



Data analysis and cleaning, such as categorisation and removal of duplicates, were done in STATA v.15. The analysis was guided by this study's new-born pathway framework (Figure 4.2), which was generated based on the available variables in the dataset and literature on the factors associated with new-born mortality and low birth weight. The outcome variables (LBW, prenatal mortality, late neonatal mortality) were in the form of binary, with 1 – indicating the presence of outcome exposure and 0 – the absence of outcome exposure. I, therefore, used a generalised linear modelling approach with a logit link function. To examine the new-born mortality pathway, several analysis steps were applied. Bivariate model(s) with all covariates on the perinatal, late mortality and LBW as outcome variables were performed to identify the variables that would significantly affect outcomes of interest in the adjusted models. The results were reported in terms of odds ratios (OR) and 95% confidence interval (CI). The level of significance was determined at a p-value of <=0.05. Details on the analysis of the mediation effect of LBW on new-born mortality are indicated in Chapter 2 (section 2.6.4).

The model was assessed for multicollinearity between the independent variables. Considering the presence of multicollinearity at the cut-off point of Variance Inflation Factor (VIF) <10 (Hair et al., 2006), there was no evidence of potential multicollinearity as each variable's VIF was less than 6 (Appendix 4.1). However, because of strong correction between the multiple birth and LBW, the multiple birth variable was dropped under the perinatal mortality multivariable model, while LBW was dropped under the late neonatal mortality multivariable model. Furthermore, because of the homogeneity across the study clusters, such as villages and sub-counties within the HDSS, the clustering or multilevel modelling approach could not yield a variation across these clusters. Nonetheless, the use of a fixed-effect approach with the inclusion of variables such as place of residence (urban or rural) and household wealth index as key variables of interest provides an insight into the variation in new-born mortality across the place of residence and households.

Figure 4.7: New-born mortality pathways analysis



Sources: Generated by the author based on available variables in the dataset and literature

4.3. Results

4.3.1. Participants' characteristics

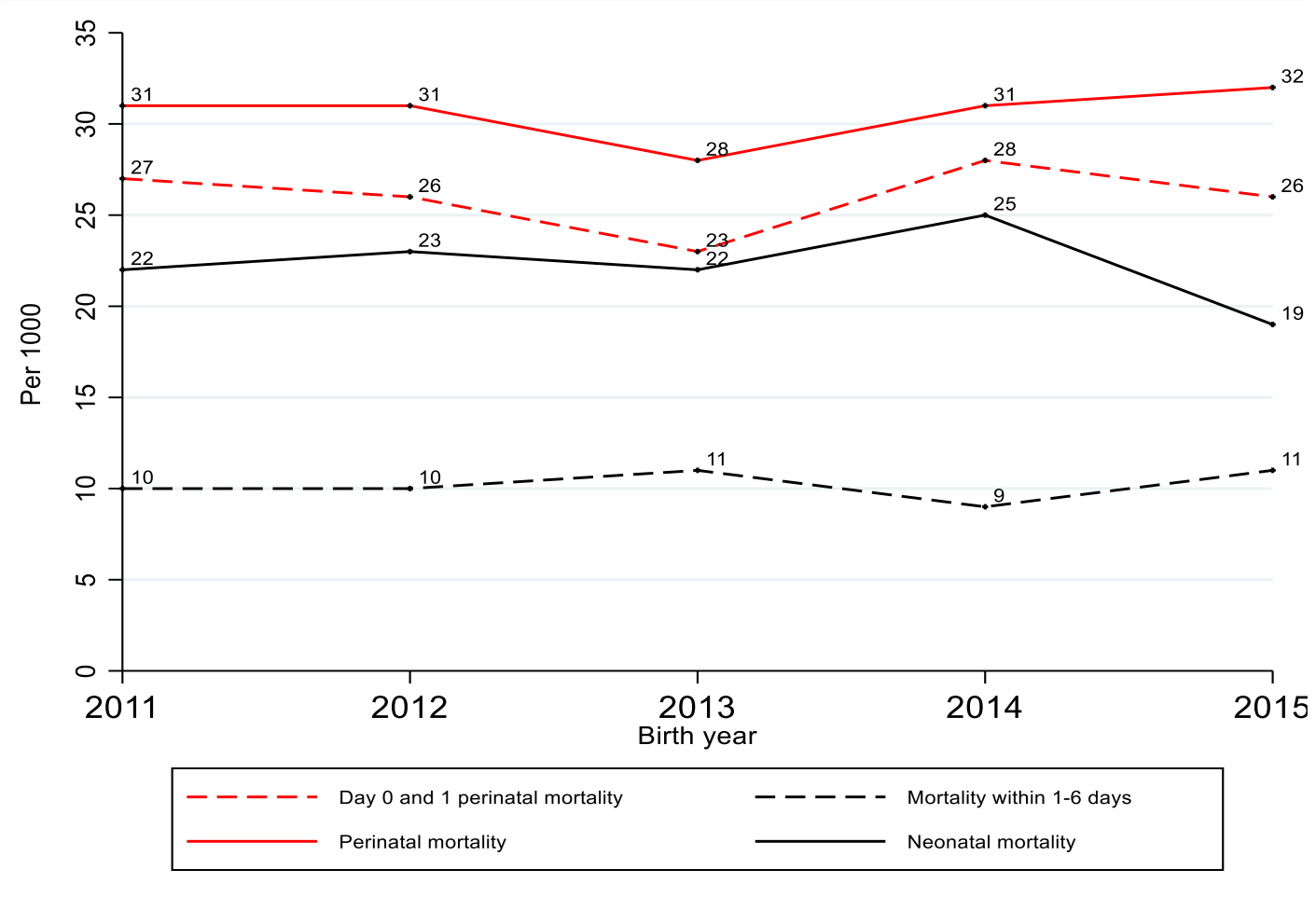
Of the total registered births between 2011 and 2015, 64% were rural residents (Appendix 6.2). The average maternal age was 27.3 years (standard deviation=±6.5), and 14% were adolescent mothers. Overall, 84% of deliveries occurred in health facilities, of which 15% occurred in private health facilities (Appendix 4.2). Regarding maternal socioeconomic, 86% of the mothers had attained at least primary level education, 53% belonged to a wealth index of 3-5, and 86% were staying with a partner or married (Appendix 4.2).

4.3.2. Perinatal mortality, neonatal mortality, and LBW estimates

Comparing the neonatal and perinatal mortality across five years of birth and death outcome registration, we see a slight change in the perinatal mortality curve between 2011-2014, with the mortality rate reducing from 31 to 28 per 1000 total birth and gaining its position in the subsequent years (Figure 4.3). The new-born mortality within days 0-1 has also not significantly changed (27 per 1000 in 2011 versus 26 per 1000 in 2015). Similarly, slight changes in neonatal mortality rates were observed between 2013 and 2015, with the rates increasing by three units between 2013 and 2014 and reducing by six units in the subsequent year (Figure 4.3). The new-born mortality within days 1-6 has also not significantly changed (10 per 1000 in 2011 versus 11 per 1000 in 2015).

Of the total prenatal mortality cases, death within 24 hours (0-1 days + stillbirths) accounted for 83%, while death within 1-6 days accounted for 30.8% (Figure 4.4). Similarly, the overall neonatal mortality rate in the five years preceding 2016 was 22 per 1000 live births. Of the neonatal mortality cases, 62% were deaths within 24 hours of life (0-1 days), and 14 per 1000 live births were deaths within 7-27 days (Figure 4.4).

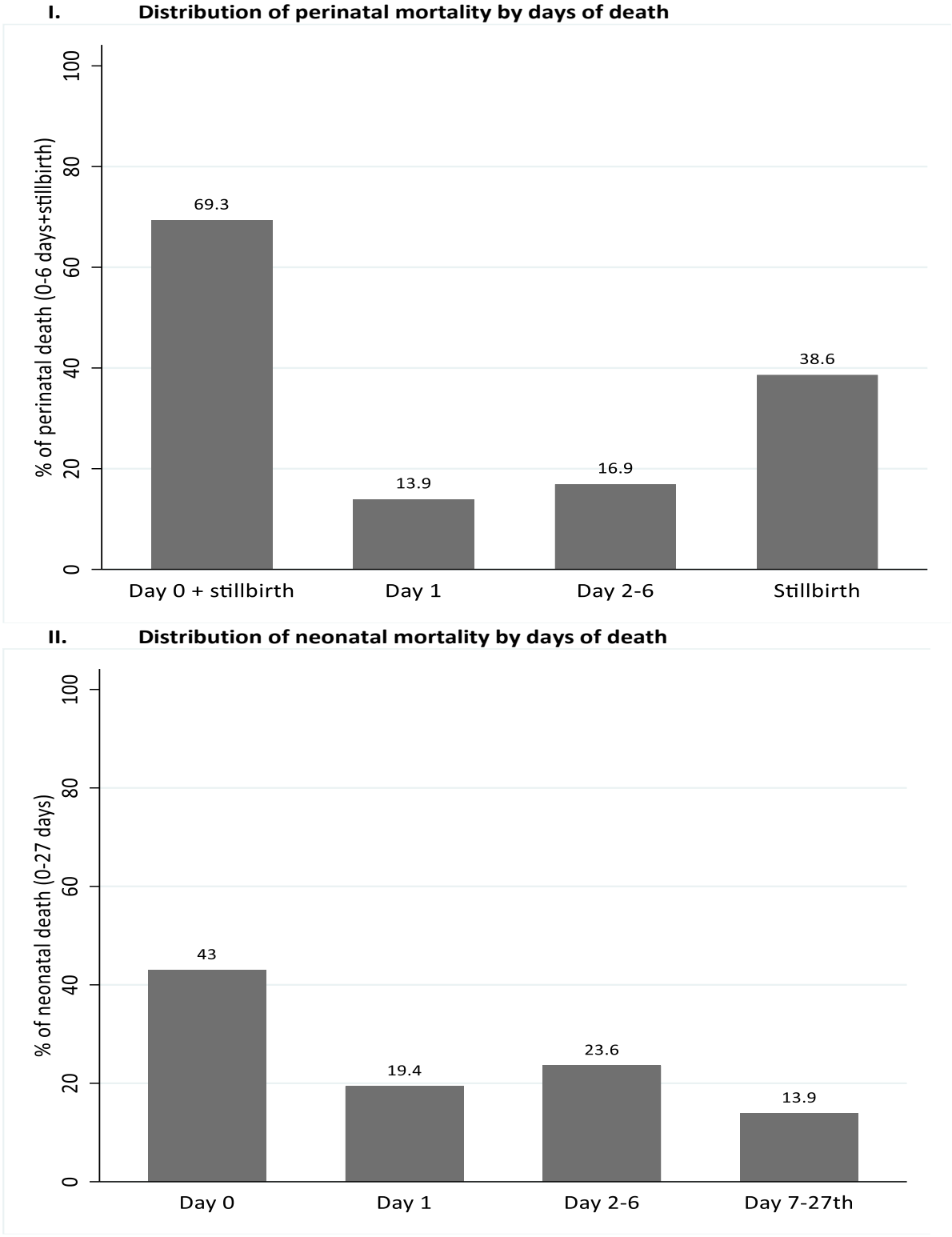
Figure 4.8: Annual changes in perinatal mortality and neonatal mortality rates



Note:

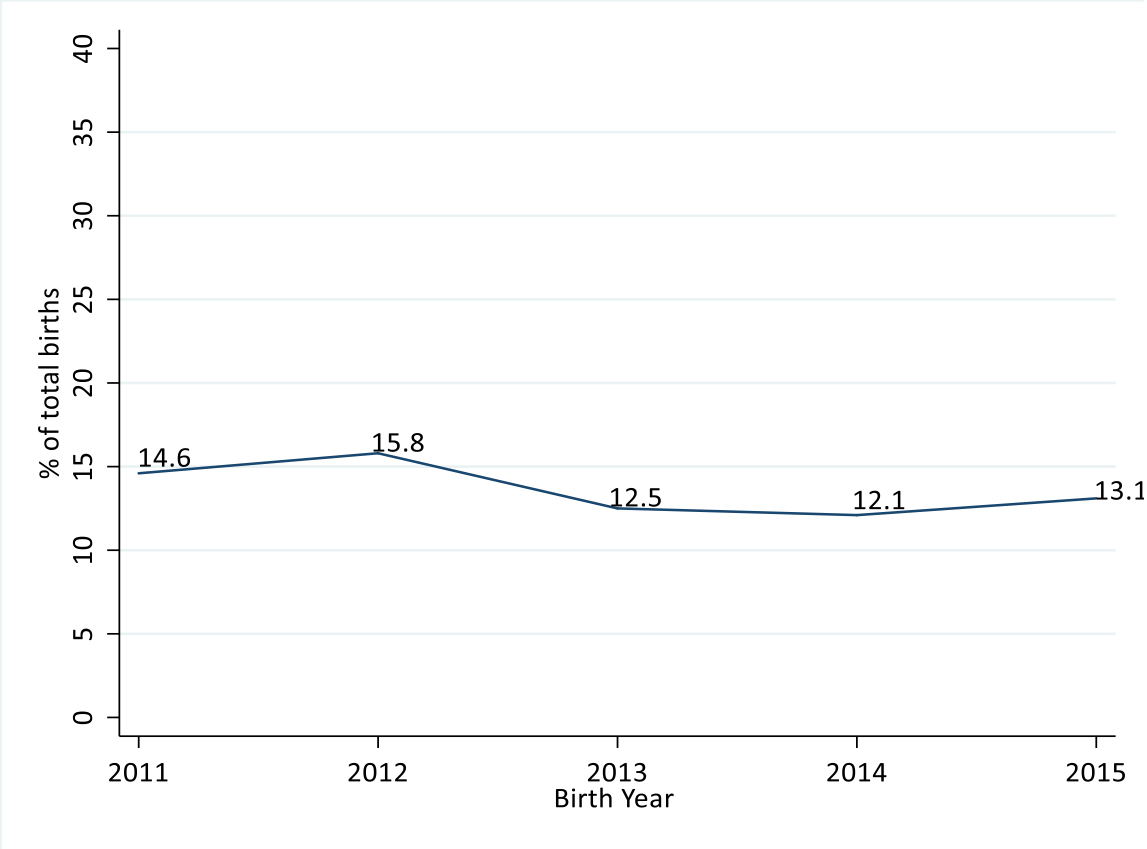
1. *Perinatal mortality was calculated as the number of births that resulted in stillbirths or died within 6 days after birth per the number of births (0-6 days + stillbirths).*
2. *Neonatal mortality was calculated as the number of new-borns that died within 27 days immediately or during birth (0-27days)*
3. *Mortality within 1-6 days was calculated as death among new-borns who were alive after their birthday*

Figure 4.9: Perinatal and New-born mortality distribution by days of death



Regarding the LBW, we observe a linear trend between 2011 and 2012 that was later reduced by three units in the subsequent year – remaining uniform for the rest of the reporting years (Figure 4.5).

Figure 4.10: Annual changes in low birth weight



4.3.3. Perinatal mortality, neonatal mortality, and LBW distribution by social-economic and demographic characteristics

I examined the study's LBW distribution and perinatal and neonatal mortality by socio-economic and demographic characteristics. LBW among adolescent aged women, unmarried women, and rural residents was 5%, 4% and 5%, points higher than those aged 20 years and above; married women and rural residents, respectively (Table 4.1). Similarly, LBW among new-borns whose mothers have ever experienced child loss and children born as multiple was 5% and 15% points higher than those whose mothers never experienced child loss and singleton births, respectively (Table 4.1). Perinatal and new-born mortality were slightly higher among adolescents and advanced aged mothers than those aged 20-29 years, and also slightly higher among rural residents than urban residents (Table 4.1). Additionally, perinatal and new-born mortality among low birth weight was 3% points higher than those with normal birth weight. Similarly, new-born mortality among children born as multiple births was 3% higher than in singleton (Table 4.1).

Table 4.1: Distribution of new-born mortality and LBW by stratifiers

	Perinatal mortality distribution	Neonatal mortality distribution	LWB distribution
Childbirth weight			
Low birth weight (<2.5Kgs)	6.3	4.7	-
Normal Birthweight	2.6	1.8	-
Institutional delivery			-
Public Health facility	3.1	2.3	-
Community	3.5	2.1	-
Private health facility	2.6	2.1	-
Maternal education level			
None	4.7	2.1	15.3
Primary	3.1	2.4	13.9
Post primary	2.4	2.1	12.7
Maternal age group (years)			
<20	3.4	2.7	17.9
20-29	2.5	1.8	12.9
30+	3.9	2.7	13.3
Childbirth order			
1	2.7	1.9	13.2
2	3.6	2.5	14.1
3	1.7	2.0	14.3
Place of residence			
Rural	3.4	2.4	15.1
Urban	2.5	1.9	11.3
Marital status			
Has a partner	3.0	2.1	13.1
Does not a partner	3.9	3.1	17.5
Previous experience of death			
Experienced pregnancy loss	10.4	8.0	18.0
Never experienced pregnancy loss	2.7	1.9	13.5
Birth season in annual quarters			
1	2.7	2.0	13.1
2	2.9	2.2	14.7
3	3.4	2.3	13.6
4	3.2	2.4	13.4
Child sex			
Female	3.2	2.2	14.4
Male	3.0	2.2	13.0
Household wealth index			
Index 1 and 2	3.2	2.3	14.7
Index 3	3.2	2.5	14.9
Index 4 and 5	2.8	2.0	11.8
Birth category			
Multiple	3.2	5.1	32.6
Singleton	3.1	2.2	13.2

4.3.4. The perinatal mortality pathways

To describe the perinatal mortality pathway, I provide the results in two tables (Table 4.2 and Table 4.3). Table 4.3 indicates how the association of LBW with perinatal mortality changes with institutional delivery and the inclusion of other factors. Table 2 shows the indirect factors associated with perinatal mortality via LBW. At the bivariable level, the crude odds of perinatal mortality were slightly higher for facility deliveries relative to those conducted in the community (Odds Ratio (OR)=1.01, 95% confidence interval (95%CI) = 0.80-1.28) (Table 4.2). Also, at the bivariable level, the crude odds of perinatal mortality were higher among LBW babies than those weighing 2.5Kgs+ (OR=2.54, 95%CI=1.74-3.70). Controlling for health facility delivery and introducing an interaction between LBW, a modest effect of health facility delivery on the effect of LBW was observed (OR=0.91, 95%CI=0.40-2.07) (Table 4.2). Controlling for other factors in the final model, the odds of perinatal mortality among the LBW new-borns remained almost the same (OR=2.37, 95%CI=1.61-3.48). The other factors that were directly associated with the increased odds of perinatal mortality were being a rural resident (OR=1.38, 95%CI=1.02-1.85), a mother's previous experience of perinatal mortality (OR=3.93, 95%CI=2.85-5.42), advanced maternal age (OR=1.5, 95%CI=1.21-1.99) and having no education at all (OR=1.63, 95%CI=1.22-2.19). Birth of 5th order and above was inversely associated with perinatal mortality (OR=0.39, 95%CI=0.17-0.89) (Table 4.2).

As mentioned earlier, LBW was strongly associated with perinatal mortality and was considered a potential mediating factor for perinatal mortality. Table 4.3 indicates the magnitude effect of the LBW factors in the study's dataset. The factors that were associated with the increased odds of LBW were adolescent mothers (OR=1.40, 95%CI=1.14-1.71), rural resident mothers (OR=1.40, 95%CI=1.19-1.65), mothers with previous experience of new-born or pregnancy loss (OR=1.33, 95%CI=1.01-1.76), babies born as multiple births (OR=3.12, 95%CI=2.31-4.21). Having a partner or being married was inversely associated with LBW (OR=0.76, 95%CI=0.63-0.92) (Table 4.3).

Of the total effect attributable to each of these factors, LBW mediated +47% of rural resident mothers, +54% of adolescent mothers, +15% of mothers with previous experience of new-born or pregnancy loss, +100% of multiple births and -45% of mothers with partners **(**Table 4.4).

4.3.5. Factors associated with late neonatal mortality

The increase in the odds of late neonatal mortality was associated with previous experience of pregnancy loss or neonatal mortality (OR=3.17, 95%CI= 1.15-8.74) and multiple births (OR=6.93, 95%CI=2.58-18.55) (Table 4.5).

Table 4.2: Analysis of direct determinants of perinatal mortality using 2011-2015 Iganga-Mayuge HDSS event histories data

	Unadjusted		Adjusted 1		Adjusted 2		Fully adjusted	
	OR	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**
Childbirth weight								
<2.5 Kgs	1.00	-	1.00	-	1.00		1.00	-
25 Kgs+	2.54	[1.74-3.70]***	2.54	[1.75-3.71]***	2.73	[1.21-6.14]*	2.37	[1.61-3.48]***
Place of delivery								
Community	1.00	-	1.00	-	1.00	-	1.00	-
Health facility	1.01	[0.8-1.28]	1.04	[0.82-1.32]	1.06	[0.82-1.37]	1.14	[0.88-1.47]
Place of delivery and LBW interaction [a]								
<2.5 Kgs and health facility delivery interaction	-	-	-	-	0.91	[0.4-2.07]	-	-
Annual birth quarters								
1	1.00	-	-	-	-	-	1.00	-
2	1.08	[0.78-1.49]	-	-	-	-	1.07	[0.78-1.49]
3	1.26	[0.93-1.72]	-	-	-	-	1.23	[0.90-1.68]
4	1.20	[0.87-1.64]	-	-	-	-	1.19	[0.87-1.65]
Maternal education level								
Primary+	1.00	-	-	-	-	-	1.00	-
None	1.69	[1.27-2.25]***	-	-	-	-	1.63	[1.22-2.19]**
Maternal age								
<20	1.12	[0.83-1.53]	-	-	-	-	1.28	[0.89-1.83]
20—29	1.00	-	-	-	-	-	1.00	-
30+	1.48	[1.18-1.85]***	-	-	-	-	1.55	[1.21-1.99]**
Childbirth order								
1	0.79	[0.62-1.01]	-	-	-	-	0.97	[0.73-1.29]
2—4	1.00	-	-	-	-	-	1.00	-
5th+	0.51	[0.23-1.14]	-	-	-	-	0.39	[0.17-0.89]*

Note: [a] base – community delivery – birth weight 2.5Kgs and above interaction; 95%CI – 95% confidence interval; OR – Odds Ration; *** P<0.001; ** P<0.01; * P<0.05

Table 4.2 Continued

	Unadjusted		Adjusted 1		Adjusted 2		Fully adjusted	
	OR	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**
Place of residence								
Urban	1.00	-	-	-	-	-	1.00	-
Rural	1.40	[1.1-1.78]**	-	-	-	-	1.38	[1.02-1.85]*
Marital status								
No partner	1.00	-	-	-	-	-	1.00	-
Has a partner	0.74	[0.54-1.02]	-	-	-	-	0.75	[0.52-1.06]
Experienced neonatal or pregnancy loss previously								
No	1.00	-	-	-	-	-	1.00	-
Yes	4.18	[3.1-5.63]***	-	-	-	-	3.93	[2.85-5.42]***
Household Wealth								
Poor(er) (1-2)	1.00		-	-	-	-	1.00	-
Less poor (3-5)	1.10	[0.88-1.38]	-	-	-	-	0.86	[0.65-1.13]
Child sex								
Male	1.00	-	-	-	-	-	1.00	-
Female	1.07	[0.82-1.40]	-	-	-	-	1.04	[0.79-1.36]
Birth category								
Singleton	1.00	-	-	-	-	-	-	-
Multiple	1.02	[0.5-2.08]	-	-	-	-	-	-
Intercept	-	-	-	-	-	-	0.02	[0.01-0.03]***

Note: 95%CI – 95% confidence interval; OR – Odds Ration; *** P<0.001; ** P<0.01; * P<0.05

Table 4.3: Perinatal mortality indirect determinants mediated through LBW using Iganga-Muyuge HDSS event history data

	Unadjusted		Adjusted	
	OR	**95%CI**	**OR**	**95%CI**
Annual birth quarters				
1	1.00	-	1.00	-
2	1.11	[0.93-1.34]	1.12	[0.93-1.35]
3	1.05	[0.87-1.27]	1.06	[0.88-1.27]
4	1.03	[0.86-1.24]	1.03	[0.85-1.24]
Maternal education level				
Primary+	1.00	-	1.00	-
None	1.14	[0.95-1.37]	1.14	[0.94-1.37]
Maternal age				
<20	1.43	[1.2-1.7]***	1.40	[1.14-1.71]***
20—29	1.00	-	1.00	-
30+	0.94	[0.82-1.08]	0.98	[0.84-1.14]
Childbirth order				
1	0.91	[0.8-1.04]	0.88	[0.75-1.02]
2—4	1.00	-	1.00	-
5^{th}+	1.03	[0.75-1.41]	0.97	[0.70-1.35]
Place of residence				
Urban	1.00	-	1.00	-
Rural	1.39	[1.22-1.59]***	1.40	[1.19-1.65]***
Marital status				
No partner	1.00	-	1.00	-
Has a partner	0.71	[0.6-0.85]***	0.76	[0.63-0.92]**
Experienced neonatal or pregnancy loss previously				
No	1.00	-	1.00	-
Yes	1.45	[1.11-1.89]**	1.33	[1.01-1.76]*
Birth category				
Singleton	1.00	-	1.00	-
Multiple	3.10	[2.31-4.16]***	3.11	[2.30-4.19]***
Household Wealth				
Poor(er) (1-2)	1.00	-	1.00	-
Less poor (3-5)	1.16	[1.02-1.32]*	0.92	[0.79-1.09]
Child sex				
Male	1.00	-	1.00	-
Female	1.13	[0.99-1.29]	1.12	[0.99-1.28]
Intercept			0.15	[0.11-0.19]***

Note: 95%CI – 95% confidence interval; OR – Odds Ration; *** P<0.001; ** P<0.01; * P<0.05

Table 4.4: Indirect pathways of the association between LBW and perinatal mortality

	Indirect effect (IE)	Total effect (TE)	% Mediated through LBW (IE/TE*100)
Multiple birth	1.134	1.134	100.0
Experienced neonatal or pregnancy loss previously	0.246	1.615	15.2
Has a partner	-0.237	-0.524	45.2
Adolescent age	0.290	0.537	54.0
Rural residence	0.290	0.615	47.4

Table 4.5: Late neonatal mortality risk factors using 2011-2015 Iganga-Mayuge HDSS event histories data

	Unadjusted		Adjusted	
	OR	**95%CI**	**OR**	**95%CI**
Annual birth quarters				
1	1.00	-	1.00	-
2	1.55	[0.55-2.91]	1.65	[0.58-4.68]
3	1.63	[0.59-3.02]	1.64	[0.59-4.56]
4	1.43	[0.49-2.72]	1.41	[0.49-4.09]
Education Level				
No level of education	1.00	-	1.00	-
Primary education+	1.37	[0.56-2.35]	1.24	[0.51-3.06]
Maternal age (years)				
<20	0.87	[0.31-1.66]	1.21	[0.37-3.97]
20-29	1.00	-	1.00	-
30+	1.73	[0.87-2.63]	1.73	[0.81-3.69]
Childbirth order				
1st	0.70	[0.34-1.07]	0.88	[0.38-2.04]
2—4	1.00	-	1.00	-
5th+	2.20	[0.67-4.54]	1.89	[0.54-6.61]
Place of residence				
Urban	1.00	-	1.00	-
Rural	0.77	[0.38-1.17]	0.82	[0.35-1.95]
Marital status				
Has no partner	1.00	-	1.00	-
Has a partner	0.66	[0.27-1.14]	0.54	[0.21-1.43]
Experienced neonatal or pregnancy loss previously				
No	1.00	-	1.00	-
Yes	3.60	[1.39-6.46]**	3.17	[1.15-8.74]*
Birth category				
Singleton	1.00	-	1.00	-
Multiple	7.71	[2.95-13.85]***	6.93	[2.58-18.55]***
Household Wealth				
Poorer (1-2 index)	1.00	-	1.00	-
Less poor (3-5 index)	0.75	[0.37-1.16]	0.72	[0.29-1.74]

Note: 95%CI – 95% confidence interval; OR – Odds Ration; *** P<0.001; ** P<0.01; * P<0.05

Table 4.5 Continued

	Unadjusted		Adjusted	
	OR	**95%CI**	**OR**	**95%CI**
Child sex				
Male	1.00	-	1.00	-
Female	0.57	[0.28-0.88]	0.55	[0.27-1.12]
Place of delivery				
Community	1.00	-	-	-
Health facility	1.22	[0.57-1.95]	-	-

Note: 95%CI – 95% confidence interval; OR – Odds Ration; *** P<0.001; ** P<0.01; * P<0.05

4.5. Discussion

To the best of my knowledge, this is the first study in a resource-poor setting that seeks to understand how LBW new-born mediates new-born mortality and how the institution delivery may moderate the LBW effect on new-born survival. The analysis was based on an event history health demographic dataset that has not been exploited in studying new-born survival in Uganda and other countries with the same context. The study results provide an insight into new-born survival life-course and health systems interventions, particularly targeting the prevention of LBW occurrences and management of or care for LBW new-borns. In the subsequent sub-sections, I discuss 1) the health facility pathways in affecting the survival of new-borns, and 2) the pathway through which LBW mediate the new-born survival. The results are interpreted, and where possible, recommendations for the design of appropriate interventions are discussed based on the available studies and implementation research evidence in a similar context.

4.5.1. Health facility delivery and neonatal mortality

The study results confirm the persistent high perinatal mortality rates in Uganda, with stillbirths and death within 24 hours contributing the largest share. The modest effect of health facility delivery on the survival of LBW new-borns and the large proportion of new-born death within 24 hours after birth indicates a gap in accessing the required health services. We know that, during labour, women should be attended to by skilled health workers who are knowledgeable and qualified to screen for labour complications such as obstructed labour conditions, which need life-saving emergency services, for instance, caesarean section (Darmstadt et al., 2013; Das et al., 2014). However, access to these interventions is usually limited in such resource-limited settings (Zupan, 2005). Further, the substantial effect of LBW on the survival of new-borns is well documented (Barros et al., 2011; Blencowe et al., 2012), but interventions for preventing or controlling the effect of LBW are always inadequately available in such resource-limited settings. For instance, kangaroo mother care and resuscitation that are easy to implement, inexpensive and effective (Das et al., 2014; Dickson et al., 2014) for helping such new-borns survive are not universally implemented in most health facilities in such settings. Additionally, access to ANC, such as

screening for maternal morbidities and prenatal interventions, may help protect the mother-foetus dyad from maternal morbidities (Lincetto et al., 2013) and ultimately reduce the likelihood of adverse outcomes. However, usually, most women do not access such services (Benova et al., 2018).

Noteworthy is that in this study's setting and in sub-Saharan Africa in general, such interventions may fail to work effectively because of community contextual problems, particularly poor transport and referral systems, which contribute to delays and failures in receiving required services. For instance, one public hospital (Iganga Hospital) in this study setting provides Comprehensive Emergency Obstetric and New-born Care services in the district (Uganda Ministry of Health 2018b). However, because of the long-distance coupled with poor transport and referral systems, women from rural or remote areas usually fail to access the services and, for those that make it, reach when they are in advanced stages of complications. Such could perhaps explain why rural residents were associated with a high risk of perinatal mortality in this study.

Further, most women first access services at different care points within the community in such settings because of pluralism in healthcare. They are later referred or go to accredited or higher-level facilities when adverse complications have emerged. Thus, most women who deliver in higher-level facilities often have complications associated with a high likelihood of perinatal mortality. These highlighted challenges could explain why health facility delivery could not contribute substantially to the reduced probability of stillbirth and death within 24 hours. Additionally, the rural communities are characterised by cultural and social behaviours that affect access to pregnancy, delivery and new-born care interventions. These findings suggest interventions that simultaneously improve healthcare access coverage and quality of care if the facility interventions match better outcomes.

4.5.2. LBW effect on perinatal and neonatal mortality

LBW was identified as a potential determinant of perinatal mortality. The other determinants of new-born mortality were marital status, maternal age, and maternal education. Having a partner was inversely associated with LBW, which was consistent with another study on the effect of marital status on the birth outcome (Singh et al., 2017) – implying that it may reduce perinatal mortality indirectly through birth weight. The effect of marital status on child health outcomes could be via decision-making power, influencing the choice of appropriate services. In the study's context and sub-Saharan Africa, men usually possess resources and assets; thus, unmarried or single women access inadequate health services (Cohen et al., 2014). In addition to the negotiating power with the health workers, married women have support from their spouse in terms of joint income, joint care and joint decision-making, which may contribute to their birth preparedness (Kaiser et al., 2018), child nutrition and general health of the household.

Furthermore, the health policy or rule in Uganda that requires women to attend maternal services in accompany of their spouses may limit their unmarried from accessing maternal health facility services (Påfs et al., 2015; Peneza & Maluka, 2018; Sochas, 2019) that would address LBW. Studies done in similar settings have indicated that women would be denied services unless they attended with their husbands. Sometimes, those with husbands would be prioritised (Påfs et al., 2015; Peneza & Maluka, 2018; Sochas, 2019). While male engagement is a positive factor, it has been found that it could end up being a discriminative strategy that could create stigma among unmarried women, inhibiting them from accessing the required services (Påfs et al., 2015; Sochas, 2019). Inclusive interventions that target all women groups regardless of statuses, such as age and marital status, should be designed.

Maternal age of 30 years+ was positively associated with perinatal mortality as the adolescence age (15-19 years) was positively associated with LBW – indicating how the tail ends of maternal age are associated with the increased likelihood of new-born mortality. Notwithstanding, the effect of maternal age on perinatal mortality needs to be interpreted with care because of other confounding factors such as birth order or parity. On the first hand, the effect of maternal age of 30 years+ could be related to birth order. Consistent with a study done in India and Bangladesh (Al Kibria et al., 2018), new-borns of birth order of at least 5 were at lower risk of mortality compared to the first birth order. When an interaction between maternal age and birth order was introduced, the first births among women aged at least 30 years were positively associated with perinatal mortality.

On the other hand, we also know that high parity is associated with pregnancy complications such as hypertension, leading to an increased likelihood of adverse birth outcomes. In low and middle-income countries where maternal age at the first delivery begins as early as 10 years (Christiansen et al., 2013), by the age of 25-30, most women have experienced at least four pregnancies that would increase the risk of hypertension and ultimately adverse birth outcomes. In this study, 28% and 49% of women aged 20-29 and 30 years, respectively, had children of 3rd and 4th birth order. These results suggest adolescent pregnancy and fertility control interventions targeting adolescents, newly delivered women and multiparous women. Furthermore, the results suggest clinical screening and treatment for morbidity in pregnancy, which may reduce adverse birth outcomes.

In this study, multiple births were not strongly associated with perinatal mortality but were strongly associated with mortality at a later age. Although some studies have indicated multiple births to be highly associated with infant and under-five mortality (Monden & Smits, 2017; Uthman et al., 2008), this study highlights that the association may vary by age. The association of multiple births with perinatal mortality in this study has been indicated to be mediated by LBW. The association of multiple births with LBW and preterm births has also been studied in other studies (Blondel et al., 2002; Dudenhausen & Maier, 2010). Women with multiple births need special care (Heather et al. 2017; Montgomery et al. 2005) in terms of nutrition to produce enough breast milk to feed the new-borns.

Further, multiple new-borns are more likely to be very small new-borns, and appropriate regular postnatal examinations are recommended (Dudenhausen & Maier, 2010). However, such care could be inadequate for marginalised communities and families because of limited resources. In addition, multiple birth children are, in most cases, preterm or very LBW new-born and thus susceptible to recurrent infections that may need frequent health care services, which are often inadequately available in rural communities. Interventions within community and health facility levels for supporting women with multiple births are thus needed. I also recommend a comprehensive study on the care for multiple births, including small new-borns, beyond the facility interventions, particularly focusing on the burden and the community practices of caring for such new-borns in a resource-limited setting.

Attending at least a primary education level was directly associated with the reduced likelihood of perinatal mortality – a finding that has been indicated in another study (Nattey et al., 2013). The pathway could be better health behavioural practices such as nutrition, better sanitation, and appropriate healthcare access. In most cases, educated women have access to health information on maternal nutrition, good hygiene practices and maternal danger signs that could have been attained either while at school or through reading media publications. These findings suggest a need to design and implement behavioural interventions that integrate less educated communities. One of the strategies that have been effective in mobilising and sensitising poor and illiterate communities in such resource-limited settings is the use of community health workers, which could be exploited to target such groups with maternal and new-born specific health information. Additionally, interventions that promote girl child education and prevent early pregnancies targeting girls and families could increase education levels among women in the long run.

Previous stillbirth and neonatal death experience was related to a high likelihood of perinatal mortality and continued to affect the neonates in the later stage, which is consistent with other studies done in developed countries (Heazell & Clewlow, 2015; Patterson et al., 2014). Women with previous experience of pregnancy loss are susceptible to risk conditions such as preeclampsia, preterm births, intrauterine growth retardation and foetal distress that could affect the health of subsequent pregnancies (Getahun et al., 2009). Additionally, perinatal mortality recurrence, particularly stillbirths, could be related to chronic maternal conditions (Heazell & Clewlow, 2015). Proper screening for the histories of pregnancy loss and neonatal mortality in addition to the histories of related risk factors such as hypertension, diabetes and epilepsy should be emphasised during the prenatal and labour period.

4.6. Conclusion

This manuscript contributes to understanding child mortality by analysing the new-born mortality pathways in a resource-poor setting. The study affirms the role of LBW in mediating the association of socio-economic and demographic factors with new-born mortality. The study has also identified the continued effect of multiple birth and the mother's previous pregnancy loss experiences on new-borns survival at a later age. Further, in addition to the

large proportion of mortality that occurs within the first day (24 hours), the study has discovered that institutional deliveries had a modest moderation effect on the association of LBW with new-born mortality.

The continued association of the multiple birth or low birth weight and previous experience of new-born loss with child mortality in the later stage, as well as the association of maternal factors such as adolescence and advanced age pregnancies that could be prevented through preconception interventions, demonstrate the need for a life-course approach in the design of interventions. These interventions should include control of LBW and management or treatment of LBW new-borns. The LBW control interventions should target the socially and economically disadvantaged women, who include adolescents, unmarried women and rural residents, with information on birth preparedness and care for pregnancies. I propose a postnatal treatment and care package for mothers and health workers throughout the new-born life-course for the LBW new-borns and multiple birth. Intensifying the health systems by replicating known LBW effective strategies such as identifying LBW cases through immediate new-born weighing and their management through kangaroo mother care, better nutrition, and other medical interventions are needed.

Additionally, the effect of institutional delivery in such resource-limited settings is complex because of the plural health services points the women go through before reaching the formal care points. The challenges of inadequate amenities for maternal and new-born health, including qualified staff, may make it difficult for the health facilities to address obstetric emergencies appropriately. I suggest a comprehensive health systems audit, both internal and external, to provide an insight into the reasons for the insignificant effect of institutional deliveries on the survival of LBW new-borns and the large proportion of death within the first day of life.

4.7. Strengths and limitations

The main strength of HDSS in the estimation of new-born mortality is that the HDSS register and follow-up all pregnant women until the end of pregnancy. In addition, collecting data in two rounds annually helps get information on those who were missed to be registered in the preceding rounds due to some issues, including migration and sociocultural issues related to the registration of pregnancies. However, various limitations relate to the representation, collection, and analysis of the provided datasets. First, the study findings are generalisable to Iganga-Mayuge districts; however, because of the similarities in most Ugandan communities in terms of social and health systems, the findings may provide an insight into the national and sub-national (Busoga region) perinatal and new-born mortality estimates. Second, as alluded to earlier, HDSS has been indicated to have issues with the reporting stillbirth and new-born mortality that affect the estimates (Akuze et al., 2020; Kadobera et al., 2017; Nareeba et al., 2021), which is explained by the discrepancies in the death reported in verbal autopsy and birth registration data reported in Section 2.6.7 (Chapter 2). Third, the high

proportion of birth weight missingness and heaping poses a concern to the quality of the data in providing reliable birth weight categories. Last, the causes of death could be misclassified since the causes of death are based on the child's mother's narrative of the signs and symptoms recognised before death (Amek et al., 2018; Anker, 1997; Chandramohan et al., 2001; Herrera et al., 2017). For instance, the death due to malaria could be misclassified since malaria is usually based on fever as a major symptom, which is usually a diagnostic symptom for other morbidities such as diarrhoea and respiratory infections. Such misclassification leads to underestimation or overestimation of the true mortality cause-specific fraction. Nonetheless, in areas where most deaths are unregistered and unverified, VA remains an important way of establishing the causes of death. Details on the strengths and limitations of HDSS are provided in Section 7.3 (Chapter 7) of this thesis.

Appendix 4.1: Multicollinearity assessment for perinatal and neonatal mortality variables in the event history dataset

Variable	VIF	SQRT VIF	Tolerance	R-Squared
Birth season in quarters				
2	1.53	1.23	0.6557	0.3443
3	1.54	1.24	0.6481	0.3519
4	1.56	1.25	0.6404	0.3596
Child as Low birth weight	1.43	1.19	0.7006	0.2994
Child low birth weight and delivered in private facility	1.38	1.18	0.7238	0.2762
Child low birth weight and delivered in community	1.4	1.19	0.7118	0.2882
Primary Education	5.04	2.25	0.1982	0.8018
Post Primary Education	5.41	2.33	0.1848	0.8152
Delivered in private health facilities	1.3	1.14	0.7712	0.2288
Delivered in community	1.25	1.12	0.7991	0.2009
Maternal age				
<20 years	1.3	1.14	0.7707	0.2293
30+ years	1.19	1.09	0.8435	0.1565
Birth order 1	1.39	1.18	0.7208	0.2792
Birth order 5+	1.06	1.03	0.9397	0.0603
Rural residence	2.23	1.49	0.4477	0.5523
Has a partner	1.19	1.09	0.8412	0.1588
Experienced pregnancy or child loss previously	1.04	1.02	0.9631	0.0369
Multiple birth	1.02	1.01	0.9833	0.0167
Child sex as female	1	1	0.997	0.003
Wealth index				
Index 3	1.26	1.12	0.794	0.206
Index 4 and 5	2.81	1.68	0.3557	0.6443
Mean VIF	1.78			

Appendix 4.2: 2011-2015 Iganga-Mayuge HDSS event histories participants' descriptive statistics

	Complete case*		Imputed
	n=10,758		
	%ge	*missing*	*%ge*
Institutional delivery		**1.0**	
Public Health facility	68.7		68.7
Community	16.0		16.0
Private health facility	15.4		15.4
Maternal education level		**0.5**	
None	14.3		14.3
Primary	52.3		52.3
Post primary	33.4		33.4
Maternal age group (years)		**0.0**	
<20	13.7		-
20-29	53.6		-
30+	32.8		-
Place of residence		**0.0**	
Rural	64.0		-
Urban	36.0		-
Marital status		**9.1**	
Has a partner or married	86.2		86.2
Has no a partner	13.8		13.8
Household wealth index		**18.8**	
Index 1 and 2	46.0		43.7
Index 3	21.2		20.6
Index 4 and 5	32.8		35.7
Previous experience of death		**0.0**	
Experienced pregnancy loss	5.1		-
Never experienced pregnancy loss	94.9		-
Childbirth weight		**27.3**	
LBW (<2.5Kgs)	13.1		13.7
Normal Birth weight	86.9		86.3
Childbirth order		**1.2**	
First	45.0		45.0
2^{nd}-4^{th}	50.6		50.7
5^{th} +	4.3		4.3
Child sex		**1.2**	
Female	50.2		50.2
Male	49.8		49.8
Birth category		**0.9**	
Multiple	2.4		2.4
Singleton	97.6		97.6

Appendix 4.2 Continued

	Complete case*		Imputed
	n=10,758		
	%ge	*missing*	*%ge*
Birth season in annual quarters		**0.0**	
1	25.2		-
2	24.6		-
3	26.1		-
4	24.1		-
Birth Year		**0.0**	
2011	21.9		-
2012	21.6		-
2013	20.5		-
2014	17.9		-
2015	18.0		-
New-born mortality			
Deaths with 28 days (0-27 days)	2.2**		-
Deaths within 7 days (0-6 days)	1.9**		-
Stillbirths	1.19		-
Deaths within 7 days (0-6 days) +Stillbirths	3.1		-
Late neonatal mortality (7-27 days)	0.32***		
Note: ** the denominator excludes stillbirths (128), ***the denominator excludes those who died in the first seven days of life + stillbirths			

CHAPTER FIVE
HOUSEHOLD AND INDIVIDUAL-LEVEL PREDICTORS OF SUSPECTED PNEUMONIA AND DIARRHOEA AMONG UNDER-5

The paper is under production in PLOS Global Public Health as: Kananura RM. Machine learning predictive modelling for identification of predictors of acute respiratory infection and diarrhoea in Uganda's rural and urban settings (https://doi.org/10.1371/journal.pgph.0000430).

Abstract

Despite the widely known preventive interventions, the dyad of acute respiratory infections (ARI) and diarrhoea remain among the top global under – 5 years mortality causes. Studies on child morbidity have enormously applied "traditional" statistical techniques that have limitations in handling high dimension data, which leads to the exclusion of some variables. Machine Learning (ML) models appear to perform better on high-dimensional data. Using Uganda's 2006-2016 DHS pooled data on children aged 6-59 months, I applied ML techniques to identify rural-urban differentials in the predictors of child's diarrhoea and ARI. I also used ML to identify other omitted variables in the current child morbidity frameworks. Four categories of variables were considered: child characteristics, maternal characteristics, household characteristics and immunisation. For each area of residence (urban and rural), the data was partitioned into three sets: testing set (10%), validation set (30%) and training set (60%). The measure of prediction was based on 10-fold cross-validation. The gradient-boosted machine was the best-selected model for identifying ARI predictors (Accuracy: 100% -rural and 100%-urban) and diarrhoea predictors (Accuracy: 70%-rural and 100%-urban). These factors relate to the household's structure and composition, which is characterised by poor hygiene and sanitation and poor household environments that make children more suspectable of developing these diseases; maternal socio-economic factors such as education, occupation, and fertility (birth order); individual risk factors such as child age, birth weight and nutritional status; and protective interventions (immunisation). The study findings confirm the notion that ARI and diarrhoea risk factors overlap. The results highlight the need for a holistic approach with multisectoral emphasis in addressing the occurrence of ARI and diarrhoea among children. In particular, the results provide an insight into the importance of implementing interventions that are responsive to the unique structure and composition of the household. Finally, alongside traditional models, machine learning could be applied in generating research hypotheses and providing insight into the selection of key variables that should be considered in the model.

Keywords: *Machine Learning; algorithmic analysis; child health; pneumonia; diarrhoea*

5.1. Introduction

The global inequities in child mortality have consistently remained large, with sub-Saharan Africa contributing the largest share (United Nations Inter-agency Group for Child Mortality Estimation (UN IGME), 2017, 2018, 2019b). In 2019, the under-five mortality rate in sub-Saharan Africa was 78 per 1000 live births, twice higher than the global rate and at least 16 times higher than high-income countries' average (UN IGME, 2019). Despite the widely known yet cost-effective preventive and protective measures (Bhutta et al., 2013), pneumonia and diarrhoea have persistently appeared among the leading causes of under-five mortality. Globally, pneumonia and diarrhoea have recurrently contributed an estimate of at least 24% of all under-five years mortality causes (UN IGME, 2019, 2018, 2017) and the burden of the two diseases remains high in sub-Saharan Africa (Mokomane et al., 2017; Scharf et al., 2014; UN IGME, 2017; Whitney, 2017; WHO, 2018).

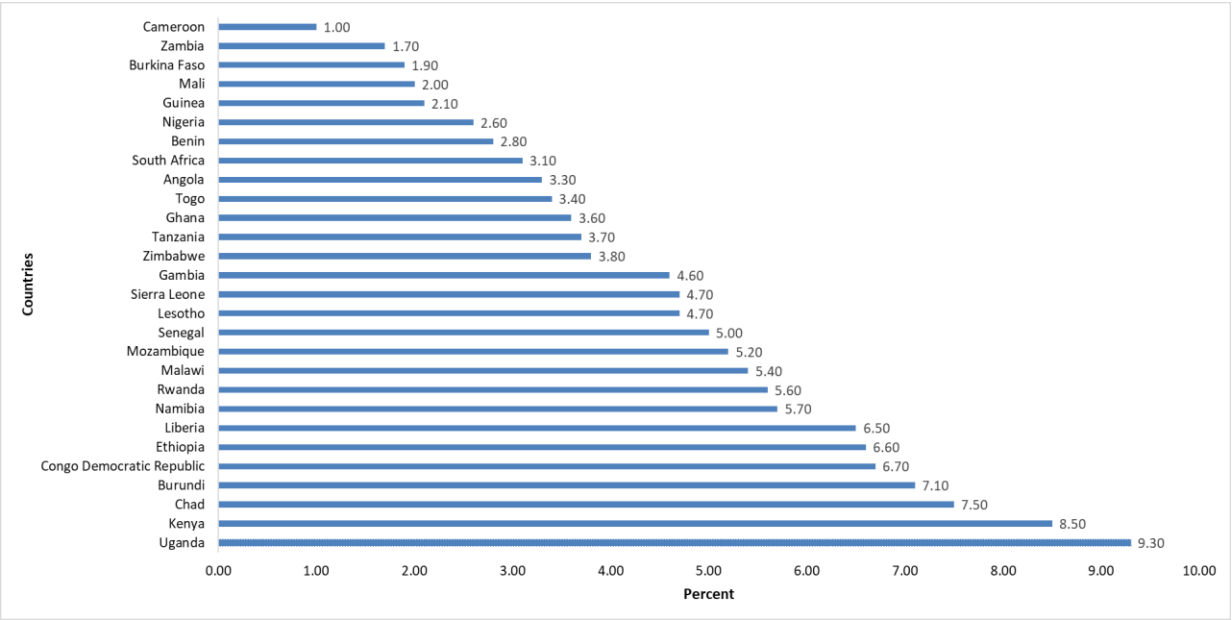
In Uganda, the prevalence of *suspected pneumonia* (hereinafter referred to as "Acute Respiratory Infection (ARI)") and diarrhoea in the recent Uganda Demographic and Health Survey (UDHS) is estimated at 20% and 9%, respectively (Uganda Bureau of Statistics and ICF International, 2018) – making Uganda among the top 5 countries with a high proportion of children that experience diarrhoea and ARI (Figure 5.1). Like other sub-Saharan African countries, pneumonia and diarrhoea are the leading causes that burden the health facilities in Uganda. For instance, in Uganda, out of the 8.8 million under-five health facility outpatient admissions in 2017/2018, 13.3% were due to either pneumonia (4.3%) or diarrhoea (9.1%) (Uganda Ministry of Health, 2018a). During the same period, out of 0.68 million under-five health facility inpatient admissions, 22% were due to pneumonia (14%) and diarrhoea (8.1%) (Uganda Ministry of Health, 2018a). The recurrent episodes of pneumonia and diarrhoea among children in sub-Saharan Africa lead to not only persistent high child mortality and long-term disabilities in the region but also catastrophic expenditure as well as a long-term economic burden on the individuals and families (Baral et al., 2020; Ekirapa – Kiracho et al., 2021; Memirie et al., 2017; Niyibitegeka et al., 2021; Soremekun et al., 2018). For instance, the studies done in Ethiopia and Uganda indicated an average of $62-64 for each hospitalised episode of pneumonia and an average of $79 for each hospitalised episode of diarrhoea (Ekirapa – Kiracho et al., 2021; Memirie et al., 2017).

Diarrhoea and ARI have common risk factors such as poor nutrition, poor hygiene and sanitation, and poor living conditions (Bhutta et al., 2013; Chan & Lake, 2013) and both diseases lead to the occurrence of other health consequences such as anaemia that could later increase the probability of death or inhibit children from thriving. Noteworthy, the association of the risk factors with the prevalence of morbidities is a complex process of interrelated mechanisms (Mokomane et al., 2017), and the health sector cannot solely address such complexity. Indeed, the SDGs framework and the Global Strategy for Women's, Children's and Adolescents' Health underscore the interrelations between most of the goals by highlighting how progress in one area may affect progress in many others, which calls for

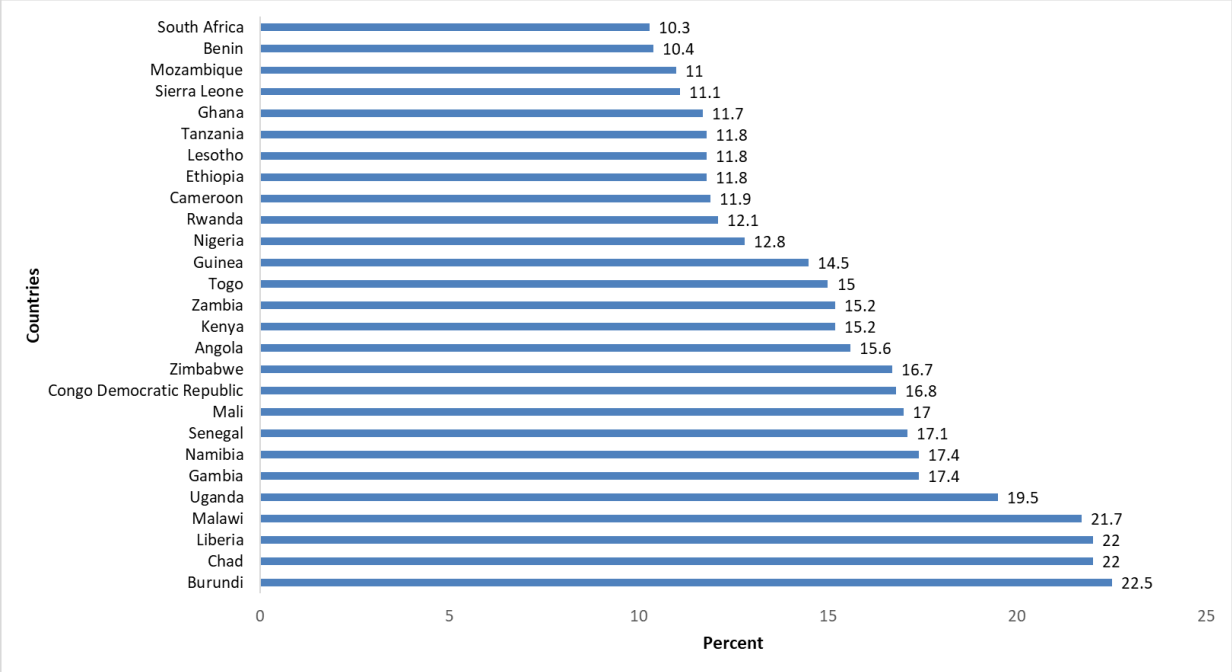
a multisectoral approach in design and implementation of child health interventions (Every Woman Every Child, 2015; WHO, 2015).

Figure 5.1: Percentage of under-five aged children with suspected pneumonia and diarrhoea in sub-Saharan countries

a. Suspected pneumonia



b. Suspected diarrhoea



Source: *The DHS Program STATcompiler, with recent data (2013-2018) as of August 2020.*

Ending the preventable causes of child death, such as pneumonia and diarrhoea, is among the global health priorities (Every Woman Every Child, 2015; WHO, 2015). Sustainable development goals (SDGs) include interrelated goals that contribute to the reduction of deaths due to preventable causes. The Global Strategy for Women's, Children's and

Adolescents' Health, which is aligned to SDG targets, recognises how a range of health and health-related goals and targets must be addressed for children to "Survive-Thrive-Transform"(Every Woman Every Child, 2015), thus, emphasising the importance of the multisectoral approach in the design and implementation of child health interventions. Some of the SDG indicators that are relevant in reducing the occurrence of pneumonia and diarrhoea include 1) SDG target 3.9 – reducing mortality and morbidity due to water and soil pollution and contamination; 2) SDG target 2.2 – ending all forms of malnutrition: child stunting, child wasting, child overweight; 3) SDG target 6.1 – achieving universal and equitable access to safe and affordable drinking water for all; 4) SDG 6.2 – achieving access to adequate and equitable sanitation and hygiene for all; 5) SDG 7.1 – ensuring universal access to affordable, reliable and modern energy services; 6) SDG 11.1 – ensuring access for all to adequate, safe and affordable housing and basic services and upgrade slums. And end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations; and 7) including other parts of targets in goals on poverty, hunger, education, gender.

Furthermore, children's health and well-being depend dramatically on where they are born or reside (CSDH, 2008). Such differences could be due to the residential variations in the earlier alluded risk factors: environmental, healthcare access, socio-economic and demographic characteristics, and food access. For instance, it is known that rural dwellers' children are susceptible to a high risk of diseases such as malaria, pneumonia, and diarrhoea (X. Bai et al., 2012; Van de Poel et al., 2007), which could be explained by the poor environmental measures such as lack of access to clean water, poor toilet coverage, and indoor pollution and socioeconomic factors such as poverty and low levels of education (Sahn & Stifel, 2003). However, it should also be noted that those in the urban marginalised setting are susceptible to a high risk of morbidities such as malaria, pneumonia and diarrhoea compared to their rural counterparts (X. Bai et al., 2012; Fotso, 2007; Van de Poel et al., 2007). The urban marginalised are more characterised by risk factors that have been mentioned to increase the likelihood of morbidities prevalence among rural dwellers (X. Bai et al., 2012). Nonetheless, information on the differences in the predictors of pneumonia and diarrhoea between urban and rural settings is elusive since the analysis usually considers rural-urban disaggregation, which masks the vulnerable groups living in urban areas.

In light of the above, there is a need for risk assessment approaches that can comprehensively provide a set of variables that may describe a child at risk of contracting morbidities and how these variables may differ across the place of residence. Such is not only important in setting priority areas of focus but also in guiding the collaboration and integrations at different societal levels and ultimately addressing the fragmentation of different pieces of interventions. We know that pneumonia and diarrhoea have a range of risk factors and determinants that are usually correlated, which usually limit the number of variables in the traditional models, such as logistic regression, linear regression, and Cox regression. On the one hand, because of the limitations of traditional statistical approaches in handling highly

dimensional and correlated variables (collinearity assumption), usually, variables are dropped out of the model, and normally, the exclusion or inclusion of variables is dependent on the researchers' interest. On the other hand, dimensionality reduction approaches such as factors analysis or principal component analysis are always applied to create indices, thus leading to the loss of information.

Furthermore, the conclusion and interpretation of traditional models are based on statistical significance (p-value), where the focus is usually on variables with a lower p-value for a given level of significance. Conclusion and interpretation of data based on p-value have been recognized to provide limited information about the data (Halsey, 2019). Additionally, large samples generate smaller p-values and therefore relying on p-values may lead to claim support for results (Lin et al., 2013). Drawing on the limitations of the traditional models that have been applied in the current literature, the available frameworks or theories that have based their formulation on traditional analysis approaches may lead to inappropriate conclusions and fragmentation of interventions (Breiman, 2001; Luo et al., 2015).

Building on the limitations of the traditional statistical models, such as linear and non-linear regression models that have been applied in the current literature, I apply Machine Learning (ML) on a pooled dataset of 2006-2016 UDHS with the main aim of examining the urban-rural differences in the predictors of pneumonia and diarrhoea. ML models such as lasso, random forest and deep learning appear to perform better than the traditional linear and non-linear models on high dimensional datasets or correlated variables and datasets with more variables than observations (Breiman, 2001; Luo et al., 2016). The ML modelling idea is to let the algorithm determine the way the outcome and independent variables are linked (Breiman, 2001; Song et al., 2004). So far, ML has not been extensively applied to the available cross-sectional data in LMICs. The key applications refer to clinical research data (Correa et al., 2018; Delen et al., 2010; S. Gupta et al., 2014; Huang et al., 2018; Naydenova et al., 2016; Rose, 2013; Silterra et al., 2017) and only a handful studies have applied ML using cross-sectional population health data (Daoud et al., 2019; Luo et al., 2015). Thus, to my knowledge, this study is the first to apply an algorithmic modelling approach to identify predictors of pneumonia and diarrhoea in LMICs settings based on cross-sectional surveys. I study how the predictors of ARI and diarrhoea vary across the places of residence (rural versus urban). The identification of these predictors not only provides a set of measures for vulnerable children at risk of ARI and diarrhoea but also provides a new direction for rethinking the implementation mechanism of preventive interventions that target communities, families, and children with such identified characteristics. Finally, studying how the predictors by place of residence may give us an insight into a package of interventions for each of the places of residence.

5.2. Analysis and theoretical approaches to the measures of child morbidity risk factors

While available studies (Kamal et al., 2015; Kandala et al., 2009, 2008; Mulatya & Ochieng, 2020) have based their analysis on Mosley and Chen model to understand the determinants of child morbidities in developing countries (Mosley & Chen, 1984), the application of traditional analysis approaches appear to have limited the consideration of other important variables. The framework by Mosley and Chen considers a range of social, economic, cultural, and health system variables that impact child health and survival through a set of proximate determinants. These are categorized as maternal demographics and socioeconomic, environmental, nutrient deficiency, and geographic position. The occurrence of diarrhoea has been indicated to be highly associated with underweight or malnourished children (Amare et al., 2019; McGovern, 2019; Ntenda, 2019; Rahman et al., 2016). The socio-economic factors that are associated with the occurrence of ARI and diarrhoea among children include the wealth position of the family, the education level of the parents and employment status (Kamal et al., 2015; Kandala et al., 2008). For instance, in their study on morbidity among children in Bangladesh, Kamal et al.,2015 indicate that children from low-income families were at least 40% more likely to suffer from a common illness than those from less poor families (Kamal et al., 2015). The demographic factors associated with ARI and diarrhoea among children include maternal and household age (Kandala et al., 2009, 2008). The main environmental factors that have been identified to increase morbidity among children are poor sanitation and hygiene, access to unsafe water, and household air pollution (Kamal et al., 2015). Notably, and as Hill, 2003 indicates, birth weight as a potential risk factor that affects the child's health throughout their childhood age is missing in the Mosley and Chen framework (Hill, 2003), although this could be correlated with the nutrition deficiency that is indicated in the framework. The association of LBW with diarrhoea and ARI has been indicated in some studies conducted in low and middle-income countries (Fonseca Lima et al., 2016; Jackson et al., 2013; Martins et al., 2016; McGovern, 2019).

While a sheer volume of research has offered a lot in understanding and improving child health, building on this available evidence, there is a need to advance research methodologies that may contribute to the generation of new interventions and implementation approaches in this area. Our current methods in this field majorly rely on "traditional" statistical analysis approaches that are based on several assumptions. For instance, the assumption of collinearity and the number of parameters versus sample size may lead to the exclusion of important variables, leading to elusive conclusions. Reducing dimensionality or exclusion of parameters reduces the information of model accuracy prediction (Breiman, 2001).

Furthermore, what has been missing is that the child health and well-being factors may vary across and within the countries/communities (Halonen et al., 2013; Martikainen et al., 2003), and perhaps the magnitude of each factor may vary. As alluded to earlier, the places of residence are characterised differently by community behaviours such as myths and

geographic characteristics such as exposure to environmental risk factors that contribute to the high incidence and re-occurrence of morbidities.

Contrary to the different approaches that have been adopted by previous studies in the same field – and this is a key strength of this study, I use an algorithmic approach to identify the potential rural-urban differentials in the predictors of child's diarrhoea and ARI in Uganda. I compare the ML results with the traditional logistic regression to identify the model with better accuracy in predicting ARI and diarrhoea. To test the impact of wealth, instead of generating indices that have been used to generate some measures, such as the wealth index, I include all the variables available in the dataset that are known to affect the health and wellbeing of children to generate diarrhoea and ARI predictive algorithm. Notably, the application of different approaches and modelling in data analysis is usually affected by the availability of the relevant data, which also affects ML approaches. Therefore, I am not claiming that ML would be the best alternative and unique approach that would not suffer from data availability limitations.

5.3. Methods

5.3.1. Data source

To have a sufficient dataset for identifying the predictors of this study's outcomes, I pooled the UDHS data collected between 2006 and 2016 and publicly accessed as of March 2020. For all waves of data collection considered under this study, the DHS used a multistage, stratified sampling design with households as the sampling unit. DHS has a standard household questionnaire that collects information on characteristics of the household's dwelling unit, such as the source of water, type of toilet facilities, materials used for the floor of the dwelling unit, and ownership of various household items. The household tool also includes a household roster that captures data on each household member's age and sex, which is used to identify women, men, and children eligible for individual interviews, anthropometry measurement, and anaemia testing. Furthermore, the DHS uses the women's questionnaire to collect information about their reproduction and fertility history, sexuality, pregnancy and birth experience, and child health. The questions on child health include asking eligible women to recall if their children had symptoms of diarrhoea and ARI in the recent period preceding the day of data collection. Information on vaccination coverage was collected from the child's health card or the mother's direct report. In Uganda, the pneumococcal conjugate vaccine was introduced in April 2013. Although the rotavirus vaccine became part of the national routine immunisation schedule in February 2018, while it was not part of the schedule at the time of the recent (2016) survey, some private health facilities were offering the rotavirus vaccine for a fee.

Furthermore, questions that are used to identify a child who experienced a recent episode of diarrhoea and ARI are: 1) Has (NAME) had diarrhoea in the last 2 weeks?; 2) Has (Name) had an illness with a cough at any time in the last 2 weeks?; 3) When (NAME) had an illness with a cough, did she breathe faster than usual with short, rapid breath or have difficulty

breathing?; and 4) Was the fast or difficult breathing due to a problem in the chest or to a blocked or runny nose?. These questions were the same for all data collection periods (2006, 2011, 2016) considered in this study.

The data were pooled using IPUMS-DHS online system (Elizabeth Heger et al., 2019), by choosing children under the age of five years and their related records. This included only children aged 0-59 months born in the five years preceding the survey. Supplement 2 summarises the data variable for each of the categories that were selected using IPUMS-DHS.

5.3.2. Response and explanatory variables

The key outcome (response) variables are the prevalence of suspected pneumonia and diarrhoea. In the DHS, the measurement of suspected pneumonia is based on the occurrence of short, rapid breathing that is chest-related and/or difficult breathing that is chest-related that is based on women's ability to recall. This was categorised as '1' presence of disease and '0' otherwise. For diarrhoea, women are asked to recall if their children have had diarrhoea in the last 2 weeks, which was categorised as '1' presence of disease and '0' otherwise.
The key predictors (explanatory) were selected from a set of 28 variables that were categorised as mothers' demographic position, household assets, household environmental characteristics, and child characteristics. The consideration of the covariates was based on a literature review.

Under household environmental characteristics, studies have indicated how the number of people living under one roof (congestion), the house structure, availability of toilets, treatment of drinking water and indoor air pollution (cooking inside the house or use of firewood) are associated with the occurrence of pneumonia and diarrhoea (Kamal et al., 2015; Kandala et al., 2008; Mahalanabis et al., 2002; Mondal & Paul, 2020; Omona et al., 2020). For child characteristics, studies have indicated how the birth weight of the child, birth category (multiple or single), child age, child sex, and anthropometric measures (height and weight) are associated with the occurrence of suspected pneumonia and diarrhoea (Cesar, G. et al., 1994; Fonseca Lima et al., 2016; Jackson et al., 2013; Martins et al., 2016; McGovern, 2019; Omona et al., 2020). Furthermore, studies have also indicated how the mothers' demographic position measures such as maternal age, household head age, household head sex and maternal education are associated with the occurrence of suspected pneumonia and diarrhoea (Gebru et al., 2014; Mondal & Paul, 2020; Omona et al., 2020). Lastly, households' assets that have often been used as the measure of household wealth through principal component analysis have been indicated to be associated with pneumonia and diarrhoea (Gebru et al., 2014; Mahalanabis et al., 2002; Mondal & Paul, 2020). Supplements 2 and 3 summarise the data variable for each of the categories that were selected using IPUMS-DHS.

5.3.3. Data analysis

Cleaning of data and the descriptive analysis were done in Stata 16, while ML analysis was performed using R statistical software version 3.6.1 with the caret package (Kuhn, 2008).

During data cleaning, I excluded 7% of children who were not staying with the mothers on the interview day for better estimates, which is not in line with the standard DHS analysis (ICF, 2018) and may lead to differences in the reported estimates of ARI and diarrhoea. The premise was that including children that were not living with their parents at the time of data collection may lead to underestimation as mothers may not be sure of their health status in recent days when they were not home. The total sample size for the pooled dataset includes only children who were residing with their parents at the time of the interview is 27687. **Table 5.1:** shows the distribution of unweighted sample size across years of data collection.

Table 5.1: Distribution of unweighted sample size across years of data collection

	Sample size of all children				**Sample size that only includes children residing with their parents at the time of interview**			
Place of residence	2006	2011	2016	Total sample	2006	2011	2016	Total sample
	0-59 months							
Rural	6,746 (88.9%)	5,772 (78.4%)	12,037 (81.8%)	24,555 (82.8%)	6,436 (89.4%)	5,492 (79.6%)	11,222 (82.5%)	23,150 (83.6%)
Urban	847 11.1%	1,583 (21.6%)	2,673 (18.2%)	5,103 (17.2%)	763 (10.6%)	1,407 (20.4%)	2,367 (17.5%)	4,537 (16.4%)
Total	7,593	7,355	14,710	29,658	7,199	6,899	13,589	27,687
	6-59 months							
Rural	6035 (89%)	5171 (78.9%)	10824 (81.6%)	22030 (82.7%)	5726 (89.6%)	4894 (80.1%)	10023 (82.4%)	20643 (83.7%)
Urban	747 (11%)	1387 (21.2%)	2445 (18.4%)	4579 (17.2%)	664 (10.4%)	1213 (19.9%)	2142 (17.6%)	4019 (16.3%)
Total	6782	6558	13269	26609	6390	6107	12165	24662

The dataset was filtered to generate based on the place of residence to generate two datasets: Urban and Rural residents' datasets. Modelling was done on each of the datasets separately. To identify the community and household predictors of suspected pneumonia and diarrhoea, I used two models based on ML techniques and a traditional logistic regression model to select the best model that predicts the probability of ARI and diarrhoea prevalence. The ML models were lasso logistic and gradient boosting machine. Based on the theoretical framework, including available literature (Kamal et al., 2015; Kandala et al., 2008; Mosley & Chen, 1984), the predictor variables (Supplement 2) that could be associated with the occurrence of diarrhoea and ARI were entered in all the ML models. Instead of generating a latent variable or index that is normally done through principal component or factor analysis, for instance, assent index (a measure of wealth) that is based on the list of household assets and an environmental index that is based on the household environmental characteristics, all the variables (**Appendix 1**) were included in the models to determine those that were substantial in predicting the occurrence of diarrhoea and ARI.

5.4. Results

5.4.1. Descriptive Statistics

Maternal and household characteristics

As of 2016, the mean age of the children's mothers and household heads was 27 ± 7 and 37 ± 12, respectively, which were not different from the 2006 and 2011 estimates. Almost 90% and 28% of the children's caretakers or mothers had at least a primary and at least a secondary level of education, respectively, which increased by two times between 2006-2016. Regarding the household structure, as of 2016, 32%, 68% and 9% of the households had incomplete roofs, floors, and walls, respectively. During the same period, 36% of the household had shared toilets, and 99% used wood or charcoal (22% for charcoal). Appendix 2 presents the maternal and household characteristics.

Child-related individual characteristics

Supplement 3 presents the child-related individual characteristics. As of 2016, 34% of the children were of 5th and above birth position, and 3% were born as multiple, and the estimates were the same in the 2006 and 2011 reporting years. Within the same reporting year, 28% were stunted – declining by 9% between 2006-2016, 10% underweight for age (underweight) – declining by 6% between 2006-2016, and 4% under-weight for height (wasted) – decreasing by 2% between 2006-2016. During the same reporting year, the average birth weight was 3.3 kg with a standard deviation of ± 0.8.

Trends in the prevalence of ARI and diarrhoea among under-5 of age children

Table 5.2 shows the changes in the prevalence of diarrhoea and ARI across time, with their respective confidence intervals disaggregated by the place of residence. Overall, between 2006 and 2016, the national prevalence of suspected diarrhoea reduced by 6% point (27% in 2006 to 21% in 2016), while ARI reduced by 5% point. Disaggregating the estimates by place of residence, the prevalence of diarrhoea declined by 7% point in the rural area and 2% point in the urban area. Similarly, the prevalence of ARI reduced by 6% point in the rural area and 4% point in the urban area.

Table 5.2: Trends in the prevalence of ARI and diarrhoea among under-5 of age children

Category	*Year*	*Diarrhoea*		*ARI*	
		%	*95% CI*	*%*	*95% CI*
Rural	2006	27.6	25.9-29.3	15.5	14.1-17.2
	2011	24.6	22.8-26.6	15.7	14.2-17.3
	2016	21.1	19.8-22.4	10.3	9.5-11.3
Urban	2006	21.3	17.3-25.9	11.8	8.3-16.5
	2011	23.7	20.0-27.9	13.8	11.1-17.1
	2016	18.6	16.6-20.7	7.6	6.1-9.5
National	2006	26.9	25.3-28.5	15.1	13.8-16.6
	2011	24.5	22.8-26.3	15.5	14.1-16.9
	2016	20.6	19.5-21.7	9.8	9.0-10.6

The estimates are based on the live children who were staying with the parents or caretakers at the time of the interview.

5.4.2. Rural-urban differences in the predictors of diarrhoea and ARI using 2006-2016 UDHS data

In the following sub-sections, I present the results on the predictors of diarrhoea and ARI that were identified using the ML modelling technique. I first present the results of the model assessment from which the best model was selected and subsequently present the key predictors that were identified based on the best model. Results on how the identified predictors affect the occurrence of morbidities are presented based on predicted probabilities.

Assessing the best model for selection

The best model was chosen based on the accuracy and sensitivity of the model in predicting the occurrence of ARI and diarrhoea (Table 5.3). Compared to the traditional logistic model and lasso logistic model, GBM model was found to be superior in determining the potential predictors of ARI and diarrhoea. Contrary to other models, the GBM accuracy, sensitivity, specificity, and area under the ROC curve result in predicting the occurrence of ARI and diarrhoea among urban and rural residents on new datasets (testing and validation) were high and consistent (Table 5.3). While the traditional logistic model showed good accuracy in predicting ARI and diarrhoea, the likelihood of the model in identifying the positive cases correctly (sensitivity) was low and inconsistent across the validation and testing datasets (Table 5.3).

Table 5.3: Comparing the performance of logistic, Lasso and GBM models in the identification of the predictors of ARI and diarrhoea

	Rural			**Urban**		
	Testing set(10%)	Validation set (30%)	Training set	Testing set(10%)	Validation set (30%)	Training set
	ARI					
	GBM					
Sensitivity	1.00	1.00	1.00	1.00	1.00	1.00
Specificity	0.90	0.91	0.90	0.96	0.97	0.96
Accuracy	0.91	0.91	0.91	0.96	0.97	0.96
ROC	0.95	0.94	0.94	1.00	1.00	1.00
	Lasso					
Sensitivity	0.33	0.87	0.86	0.75	0.75	0.75
Specificity	0.87	1.00	0.43	0.93	0.94	0.94
Accuracy	0.86	0.87	0.87	0.93	0.93	0.93
ROC	0.73	0.75	0.75	0.91	0.88	0.90
	Logistic					
Sensitivity	0.08	0.42	0.04	0.59	1.00	0.38
Specificity	0.99	0.98	1.00	0.97	1.00	0.99
Accuracy	0.87	0.91	0.87	0.94	1.00	0.93
ROC	**0.78**	**0.90**	**0.75**	0.97	1.00	**0.89**

Table 5.3 continued

	Rural			Urban		
	Testing set(10%)	Validation set (30%)	Training set	Testing set(10%)	Validation set (30%)	Training set
			Diarrhoea			
				GBM		
Sensitivity	0.69	0.73	0.70	1.00	1.00	1.00
Specificity	0.78	0.77	0.78	1.00	1.00	1.00
Accuracy	0.77	0.77	0.77	1.00	1.00	1.00
ROC	0.80	0.76	0.78	1.00	1.00	1.00
				Lasso		
Sensitivity	NA**	NA**	NA**	NA**	NA**	NA**
Specificity	0.74	0.75	0.75	0.78	0.79	0.78
Accuracy	0.74	0.75	0.75	0.78	0.79	0.78
ROC	0.71	0.68	0.70	0.74	0.76	0.74
				Logistic		
Sensitivity	0.28	0.43	0.18	0.46	1.00	0.38
Specificity	0.94	0.89	0.96	0.96	1.00	0.96
Accuracy	0.77	0.78	0.76	0.85	1.00	0.83
ROC	**0.77**	**0.84**	**0.74**	0.86	1.00	**0.81**

*** The predictive True Positive was zero*

5.4.3. Key household and individual predictors of diarrhoea in rural and urban areas

Table 5.4 presents the differences in identified predictors of diarrhoea in traditional logistic regression and GBM. In rural areas, using the traditional logistic regression model based on 95% statistical significance, six variables (child age, childbirth order, maternal age, safe drinking water, and pneumococcal vaccine) would be considered the most important predicators of diarrhoea (Table 5.4). However, the GBM identified 17 important predictors (Table 5.4). While in urban areas, using the traditional logistic regression model based on 95% statistical significance, 10 variables would be considered the most important predicators of diarrhoea and 13 were identified under GBM (Table 5.4).

Table 5.4: Differences in identified predictors of diarrhoea in traditional logistic regression and GBM

	Rural		Urban	
	Logistic	GBM	Logistic	GBM
Variables	P-value	Level of importance	P-value	Level of importance
Child characteristics				
Child age	0.04	100	0.006	100
Birth weight	-	26.6	-	16.9
Birth order	0.008	3.3		10.1
Nutritional status: Stunted			-	9
Maternal characteristics				
Maternal age	0.019	28.1	0.031	16.4
Maternal occupation: Professional	0.105			
Maternal occupation: Agriculture	0.146		0.041	-
Maternal occupation: Domestic and services	0.011			
Maternal occupation: Manual worker	0.094	13.2		

Table 5.4 continued

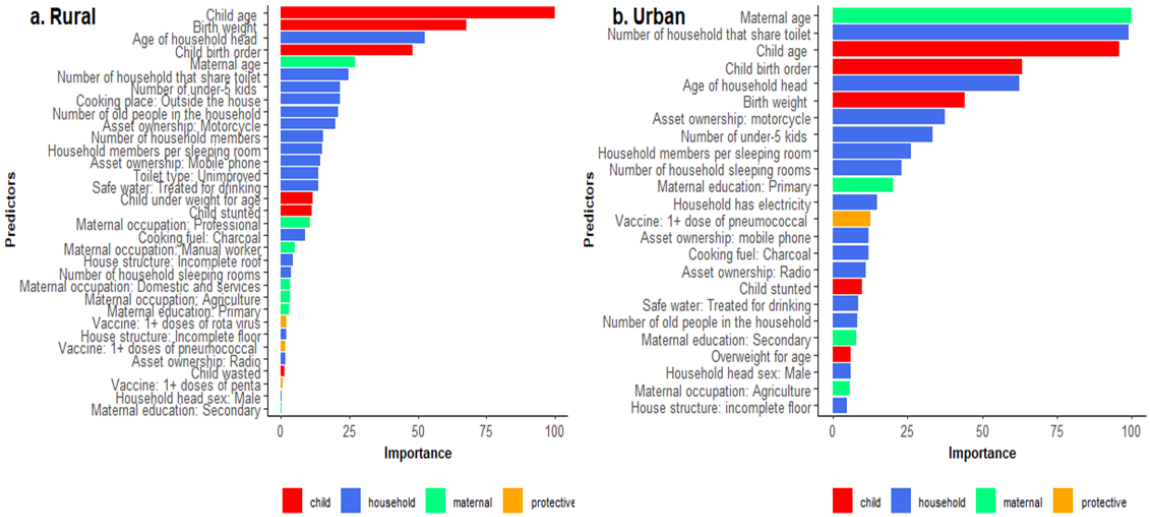
	Rural		Urban	
	Logistic	GBM	Logistic	GBM
Variables	P-value	Level of importance	P-value	Level of importance
Education level: Primary	0.037		0.044	-
Maternal education: Secondary	0.015			
Education level: Higher level	-	-	-	6.9
Household characteristics				
Hygiene and sanitation				
Toilet Type: Unimproved	-	20.8	0.161	9.5
Number of households that share toilet	-	15.8		
Household treats water for drinking	0.016			
Household asset position				
Household has electricity	-	3.3	0.003	10.4
Asset ownership: Radio		3.8		
Household asset: TV	0.986		0.027	-
Household congestion measure				
Number of household members		6.3	0.017	-
Number of household members per room	0.102	-	0.001	21.6
Number of old people in the household	-	7	0.002	27.1
Number of under-5 children			0.007	6.3
Household head characteristics				
Age of household head	-	26.5	-	9.5
Household head sex: Male	0.098	7.2		
Exposure to smoke				
Cooking place: Separate room or house	-	5.3		
Cooking fuel: Charcoal	-	4.9		
Household structure				
Incomplete floor	0.053	-	-	6.6
Child vaccination				
vaccine: 1+ doses of pentavalent	-	25.9		
vaccine: 1+ doses of Rota virus vaccine	0.003	18.3		

Figure 5.2 shows the order of importance of the predictors of diarrhoea among rural and urban resident children based on ML (gradient boosted model).

In both places of residence, the individual (child characteristics) predictors were child age, childbirth weight and childbirth order, while nutritional status was identified amongst the predictors in urban residents. In rural areas, the traditional logistic model did not identify birth weight as an important predictor. In contrast, in urban areas, the traditional logistic model did not consider birth weight, birth order and nutritional status (Table 5.4). The maternal predictors of suspected child diarrhoea among rural and urban resident children were maternal occupation, age and education (Table 5.4). Exposure to smoking (indoor and type of fuel used for cooking), hygiene and sanitation measures (number of people sharing a toilet and unimproved toilet), wealth measures (possession of radio, electricity access), household congestion measures (number of household rooms for sleeping and number of people per sleeping room), and household head characteristics (gender and age) were identified as

important household predictors under GBM. Furthermore, pentavalent and rotavirus vaccines were also indicated as an important predictor of diarrhoea among rural residents' children but not for urban residents (Table 5.4).

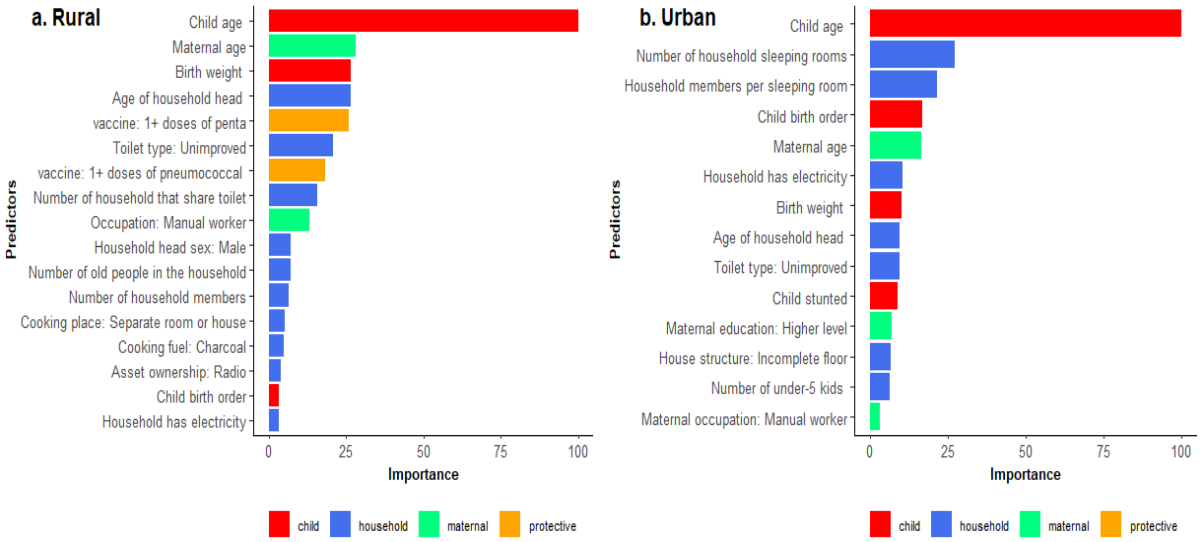
Figure 5.2: Predictors of diarrhoea among rural and urban residents in order of importance



5.4.4. Key household and individual predictors of ARI in rural and urban areas

Table 5.5 presents the differences in identified predictors of ARI in traditional logistic regression and GBM. The traditional logistic regression and GBM model share the same predictor under maternal characteristics and household characteristics themes, but some key predictors under the child characteristics theme were not identified under the traditional logistic model. In addition, all nutritional status variables, including birth weight, were not considered in the traditional logistics model (Table 5.5). Figure 5.3 shows the identified predictors of ARI in rural and urban residents.

Figure 5.3: predictors of ARI in rural and urban residents in order of importance



In rural areas, considering the level of significance (5%) as the criteria for selecting the potential predictors, occupation, treatment of drinking water, and all congestion measures, including having a separate room or space for cooking, would be considered the potential predictors. Under GBM, various variables in each category were identified (Table 5.5). Similarly, based on the level of significance (5%), most variables under child characteristic theme, maternal characteristic theme, exposure to smoking, and being vaccinated may not be considered key predictors under the traditional logistic model in urban areas (Table 5.5). The exclusion of vaccination variables such as the pentavalent vaccine under the traditional model could be due to the poor performance of traditional models on variables with rare events.

Table 5.5: Differences in identified predictors of ARI in traditional logistic regression and GBM

	Rural		Urban	
	Logistic	GBM	Logistic	GBM
Variables	P-value	Level of importance	P-value	Level of importance
Child Characteristics				
Child age	0.14	100	_	95.8
Childbirth order	0.083	47.9	0.049	63.2
Birth weight	-	67.8	0.088	44.2
Childbirth category: Singleton			0.997	-
Nutritional status: Stunted	-	11	-	9.7
Nutritional status: underweight	-	11.5	-	6.1
Nutritional status: wasted	-	1.3	0.994	-
Maternal characteristic				
Maternal age		27		100
Maternal occupation: Manual worker				
Maternal occupation: Professional	-	10.6		
Maternal occupation: Agriculture	0.008	3.3	-	5.8
Maternal occupation: Domestic and services	0.03	3.4	0.993	-
Maternal occupation: Manual worker	0.001	4.9		
Education level: Primary	-	3.1	-	20.3
Maternal education: Secondary	-	0.1	-	7.9
Education level: Higher level	0.982	-	-	-
Marital status: Married	0.151	-	0.179	-
Household characteristics				
Hygiene and sanitation				
Toilet Type: Unimproved	0.083	13.7		
Number of households that share toilet	-	24.6	0.015	98.8
Household treats water for drinking	0.102	13.5	-	8.7
Household asset possession				
Household has electricity	0.086	-	0.012	14.7
Asset ownership: Radio	-	1.5	-	11.1

Table 5.5 continued

	Rural		Urban	
	Logistic	GBM	Logistic	GBM
Variables	P-value	Level of importance	P-value	Level of importance
Asset ownership: Mobile phone	-	14.5	0.005	12.1
Asset ownership: Motorcycle	-	19.7	0.004	37.5
Household asset: TV	0.056	-		
Household congestion measure				
Number of household members	0.017	15.4	-	23
Number of household members per room	0.039	15	-	26.1
Number of sleep rooms	0.019	3.7	0.144	-
Number of old people in the household		21	-	8.3
Number of under-5 children	0.054	21.6	0.002	33.5
Household head characteristics	-	-		
Age of household head	0.135	52.7	-	62.5
Household head sex: Male	-	0.3	0.079	5.9
Exposure to smoking				
Cooking place: Separate room or house	0.014	21.4		
Cooking fuel: Charcoal	0.098	8.7	-	12
Household structure				
Incomplete floor	0.163	1.9	-	4.7
Incomplete roof	-	4.4		
Child vaccination				
vaccine: 1+ doses of pentavalent vaccine	-	0.6		
vaccine: 1+ doses of pneumococcal vaccine	-	1.5	-	12.8
vaccine: 1+ doses of Rota virus vaccine	0.045	1.9		

5.4.5. Association of identified predictors with the occurrence of ARI and diarrhoea

In both places of residence, the association between child age and the occurrence of diarrhoea is inversely associated with child age. The occurrence appeared to be high among children aged 6-36 months (Figure 5.4). In both places of residence, birth weight (Figure 5.4) appears to be almost linearly negatively related to diarrhoea. At the same time, childbirth order is observed to be positively related associated with suspected diarrhoea (Figure 5.4). All nutritional status measures (underweight, wasted, and stunting) were related to the high occurrence of suspected diarrhoea (Figure 5.4). The relationship between diarrhoea and maternal age is non-linear (almost U-shaped curve), with a sharp reduction observed between 15-20 years and a sharp increase observed among those whose mothers were aged 35 years and above (Figure 5.5). The high likelihood of suspected diarrhoea is also observed among children whose mothers are not educated (Figure 5.4), and those whose mothers' occupations are not professional (Figure 5.5).

Additionally, diarrhoea is likely high among children whose households had an unimproved toilet and did not have a separate place or room for cooking (Figure 5.6). The relationship

between diarrhoea and the household head as well as the number of household members per room, is non-linear (Figure 5.6). Furthermore, in both places of residence, the likelihood of diarrhoea was high among children who had not received the pentavalent vaccine (Figure 5.7). Finally, a substantial association between the rotavirus vaccine and diarrhoeas is observed among rural residents (Figure 5.7).

Table 5.6 shows the differences in identified predictors of ARI and diarrhoea between the places of residence. The analysis shows how diarrhoea and ARI appear to share almost the same predicators, with modest differences. The differences in the identified predictors between places of residence for each morbidity were also modest.

Figure 5.4: Association between children's characteristics and child morbidities

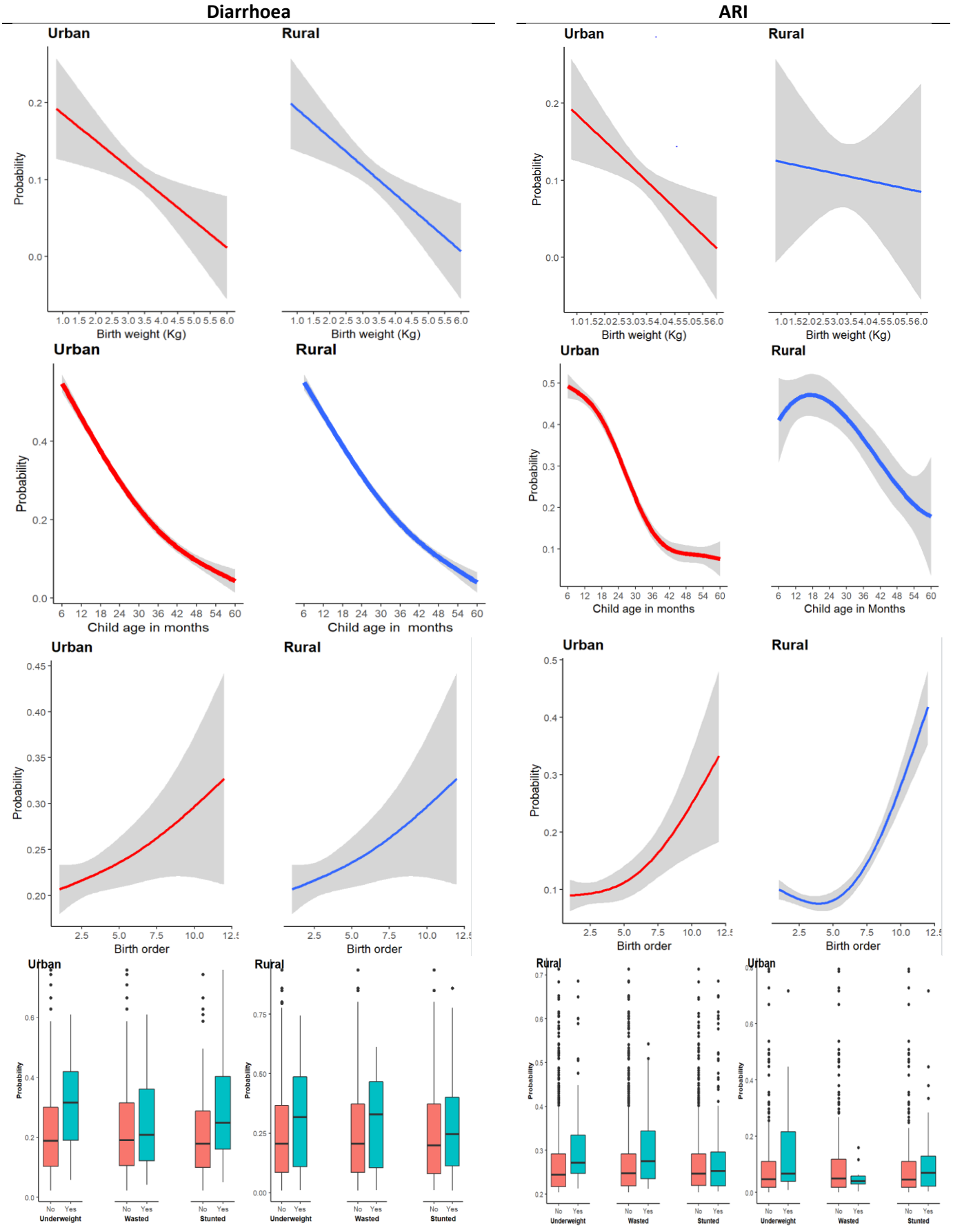


Figure 5.5: Association between maternal characteristics and child morbidities

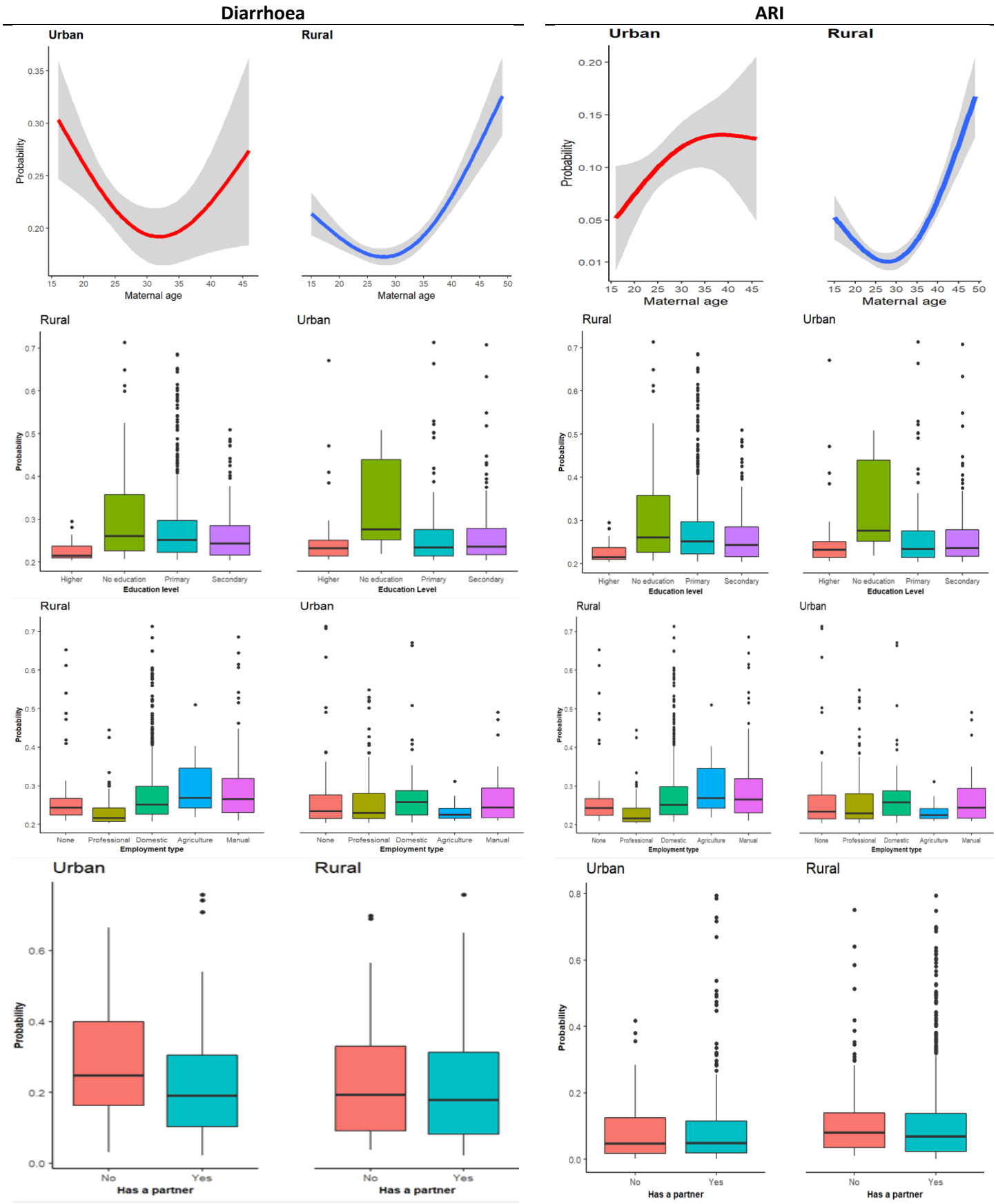


Figure 5.6: Association of household characteristics with child morbidities

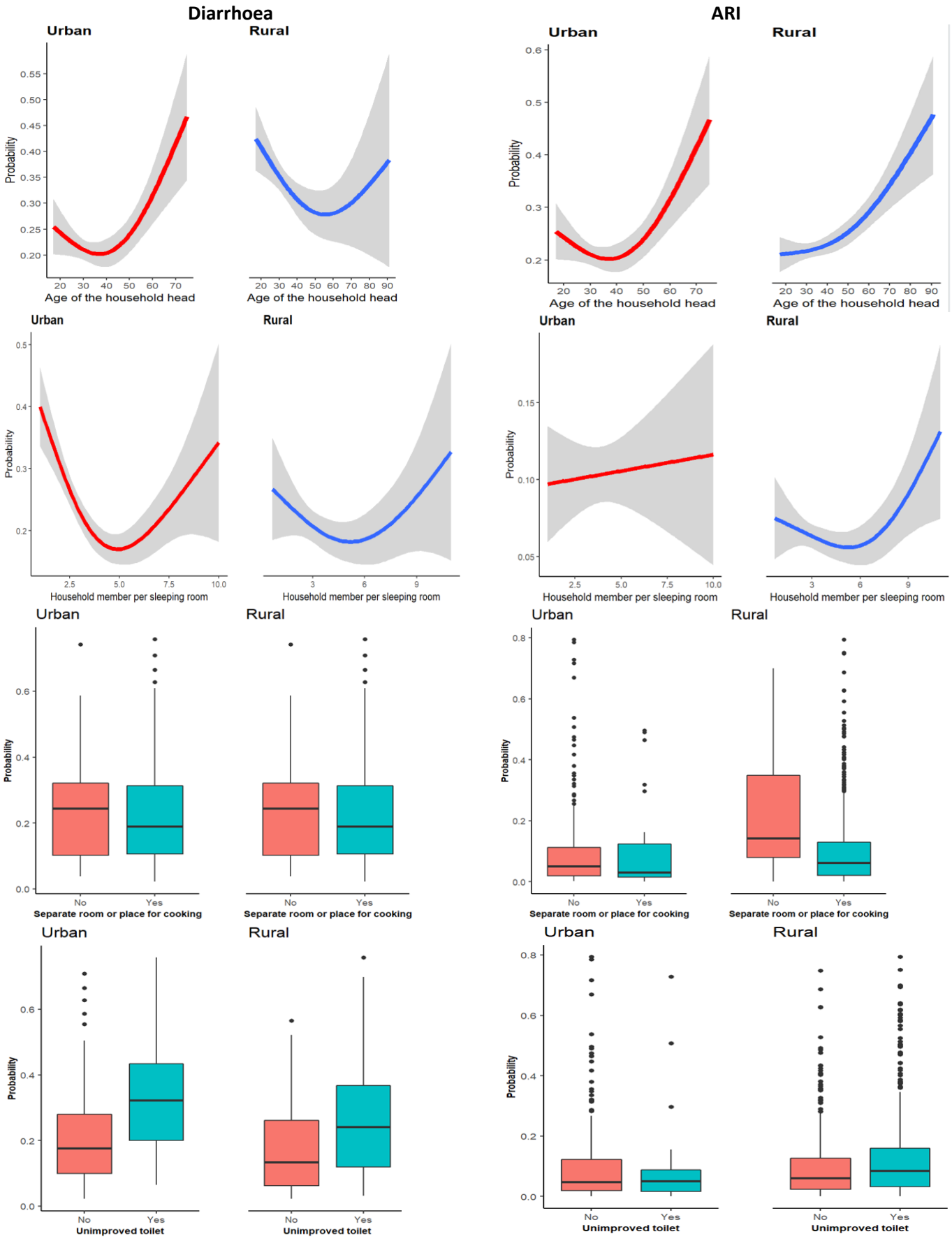


Figure 5.7: Association of vaccination with child morbidities

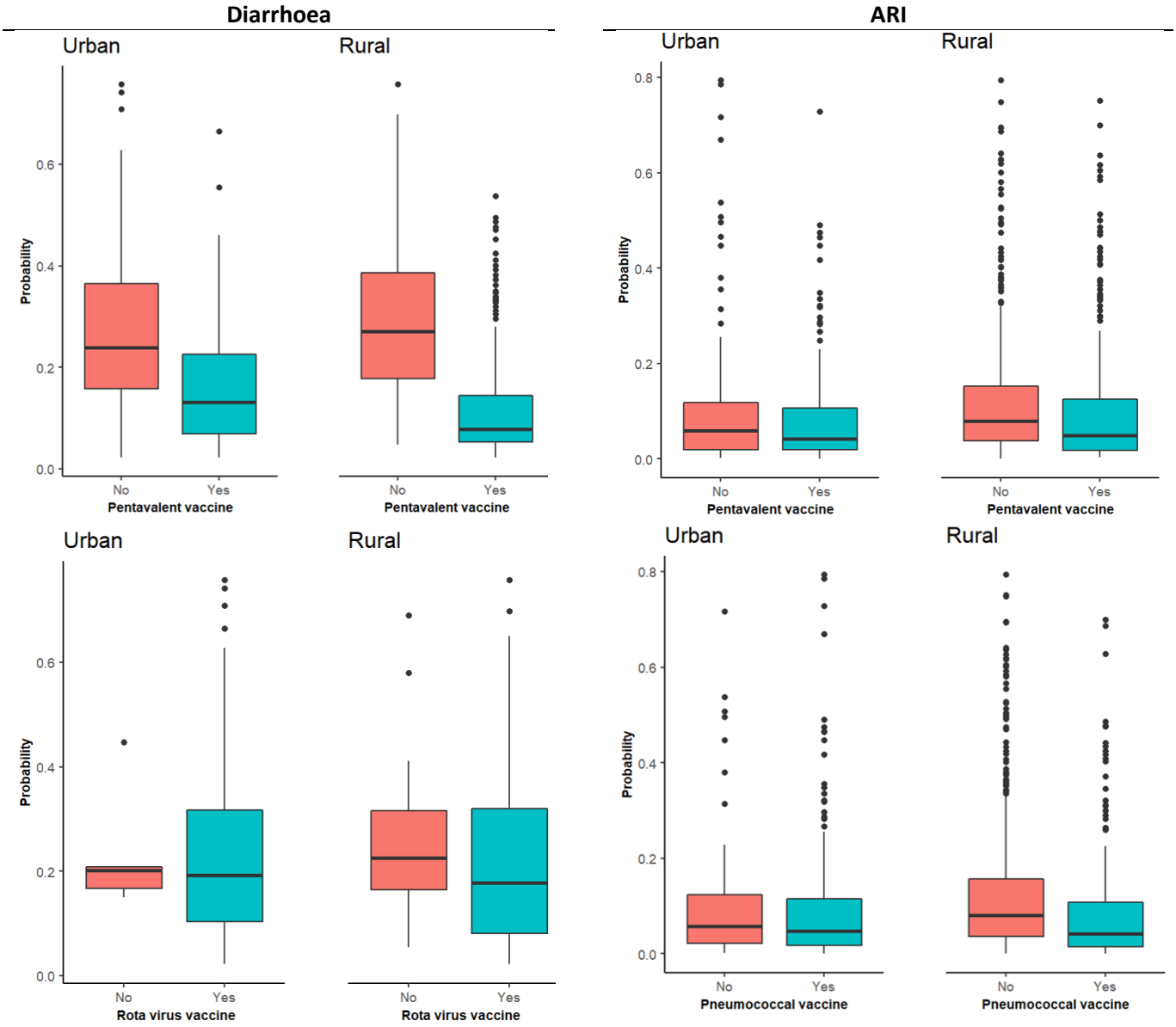


Table 5.6: Differences in identified predictors of ARI and diarrhoea between the places of residence

	Diarrhoea		ARI	
	Urban	Rural	Urban	rural
Child Characteristics				
Child age	yes	Yes	yes	yes
Childbirth order	yes	Yes	yes	yes
Birth weight	yes	Yes	yes	yes
Nutritional status: Stunted	yes	No	yes	yes
Nutritional status: underweight	no	No	yes	yes
Nutritional status: wasted	no	no	no	yes
Maternal characteristic				
Maternal age	yes	yes	yes	yes
Maternal occupation	yes	yes	yes	yes
Maternal education	yes	no	yes	yes
Marital status: Married	no	no	no	yes
Household characteristics				
Hygiene and sanitation				
Toilet Type: Unimproved	yes	yes	no	yes
Household treats water for drinking	no	no	yes	yes
Number of households that share toilet	no	yes	yes	yes
Household asset position				
Household has electricity	yes	yes	yes	no
Household asset: TV	no	no	no	no
Household asset: radio	no	yes	yes	yes
Asset ownership: Mobile phone	no	no	yes	yes
Asset ownership: Motorcycle	no	no	yes	yes
Household congestion measure				
Number of household members	no	yes	yes	yes
Number of household members per room	yes	no	yes	yes
Number of households sleeping rooms	yes	no	yes	yes
Number of under-5 children	yes	no	yes	yes
Number of old people in the household	no	yes	yes	yes
Household head characteristics				
Age of household head	yes	yes	yes	yes
Household head sex: Male	no	yes	yes	yes
Household structure				
Incomplete floor	yes	no	yes	yes
Incomplete roof	no	no	no	yes
Child vaccination				
vaccine: 1+ doses of pentavalent vaccine	no	yes		yes
vaccine: 1+ doses of pneumococcal vaccine	no	yes	yes	yes
vaccine: 1+ rota virus vaccine	no	no	no	yes
Exposure to smoking				
Cooking place: Separate room or house	no	no	no	yes
Cooking fuel: Charcoal	no	no	yes	yes

5.5. Discussion

This is the first study that has applied ML to cross-sectional population health data to identify the key predictors of ARI and diarrhoea among the under-five year of age in a low-income setting. The study has demonstrated how household, maternal, and individual characteristics as well as information on protective interventions obtained through cross-sectional studies, could be used to predict the occurrence of health outcomes, including health behaviours. Thus, this study contributes to the knowledge of the application of ML techniques in population health and social science research. The analysis approach may be replicated in other studies to develop prediction models. Additionally, the study not only contributes to the understanding of the variation in the effect of predictors across the places of residence but also explains the trends in the prevalence of diarrhoea and ARI in Uganda and how the identified predictors could contribute to the design of interventions.

Findings from this work point out two important points. First, for the last decade (2006-2016), the study's results show slow progress in reducing the prevalence of diarrhoea and ARI. Such slow progress in a decade demonstrates how Uganda is lagging in achieving the integrated global action plan for ending pneumonia and diarrhoea by 2025 (UNICEF & WHO, 2013) and the need to rethink the strategies that will help the country achieve the SDG objective of reducing deaths due to preventable causes. Understanding the context-specific morbidities' predictors contributes to the identification and implementation of area-specific interventions that may accelerate progress. Second, the ML in the form gradient boosted model (GBM) was the best ML model in generating the predictors of ARI and diarrhoea. For both testing and training datasets, the identified predictors of ARI in urban and rural areas under GBM had an accuracy of 100% in predictions, indicating that the model could correctly predict those with and without the diseases. Similarly, for both testing and training datasets, the identified predictors of suspected diarrhoea in urban and rural areas under GBM had a prediction accuracy of 100% and close to 70%, respectively.

Using ML, I identified moderate differences in the predictors of ARI and diarrhoea between rural and urban residents. The identified key predictors were categorised as child, maternal and household characteristics, as well as protective interventions. While most of the predictors identified using the traditional logistic regression model appeared in the GBM, a substantial number of predictors identified under GBM did not appear in the traditional logistic model, and the identified one may not be considered because of the selection of the variables based on level of significance (p-value). For instance, child nutritional status, hygiene and sanitation measures, asset position, household health characteristics and household structure were not identified as key predictors of suspected diarrhoea and pneumonia. I discuss the association of identified predictors in each category with the occurrence of suspected diarrhoea and pneumonia in the subsequent subsections.

5.5.1. Individual characteristics and child morbidity

The identified important individual characteristics were child age, birth weight, birth order and nutrition status. The findings affirm a non-linear relationship between a child's age and the occurrence of ARI and diarrhoea, as has been indicated in another study in similar settings (Kandala et al., 2009). An inverse relationship between morbidities' prevalence and child's age was observed, and it appeared to be high among children aged 6-36 months. The high prevalence of the diseases in the early months indicates children's exposure to morbidities' risk factors such as poor nutritional status, poor sanitation, and hygiene that this study identified as key predictors. This finding provides an insight into the need for interventions that target children within the first 36 months of life. Indeed some studies have indicated the need for targeting the first 1000 days of life with health and well-being interventions (da Cunha et al., 2015; Kattula et al., 2014).

Further, the study results show a linear relationship between a child's birth weight and the occurrence of ARI and diarrhoea. In both places of residence, the high occurrence of ARI and diarrhoea was observed among children born with a birth weight of less than 2500 grams. The association of LBW with diarrhoea and ARI has been indicated in some other studies (Fonseca Lima et al., 2016; Jackson et al., 2013; Martins et al., 2016; McGovern, 2019). The thinking could be that LBW is usually mediated by some of the determinants of the prevalence of ARI and diarrhoea such as being underweight for age and anaemia, whose risks are high among children born as LBW. The association of LBW with other child risk factors such as underweight and anaemia has been indicated in several studies (Amare et al., 2019; McGovern, 2019; Ntenda, 2019; Rahman et al., 2016). This finding suggests community interventions that target mothers or families with extreme birth weight (LBW) children, in addition to LBW preventive interventions. Exclusive breastfeeding as a recommended intervention for new-born (Were et al., 2015) has been indicated to lower the probability of pneumonia deaths among LBW (Tallo et al., 2012), while prenatal interventions focusing on better nutrition and lifestyle as well as screening for pregnancy danger signs such as diabetes and infections have been indicated as key interventions for controlling LBW (Henriksen, 2008).

Furthermore, in both places of residence, a positive linear relationship between birth order and morbidities was observed, which has been reported in other studies done in developing countries (Fadl et al., 2020; Fenta & Nigussie, 2021; Ghosh et al., 2021). The relationship between birth order and child morbidity could result from the possible correlation between the number of children and birth positions. Morosow and Kolk, 2020 argue that one of the reasons why earlier-born siblings cope better is that parents' resources (including non-economic resources such as time) are fixed, and consequently, having more children leads to fewer available resources per child (Morosow & Kolk, 2020). The increase in the number of siblings spacing between them dilutes the time and material resources parents can give to each child (Heer, 1986; Price, 2008). Ultimately, the dilution of resources hinders the well-

being of later birth orders. For instance, the lower birth order, particularly the firstborns, may receive better attention from the parents than those of birth order or born later (Price, 2008).

Finally, poor nutrition statuses were associated with a high likelihood of child morbidities. The relationship between poor nutritional status and child morbidities has been well documented in studies done in some countries in Africa and Asia (Ferdous et al., 2013; Hassen et al., 2020; Tickell et al., 2017). On the one hand, the poor nutrition outcome could be a result of exposure to poor nutrition during preconception and while pregnant, which usually leads to LBW. Good nutrition in the preconception period is crucial to ensure that women have enough nutrient stores to support both fetal and maternal nutrition throughout gestation (Keats et al., 2021). On the other hand, poor nutrition status could be due to poor maternal and feeding, hygiene, and sanitation (Keats et al., 2021). Such an argument showcases the need for a life course approach in delivering nutrition interventions. Notably, efforts could be focused on improving intervention coverage, especially for the most vulnerable.

5.5.2. Maternal characteristics and child morbidity

Marital status, as well as maternal education, age, and occupation, were associated with the likelihood of child morbidities. The relationship between maternal age and the occurrence was non-linear with a high likelihood observed among children whose mothers were aged less than 20 years and 35 years plus. The association of child health or wellbeing with the caretakers' age results from the caretaker's ability, autonomy, hygiene, and experience of children rearing (Fall et al., 2015). Adolescent age could also be associated with education levels, occupation, and marital status, which this study identified as key predictors. Similarly, maternal age could be correlated with the number of children. Therefore, the high likelihood of morbidities among children aged 35 years plus could be related to the high number of children or increasing birth order, which has been identified in this study as one of the key predictors.

Furthermore, the higher the maternal education and professional occupation, the higher the likelihood of child morbidity. This is expected as education, and professional (elite) occupations are correlated, and evidence has indicated how educated mothers and those engaged in professional work may have better knowledge and resources of child-rearing. These findings suggest the need for targeting the uneducated and younger women with information on how to care for their children. Learning from the COVID-19 experience, such information could perhaps be disseminated through all media platforms, including social media (Tsao et al., 2021), social health campaigns and the integration of sensitisation messages within the community and facility health workers' routine work.

5.5.3. Household characteristics and child morbidity

Household head age, asset ownership, type of the toilet, availability of a separate room or place for cooking, and household members were the key household characteristics that were identified among the important predictors of child morbidities. Important to note also is that the identified household characteristics are a measure of household wealth positions and

resources' access (Dungumaro, 2013; Hargreaves et al., 2007; M. L. Smith et al., 2020), which affect the health and well-being of household members including children. The findings show a non-linear relationship between the age of the household's heads and the occurrence of child morbidities. Just like maternal age, the likelihood of morbidities appeared to be high among children of adolescent household head families and those aged beyond 50 years of age. Furthermore, consistent with other studies (Fadl et al., 2020; Fenta & Nigussie, 2021; Ghosh et al., 2021), the likelihood of morbidities was observed among children living in households with unimproved toilets and households without a separate room or place for cooking. Improving households' ability to address the household-based risk factors that affect the children's health may benefit from implementing interventions that are responsive to the unique structure and composition of the household.

5.5.4. Protective interventions and child morbidity

Pentavalent, rotavirus, and pneumococcal vaccines were identified among the list of important predictors of ARI and diarrhoea among rural resident children. In contrast, pneumococcal was identified among the key predictors of ARI in urban resident children. In addition, the effect of other immunization vaccines, such as measles, on reducing the occurrence of diarrhoea and pneumonia has been reported in some studies (Bawankule et al., 2017; Bhutta et al., 2013; Feachem & Koblinsky, 1983; Jain et al., 2013).

5.6. Strengths and limitations

This study, which deliberately focused on identifying the community and household predictors of ARI and diarrhoea, makes two major contributions. First, to the best of my knowledge, the study is the first to apply an algorithmic modelling approach to identify household and individual predictors of pneumonia and diarrhoea in LMICs settings based on cross-sectional surveys. Hence, the study contributes to the knowledge of the application of ML techniques in population health and social science research. Second, the study contributes to understanding risk factors and determinants of ARI and diarrhoea in urban and rural settings, which could be used to measure vulnerable groups in each place of residence.

The limitation of DHS relates to the nature of cross-sectional studies on retrospectively collecting information on human behaviours and events. For instance, the occurrences of diarrhoea and measures of ARI and birth weight in the DHS rely on women's ability to recall. However, the DHS consideration of children born in the last five years preceding the survey may minimise such bias. Further, the DHS consideration of collecting data on occurrences of ARI and diarrhoea episodes and symptoms that occurred in the two weeks preceding the day of the interview may also minimise the reporting bias of the morbidities' symptoms and occurrences. Additionally, the reporting of the occurrences of diarrhoea and ARI are subject to the symptoms and thus may not provide accurate information as it would have been if clinical notes were available (Ayede et al., 2018; H. Campbell et al., 2013). However, for ARI, the questions on if the child had short, rapid breathing, which was chest-related or difficult breathing, are asked as a measure of the occurrence of ARI, which may increase the accuracy

in the estimation of ARI prevalence. Further, the analysis of data in this study only considered children that were staying with the parents or caretakers at the time of the interview, which could have reduced the reporting bias (under-reporting) as caretakers or parents may not know the health status of the children they do not live with.

Additionally, this approach to data analysis does not mean that there are no other variables in the data set that are associated with suspected diarrhoea and ARI, in addition to including only variables that account for the most variance in the study outcomes. Furthermore, the study's findings may be limited to Uganda's context; however, these may apply in other countries with similar contexts. Particularly, the study unveils the need for applying algorithmic modelling approaches to identify a set of vulnerable groups in cross-sectional surveys.

Finally, the use of ML leads to interpretation challenges (James et al., 2013), in particular, the causal-effect interpretation may be challenging since the selection of important variables is based on the extrapolation of patterns found in the labelled training data (Schmidt et al., 2019). Nevertheless, I explain the mechanisms through which the identified topmost variables are associated with the study outcomes by reviewing the literature.

5.7. Conclusion

The descriptive statistics on trends in the prevalence of ARI and diarrhoea show how Uganda has progressed slowly in reducing ARI and diarrhoea in a decade (2006-2016). Such progress raises worries if, at the same pace, the country will be able to achieve an integrated global action plan for ending pneumonia and diarrhoea by 2025 and SDG targets related to reducing deaths due to preventable causes. To accelerate progress, I argue that health interventions could address the risk factors identified in this study. Using ML analysis techniques, I identified a set of variables some of which would not appear when using the traditional logistic model (e.g.: household structure and composition, birthweight and child nutritional status), which shows how the approach may contribute to the design of holistic interventions. Alongside traditional models, machine learning could be applied in generating research hypotheses and providing insight into the selection of key variables that should be considered in the model.

The findings confirm the notion that ARI and diarrhoea risk factors and determinants overlap. These factors relate to the household's structure and composition, characterised by poor hygiene and sanitation, poor household environments; maternal socio-economic factors such as education, occupation, and fertility (birth order); and individual risk factors such as child age and birth weight and nutritional status. All the identified factors appear to be correlated and can be addressed with the same interventions. Additionally, while predictors were different in the order of importance, they appeared to be the same in both urban and rural areas. Such indicates that similar interventions may benefit both rural and urban residents within the identified risk factors categories.

Furthermore, these results underscore the need for the life course and multisectoral approaches in addressing some of the identified interventions. First, the association of the morbidities with LBW, younger maternal age and child's birth order confirms the need for life-course interventions that improve the health and well-being of children, including their mothers, from pregnancy, conception and early years of age (Clark et al., 2020; WHO, UNICEF, 2018). For instance, early pregnancy interventions such as good nutrition and identification of other risk factors for extreme small birth weight (such as infections) are meant to address the factors that contribute to the LBW during the foetus stage of child development (Berkley et al., 2014). We also know how LBW children are associated with a high likelihood of poor nutritional status and other morbidities, including ARI and diarrhoea. Therefore, immediately after delivery (day 0) up to two years of age and beyond, special health and social interventions could target LBW children, including younger mothers as well as households headed by younger and older caretakers. Secondly, for optimal implementation of interventions that address some of the identified predictors or factors such as nutrition status, immunisation, hygiene, and sanitation, it is important to leverage a multisectoral approach for collaboration and integration. Learning from Covid-19 response within and outside Uganda, addressing these challenges requires responsible sectors working towards integrated services. Finally, some of the factors such as congestion, household structure, household composition, asset ownership, access to electricity, in-door pollution, unimproved toilet, unemployment and informal employment, and lower education levels are measures of deprived individuals and communities such as slums in urban settings; and these were same in rural and urban areas. These findings underscore the importance of reaching all the rural and urban residents with the same intervention package, though the mode of delivery may differ given the differences in residential complexity. Beyond these findings, I recommend a study on understanding how these measures could be used to generate the deprivation level and how health outcomes are distributed across the different groups.

5.8. Acknowledgement

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5.9. Appendices

5.9.1. Appendix 1

Table 1: Variables for each of the categories based on 2006-2016 Uganda demographic health surveys

	Variables	Data type and categorisation
	Outcome categorisation	
1	Had ARI	The measurement of ARI is based on the occurrence of short, rapid breathing that is chest-related and/or difficult breathing that is chest-related that is based on women ability to recall. This was categorised as 1 – for the presence and 0 – otherwise.
2	Had diarrhoea	Women are asked to recall if their children have had diarrhoea in the last 2 weeks. This was categorised as 1 – for the presence and 0 – otherwise.
	Set of predictors	
	Mothers' demographic position	
1	Mothers age	Continuous variable
2	Household headed by a female	Dummy variable that was coded as 0 – male-headed and 1 – female-headed households
3	Mothers education	Ordinal variable that was coded as 0 – no education level at all 1 – primary education level 2 – secondary education level and 3 – tertiary education level
4	Mothers occupations	Nominal variable that was categorised as 0 – no occupation at all, 1 – professional and business work, 2 – agriculture and self-employment, 3 – domestic work, 4 – manual work
6	Marital status	Dummy variable that was coded as 0 – not married or staying with the partner and 1 – married or staying with a partner. The widows divorced or separated were considered as 0, while married or staying with the partner as if married were considered as 1.
2.0.	*Household assets*	
7	Car	These were all considered as dummy variables coded as 0 – household without the specified asset and 1 – household with the specified asset. The missing and don't know were considered as 0.
8	Motorcycle	
9	Fridge	
10	Radio and TV	
11	Electricity availability	
3.0.	*Household Environmental characteristics*	
12	Number of people in a house	Continuous variable. Missing fields were considered as 0
13	Number of children people in a house	Continuous variable. Missing fields were considered as 0
14	Number of old people in a house	Continuous variable. Missing fields were considered as 0
15	House's wall structure	Dummy variable that was coded as 0 – incomplete and 1 – complete. Complete is considered for rudimentary and modern building materials.
16	House's roof structure	Dummy variable that was categorised as 0 – incomplete and 1 – complete. Complete is considered for rudimentary and modern building materials.
17	House floor structure	Dummy variable that was coded as 0 – incomplete and 1 – complete. Complete is considered for rudimentary and modern building materials.
18	Cooking	Nominal variable that was categorised as 1 – Electricity, 2 – LPG/Gas, 3 – wood, wood, straw/shrub/grass, crops, and animal dung, and 4 – charcoal
19	Cooking done outside the house	Dummy variable that was categorised as 1 – household cooking is done in a separate house or room, 0 – otherwise

	Variables	Data type and categorisation
20	Toilet shared	Coded as 0 – toilets are not shared with other households 1 – otherwise
21	Drinking water treated	Dummy variable categorised as 0 – household drinking water is not treated 1 – otherwise
22	Protected water sources	Dummy variable categorised as 0 – household has access to protected water 1 – otherwise
23	Improved toilet	Dummy variable categorised as 0 – household has access to improved toilet 1 – otherwise
4.0.	*Child characteristics*	
24	Child sex	Dummy variable coded as 0 – male and 1 – female
25	Child age	Continuous variable measured in months
26	Birth weight	Continuous variable measured in grams
27	Weight for age	Dummy variable coded as 0 – for the standardized (standard deviation) weight for age <-2 (below the World Health Organization mean child growth standard) and 1 – otherwise
28	Weight for height	Dummy variable that was coded as 0 – for the standardized (standard deviation) weight for height <-2 and 1 – otherwise
29	Height for age	Dummy variable that was categorised as 0 – for standardized (standard deviation) height for age <-2 (below the World Health Organization mean child growth standard) and 1 – otherwise
5.0	Vaccination	
30	Pentavalent vaccine	Dummy variable that was coded as 1 – if at least one recommended doses were received and 0 – otherwise
31	Rota virus vaccine	
32	Pneumococcal vaccine	

5.9.2. Appendix 2

Table 1: Maternal and household characteristics

	2006		2011		2016	
	Weighted sample	%	Weighted sample	%	Weighted sample	%
Education level						
No education	1,646	22.7	1036	14.7	1501	11.2
Primary	4,609	63.6	4489	63.6	8214	61.5
Secondary	818	11.3	1277	18.1	2777	20.8
Higher	175	2.4	252	3.6	871	6.5
Occupation						
No occupation at all	564	7.8	1,478	21.0	2328	17.4
Professional and business work	687	9.5	275	3.9	2221	16.6
Agriculture and self-employment	5,472	75.5	4,064	57.6	6192	46.3
Domestic work	191	2.6	1,237	17.54	626	4.7
Manual work	335	4.6	-	-	1996	14.9
Household owns a TV						
No	6,908	95.3	6348	90.0	11329	84.8
Yes	341	4.7	707	10.0	2035	15.2
Household owns Radio						
No	2,770	38.2	2400	34.0	5715	42.8
Yes	4,479	61.8	4655	66.0	7649	57.2
Household treats water for drinking						
No	4,684	64.6	4173	59.2	6563	49.1

	2006		2011		2016	
	Weighted sample	%	Weighted sample	%	Weighted sample	%
Yes	2,564	35.4	2882	40.9	6801	50.9
Household toilet shared with other households						
No	4,435	61.2	4599	65.2	8537	63.9
Yes	2,814	38.8	2455	34.8	4827	36.1
Household place of cooking						
Inside the house	838	11.6	575	8.2	1121	8.4
Outside the house	6,411	88.4	6479	91.8	12243	91.6
Main cooking fuel						
Electricity	3	0.1	4	0.1	6	0.0
LPG-gas	6	0.1	28	0.4	50	0.4
Wood	6,349	87.6	5699	80.8	10292	77.0
Charcoal	890	12.3	1324	18.8	3016	22.6
Roof structure						
Incomplete	3,398	46.9	2675	37.9	4285	32.1
Complete	3,850	53.1	4380	62.1	9079	67.9
Floor structure						
Incomplete	6,061	83.6	5340	75.7	9017	67.5
Complete	1,187	16.4	1715	24.3	4347	32.5
Wall structure						
Incomplete	45	0.6	44	0.6	1171	8.8
Complete	7,204	99.4	7011	99.4	12192	91.2
Marital status						
No partner	904	12.5	812	11.5	1874	14.0
Has a partner or married	6,345	87.5	6243	88.5	11490	86.0
Sex of the household head						
Female	5,704	78.7	5634	79.9	10168	76.1
Male	1,544	21.3	1420	20.1	3196	23.9
Car ownership						
No	7,163	98.8	6,874	97.4	12,866	96.3
Yes	86	1.2	180	2.6	498	3.7
Motorcycle ownership						
No	6,836	94.3	6,318	89.6	11,371	85.1
Yes	205	2.8	631	8.9	1,646	12.3
Non-resident	208	2.9	106	1.5	347	2.6
Maternal age	Mean =28.9, ±6.8		Mean =28.8, ±6.8		Mean =28.6, ±6.8	
Age of the household head	Mean =36.9, ±11.5		Mean =37.3, ±11.7		Mean =37.4, ±12.0	
Number of rooms used for sleeping	Mean=4.1, ±1.9		Mean=4.1, ±1.9		Mean=3.6, ±1.7	
Number of household members	Mean=6.2, ±2.8		Mean=6.6, ±2.6		Mean=6.2, ±2.7	

Table 2: Child-related individual characteristics

	2006		2011		2016	
	Weighted sample	%	Weighted sample	%	Weighted sample	%
Childbirth position						
1	1,154	15.9	1,133	16.1	2,672	20.0
2	1,058	14.6	1,183	16.8	2,440	18.3
3	1,009	13.9	1,037	14.7	2,100	15.7
4	913	12.6	891	12.6	1,648	12.3
5	815	11.3	733	10.4	1,328	9.9
6	708	9.8	652	9.2	967	7.2
7	544	7.5	523	7.4	799	6.0
8	415	5.7	362	5.1	565	4.2
9	288	4.0	236	3.4	383	2.9
10+	346	4.8	304	4.4	462	3.5
Birth category						
Multiple	196	2.7	203	2.9	379	2.8
Singleton	7,052	97.3	6852	97.1	12985	97.2
Child sex						
Female	3,555	49.0	3518	49.9	6674	49.9
Male	3,693	51.0	3537	50.1	6690	50.1
SD height for age<-2						
Normal (>=-2)	1500	62.7	1,382	66.8	3,112	71.9
Stunted	891	37.3	686	33.2	1,216	28.1
SD weight for height<-2						
Normal (>=-2)	2233	93.4	1,965	95.0	4,155	96.2
Wasted	158	6.6	103	5.0	166	3.8
SD weight for age<-2						
Normal (>=-2)	2016	84.3	1,786	86.4	3,902	89.7
Underweight	376	15.7	282	13.7	447	10.3
Received at least one dose of pentavalent vaccine **						
No	3192	49.5	399	6.4	5343	44.6%
Yes	3258	50.5	5856	93.0	6631	55.4%
Received at least one dose of rota vaccine **						
No	-	-	-	-	11302	94.4
Yes	-	-	-	-	672	5.6
Received at least one dose of pneumococcal vaccine **						
No	-	-	-	-	7322	61.2
Yes	-	-	-	-	4653	38.9
Birth weight	Mean =3379.2, ±918.6		Mean =3407.3, ±955.8		Mean =3341.3, ±823.6	

Note: *The estimates are based on the live children who were staying with the parents or caretakers at the time of interview.*

*** considered only children aged 6-59 months*

CHAPTER SIX
RETHINKING ACCESS TO OBSTETRIC AND UNDER-5 CHILD HEALTHCARE ACCESS CONCEPTUAL FRAMEWORK

A version of this paper is currently being prepared for submission to the journal of Social Science and Medicine. Kananura RM: Towards a multidimensional and multisectoral approach: rethinking access to obstetric and under-5 child healthcare access conceptual framework.

Abstract

Reducing new-born and under-five mortality requires that skilled health professionals conduct all deliveries and care for all sick children. However, in sub-Saharan African countries such as Uganda, access to appropriate obstetric and sick child health care remains low. Access to appropriate health care is concurrently affected by multiple interactions within and across social and structural contexts, including the health service system. Existing obstetric and child health care access frameworks do not account for the complexity of multiple concurrent factors that influence access to appropriate health care services. Using qualitative data collected in June-November 2019 in resource-poor settings of Eastern Uganda, I examine how the interaction within the social, structural and health services system factors influence access to obstetric and sick children's healthcare. I use the findings to develop a multidimensional and multisectoral implementation framework for obstetric and child services in resource-poor settings. The findings are based on in-depth interviews (n=29) with mothers who experienced new-born death, including stillbirths, focus group discussions (n=8) with mothers and fathers of children aged 0-59 months of age, and key informants interviews with public health workers (n=6). Narrative and inductive thematic analysis were guided by concepts of social interactions, behaviour, and health institutional system' drawn from system theory. Analyses suggest that access to obstetric and child health care is a complex process that is concurrently affected by the pluralism of health care providers, multiple social agents, transport system, financial ability, health facility responsiveness, and autonomy of the primary caregiver. These factors intersect and overlap to determine when and how women and children should access appropriate healthcare. The evidence emphasises the need for simultaneous application of multisectoral and life-course approaches if healthcare access barriers are to be addressed.

6.1. Introduction

The global sustainable development goals (SDG) aim to reduce new-born and under-five mortality to below 12 and 25 per 1000 live births, respectively (WHO, 2015a). These targets are ambitious for sub-Saharan countries such as Uganda. Despite the substantial reduction in under-five mortality from 148 to 46 per 1000 live births between 1999/2000 and 2018/2019, rates remain unacceptably high (UN IGME, 2015, 2017, 2018, 2019). New-born mortality (death within the first 28 days of life) accounts for the largest share of under-five mortality. It has stagnated at 27 per 1000 live births for the last two decades (Uganda Bureau of Statistics and ICF International, 2011, 2018). Early access to appropriate obstetric services may reduce new-born mortality and stillbirths by 41% and 70%, respectively, in high-burden countries (Bhutta et al., 2014; Darmstadt et al., 2015). Similarly, a large proportion of mortality in children aged 1-59 months would be prevented if sick children accessed appropriate treatment at the right time. However, in Uganda, access to care for women during labour and sick children continues to be a challenge, with an estimated 30% of deliveries occurring outside formal health institutions and without skilled professional assistance (Källander et al., 2008, 2011; Kananura et al., 2020; Uganda Bureau of Statistics and ICF International, 2018). Less than half (48% and 39%, respectively) of children with fever and suspected pneumonia seek care within 24 hours (Uganda Bureau of Statistics and ICF International, 2018). To reach the 2030 SDG national commitment of reducing new-born and under-five mortality (Uganda Ministry of Health, 2016), increased access to appropriate care is critical.

Health care access is a complex web of relationships that include the interaction between social and structural factors in an ecological structure: individual, family, and community (Burton-Jeangros et al., 2015; Jack, 2000; Thomas et al., 2017; Umberson & Thomeer, 2020), which affect the ability of the health system to effectively reach those in need. At a family level, obstetric and child health care access is influenced by factors such as family networks, norms, socio-economic and demographic status (marital status, education, age, and wealth) (Colvin et al., 2013). At a community level, access is further influenced by the structure and the functioning of the community that shape human behaviour, cognitive functioning and decisions (Bonner, 2018; Burton-Jeangros et al., 2015; Colvin et al., 2013; Earls & Carlson, 2001). The community structure and functioning characteristics that usually impact access to health care services in resource-poor settings are transport system, societal norms, quality of leadership, and availability of social services, e.g., hospitals and civil society. Most health facilities in resource-poor settings are usually poorly equipped to respond appropriately and adequately in providing required obstetric and child health services (Christmals & Armstrong, 2019; Kruk et al., 2016, 2018), impacting patients' confidence and trust in health care access (Kruk et al., 2016; Martínez-Martínez & Rodríguez-Brito, 2020). These factors and barriers may affect the families or individuals differently, thus affecting them from accessing appropriate health care services. Families and individuals in resource-poor settings often experience multiple barriers such as poor transport system, powers relations (at individual, family, community, and with health providers), financial constraints, and inadequate health

services system. However, while there is available evidence on how multiple factors may affect access to healthcare services, we still lack evidence-based multidimensional frameworks that could guide the design and implementation of multiple yet multisectoral interventions.

The Three Delay (Thaddeus and Maine 1994), Mosley and Chen (Mosley & Chen, 1984) and Andersen and Newman frameworks (Andersen & Newman, 1973) have been applied extensively in examining barriers to and determinants of maternal and child health care access. While these frameworks have contributed to the design of socio-economic, structural and health facility-based interventions, they are too simple to emphasise how multiple interventions could be concurrently implemented to tackle access to health care services. Thus, inequities could be hidden in studies that apply these models since the focus is usually on individual behaviour rather than considering how the interaction within and across social structural context, individual behaviours and health facility system curtail the equity in services' accessibility. Such frameworks may lead to the design of unsuitable pro-poor health strategies in resource-poor settings, given the multidimensional nature of factors that concurrently affect the population's well-being.

Building on the life-course principle of agency and linked lives, I used qualitative data that I collected from women who had experienced new-born deaths, including stillbirths, focus group discussions with parents of children aged 6-59 months and key informant interviews with health facility workers, to examine how access to appropriate healthcare is shaped social constraints and opportunities. In particular, I study how social network ties, the community structure, and the organization of the health services influence child and obstetric health care access equity.

6.2. Theoretical framework

While the frameworks by Andersen and Newman, 1973; Mosley and Chen, 1984; and Thaddeus and Maine, 1994 have been crucial over the past three decades in understanding the barriers to and determinants of health care access (Andersen and Newman 1973; Mosley and Chen 1984; Thaddeus and Maine, 1994), they suggest a linear pathway of care-seeking that is out of step with the multiple overlapping factors identified in the literature: multiple social agents that influence decision making, transport system, caregivers financial ability, and poor health services. These frameworks do not comprehensively explain how access to appropriate health care is concurrently affected by the multiple interactions within and across the social structural context, individual behaviours, and health facility system. While a framework by Colvin et al, 2013 on health care seeking for child illness seems to consider how multiple barriers concurrently affect child health care access (Colvin et al., 2013; Kaiser et al., 2018), the mechanism for implementation of interventions that address these multiple barriers remains unclear. Studies that examine inequalities in obstetric and child health care access are based on population-level surveys (Alam et al., 2015; Barros et al., 2012; Barros & Victora, 2013; Boerma et al., 2008; Victora et al., 2017). While these studies give us a sense

of differentials in the distribution of health care access, they cannot reveal the underlying contextual causes of inequality or propose strategies to achieve equity (Larson et al., 2016; Young et al., 2020). Thus, with the global agenda of *"leaving no one behind",* the growing concern on health inequities among many international organisations (CSDH, 2008; UNICEF, 2017; UN IGME, 2019; WHO, 2013) and the current call for redesigning child health programs (Requejo & Strong, 2021), there is a need for an evidence-based model that can be applied to identify a package of interventions that improve equity in obstetric and child health care access.

I synthesise qualitative data collected in a resource-poor setting to understand how multiple social and structural factors concurrently affect access to obstetric and child health care services. Going beyond individual factors such as socioeconomic status, sex, gender, and race that have been used as inequality proxies (Alam et al., 2015; Barros et al., 2012; Barros & Victora, 2013; Boerma et al., 2008; Victora et al., 2017), I examine how the relationships and interactions between some of these factors and across multiple levels of society shape the health of a particular population group. Above all, this study challenges the culture of blaming the victim (in this case, a mother or family that has lost a child) by considering how community structural set-up and power relations at individual, family, community, and health providers affect health outcomes.

6.3. Methods

Results in this chapter are based on 8 focus group discussions with under-10 parents (mothers and men), 29 in-depth interviews with women who had experienced child or pregnancy loss 4 months prior to the date of interviews and 6 key informant interviews with the public health facility workers. The data was collected in Iganga and Mayuge districts located in central-eastern Uganda. The interviews were done in the Lusoga language, which is the dominant local language. Three Research Assistants (RAs) who had training experience in collecting data and an understanding of the study area context were recruited and trained in data ethics, collection, and management protocol. Upon the formal consent of the study participants, all the interviews were audio-recorded and verbatim transcribed. (See section 2.7 in Chapter 2 for study setting details). Open or inductive coding was done as I read each transcript using RQDA package (Ronggui, 2016). From the analysis, 27 codes were identified, later grouped into 3 themes and 8 sub-themes (Table 2.8 of Chapter 2 shows a list of codes and themes).

6.4. Reflexivity

While I knew the emotional concerns that could happen while interviewing the bereaved women, I was not fully equipped to provide psychosocial support. Though most women did not weep during the interview, their faces showed that they were still grieving and needed more social support. Additionally, all women involved in the in-depth interviews, including a few who wept, indicated how important it was to talk to them as they felt neglected in the community. Whereas the RAs had some training in counselling, to my observation, the bereaved women needed more psychosocial support. Unfortunately, I could not find a formal

organization that would provide psychosocial services. I suggest a post-natal psychosocial package that targets postpartum women who have experienced stillbirth and new-born death. Studies done in the same context have indicated a lack of support for bereaved families (Kiguli et al., 2015; Mills et al., 2021). Details on this chapter's reflexivity are comprehensively explained in Section 2.8 (Chapter 2) of the thesis.

6.4. Findings

6.4.1. Description of study participants

Tables 6.1 and 6.2 summarise the participants' characteristics of in-depth interviews and focus group discussions. Related to child health, overall, 23% of the women had their recent deliveries conducted in the communities. Among the FGD women participants, 41% and 22% had ever experienced child loss and stillbirth, respectively. Among women who had recently experienced child loss (in-depth interview), 48% of the new-borns had died within the first day of delivery, and all death happened within the first 6 days of life.

Table 6.1: Description of men who participated in focus group discussion.

	Freq	*%*
Education level		
None	15	53.57
Primary level	10	35.71
Primary occupation		
Community transporters (Boda-boda)	15	53.57
Business	4	14.28
Farmer	9	32.14
Religion		
Muslim	13	46.43
Christian	15	53.57
age group		
20-30	15	53.57
30-40	7	25
41+	6	21.43
Have multiple wives		
No	21	75
Yes	7	25

The stillbirth and new-born deaths within the first day of life highlight the challenges with the overall health system in accessing appropriate health care services as these are mostly resulting from labour complications can be averted given appropriate treatment and care interventions. These challenges may result from the interplay within and across individual, social and health facility systems factors. In this study, women indicated that they usually have plans to deliver in or take their sick children to the health facility but always fail because of multiple factors. The public health facilities that are known to serve the poor are located far from the communities in which most participants live. This intersects with other families, community, and health facility-level challenges to further curtail access.

Table 6.2: Interviewed women in the focus group discussion and in-depth interviews.

	Women with children aged 6-59 months – FGD		Women experienced recent child loss- IDI		Total	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
Marital status						
Married or stay with a partner	29	90.6	29	100.0	58	95.1
Unmarried	3	9.4			3	4.9
Age group						
20-30	21	65.6	19	65.5	40	65.6
30-40	9	28.1	6	20.7	15	24.6
<20	2	6.3	4	13.8	6	9.8
Education level						
None	13	40.6	1	3.5	14	23.0
Primary level	11	34.4	16	55.2	27	44.3
Post primary level	8	25.0	3	10.3	11	18
Occupation						
Civil servant	2	6.3	1	3.5	3	4.9
Business	4	12.5	7	24.1	11	18.0
Farmer or casual laborer	26	81.3	21	72.4	47	77.0
Religion						
Muslim	10	31.3	14	48.3	24	39.3
Protestant and Catholic	17	53.1	14	48.3	31	50.8
Others	5	15.6	1	3.5	6	9.8
Ever experienced child or pregnancy loss						
No	19	59.4	-	-	-	-
Yes	13	40.6	-	-	-	-
Ever experienced stillbirth						
No	25	78.1	-	-	-	-
Yes	7	21.9	-	-	-	-
Gravida						
0-4	18	56.3	19	65.5	37	60.7
5+	14	43.8	10	34.5	24	39.3
Place of delivery of the recent birth						
Clinic	6	18.8	7	24.1	13	21.3
Formal Health facility	16	50.0	18	62.1	34	55.7
Community	10	31.3	4	13.8	14	23.0
Age at death in days						
0-1	-	-	14	48.2	-	-
2-6	-	-	15	51.8	-	-
Birth weight of the child that died						
2.5+ Kg	-	-	19	62.1	-	-
<2.5 Kg	-	-	10	34.5	-	-
Missing -	-	-	1	3.5	-	-

Of six health workers that participated in the study, four were midwives and two health facility in-charges (a medical doctor and a clinical officer). Two midwives (aged 50+ years) had spent at least 20 years in service and had worked at the study facilities for at least 5 years. The other 2 midwives aged 25 and 30 years were in service for less than 5 years and had been

at the study facilities for 8-12 months. The 2 health facility in-charges (clinical officer and medical doctor) aged 28 and 30 years had spent less than 5 years in service, and all had been at the study health facilities for 12 months.

6.5. Thematic findings

I identified three main themes that relate to: how social relationships influence access to care (theme 1), how community characteristics moderate access to healthcare (theme 2), and how health facility system factors affect access to healthcare (theme 3). I use the finding to underscore how different factors (sub-themes) within these identified themes overlap and interact to affect appropriate access to obstetric and child healthcare services, and identify the different forms of vulnerability that should be considered in the design and implementation of obstetric and child healthcare interventions.

6.5.1. Theme 1: the role of family and community social support networks

The identified family networks include the child's parents, mothers-in-law, family friends, and neighbours who influence therapeutic access at different community levels (Appendix 6.1). The family support networks are involved in the discussion regarding when and how sick children and women in labour should access treatment. In addition to providing support such as finances or working as caretakers, the family support networks may also provide traditional therapy (traditional drugs or practices) to women during labour and sick children. The network members may persuade the mother on the child's health condition, thereby facilitating the kind of treatment.

The mother's involvement is at different stages. On the one hand, during pregnancy, the mother can decide when and where to access obstetric health services based on labour or obstetric danger signs. On the other hand, since the mothers spend most of their time with children, they are responsible for identifying if the child has developed sickness signs such as fever, cough, convulsion, and diarrhoea, which may facilitate when and how to access health services (Appendix 6.1). However, the urgency of accessing treatment and care choice depends on the mother's knowledge of the child's sickness and obstetric symptoms, their perception of the symptoms and their financial ability. The first treatment is usually traditional therapy and drug shops. Indeed, almost every woman knew the traditional ways of managing labour, progressing and treating the child's suspected ailment (Appendix 6.1). Some women and husbands also indicated having known some modern drugs they would buy from the drug shops whenever a child falls sick (Supplement 2).

> *"…. the fever started at night, so the baby's father got him a syrup, but the fever persisted so we went to Iganga main hospital…."*. **IDI interview**

Being major caretakers within the family, husbands and mothers-in-law play a significant role in deciding on the places of health services and may themselves provide therapeutic care (Supplement 2). A woman participant in the IDI interview indicated that she was taken to a lower health facility for delivery with her mother-in-law as the caretaker but later was referred to a higher-level health facility due to complications (Appendix 6.1). However, her

mother-in-law decided to take her to the traditional birth attendants because they feared that the mother would go under caesarean section (Appendix 6.1). In another IDI interview, a woman indicated how her mother-in-law would bring traditional drugs that she (woman) did not know.

> *"…. she used (Mother-in-law) to bring local herbs that I did not know".* **IDI interview**

Furthermore, the mothers-in-law were identified not only to influence behavioural practices like exclusive breastfeeding and weaning (Supplement 2) but also influencing their sons [women's husbands] on what they should provide for their wives, including health services' access.

> *"Sometimes, my husband first consults her mother on how I should care for pregnancy. She then gives him advises that buy for her this and leave this".* ***IDI interview***

The interview narratives revealed how caring for children and women is the husband's role (Appendix 6.2). Culturally, mothers are dominant caregivers, and this is because fathers are always away from home for a long time for work. Further, culturally, men are the custodian of resources such as finances and assets that facilitate access to the appropriate service. As such, women are not autonomous in deciding where the children should access treatment and when the treatment should be accessed (Appendix 6.2). Given the women's dependence on their partners for financial support, they must be granted permission on where and when to access the services, thereby limiting their agency in healthcare-seeking. Thus, if the child falls sick or labour contractions occur, the woman must wait until the husband returns home. The husband or family's financial ability determines where, when, and what kind of health care services should be received (Appendix 6.2).

> *"As a Musoga (relating to the culture of the participants), let me say in Busoga (participant emphasising the culture of the region) because it is where I have lived, I know that it is mainly the men who have money, …. in Busoga, it is known that the father is the supreme and most of the women just ask. I want this and then a man gives you, if a man says that they do not have, then it may be hard for my children and me to access treatment."* **FGD female participant.**

The family networks also suggest where to seek care based on their previous experience at the health facility to affect other network members from accessing health services in the same health facilities.

> *"..you may tell someone that I want to take the child to this health facility, but they then tell you that my friend has ever taken there a child, but the health workers there were unbothered or maybe she was given drugs from there that didn't match with the disease and I gave her and the child failed to get healed, so since your child is suffering from a similar disease, do you think it will get*

healed? And then you also get demoralised of going there." **FGD women participant**

I also discovered community transporters as another important community network. In this setting, the major means of community transport is motorcycles, commonly known as boda-bodas. It was indicated that every family and health facility has a telephone contact for a motorcycle (boda-boda) transporter they would contact whenever there is someone to be transported. The community transporters are important in transporting women and sick children and working as caretakers when they reach the health facilities and looking for health workers, particularly when the transportation is done at night (Appendix 6.1). The transporters were indicated to help mothers address some of the facility needs, such as buying the health facility requirements – sometimes using their money (Appendix 6.1). In cases where the families do not have enough money to transport them, the transporter would take them to health facilities on credit.

"There is someone calling you but when the situation they are in isn't good, but the money they are giving you may not be the right amount suited for the distance you are going to cover but because she is in a bad state of affairs/situation, you just help them and reach them to where they are going". **FGD Men (boda-boda ridders)**

6.5.2. Theme 2: the role of community system characteristics

Social and public infrastructures or services

The interview narratives revealed how well-equipped health facilities and a better transport system, including better roads and access to transport services within the community, are critical interdependent social infrastructures (Appendix 6.2). On the one hand, women and children living in communities with good road networks may easily access the government hospital, and most women close to communities with better road networks or those close to the district centre prefer going to the hospital instead of going to lower health facilities. On the other hand, those from hard-to-reach areas that are characterised by poor transport systems usually have challenges in reaching health facilities. The major means of transport are boda-bodas, which were indicated to be uncomfortable in transporting mothers in labour and sick children. Transport fares were indicated exorbitant because of the long distance to the health facilities and poor roads. Additionally, the poor transport system and use of boda-bodas were indicated to cause accidents, particularly, during the rainy season (Appendix 6.2). The long distances between the lower health facilities and communities and the recurrent stock out of drugs make the distance even longer as communities have to go to higher-level facilities distant from the rural communities (Appendix 6.2).

Civil society and non-governmental organizations

The presence of civil society and non-governmental organisations within the community was indicated to be important in improving the health and well-being of the children, including the general population. I identified some non-governmental institutions providing vouchers

for access to maternal services, child health treatment at a subsidised price, and other services such as malnutrition screening and support (Appendix 6.2). Marie Stopes implemented the voucher project in partnership with selected health facilities that included both public hospitals and private health centres. It was provided at 4000 Uganda shillings (equivalent to 1 USD) to all pregnant women within the organisation's implementation area regardless of their wealth or financial status. However, this seemed to had stopped at the time of research. Additionally, another organisation called "Living Goods" was providing medicine through community health workers at a standardised cost. The same organisation equipped community health workers with basic testing kits and treatment for malaria, pneumonia, fever, and diarrhoea.

> *"… earlier they used to bring us vouchers, but maybe they are done? We do not know. So now we had this Namalema health facility, they had put their voucher cards which women could use to deliver. That was the biggest luck, she would pay 4000 shillings once and even if she needed a referral, they would send her to new hope, that is how it was."* **FGD men participants**

Leadership or political will

Politicians such as a member of parliament and lower-level local leaders were found to be important in the community through resource mobilisation and enforcement of other health interventions such as better hygiene in communities and care for children. In some communities, the member of parliament had bought ambulance motor vehicles stationed at the health facilities for the referral (Appendix 6.2). However, the people that wanted to use them contributed fuel, and therefore, those without money to contribute towards fuel would not benefit.

> *"…we are a beneficiary of a committed member of parliament for this county. He provided us with two ambulances. However, we have to contribute fuel and therefore those with no money to contribute towards fuel may be transported"* **Men's FGD participant**

Community diagnostic and therapeutic providers

The community service providers identified were community health workers, traditional birth attendants, traditional healers, and drug shop owners (Appendix 6.2). The community health workers are major community resources contributing to mobilising and sensitising families on child health care and general health. The community health workers provide the drugs for sick children, provide nutrition guidance, and sometimes refer patients to health facilities.

The traditional birth attendants and healers provide services for pregnant women at the time of delivery and for new-borns—almost 3 in 10 women that participated in this study delivered under the assistance of traditional birth attendants. The preference of the TBA for health facilities results from not only their good customer work but also the worst perception of the community about the caesarean section (Appendix 6.2). Further, traditional practices,

including TBAs and traditional medicine, are due to various circumstances ranging from the poor transport system to the poor services provided at the health facilities.

> *"At the TBA we go there according to the situation has hardened when the pocket is empty."* **FGD woman participant**

> "*Labour started at around 2:00 am and my partner said now we don't have money for a motorcycle, let me put the bicycle out and I take you to deliver from there at Namukuve's (TBAs home)".* **IDI interview**

The interview narratives revealed that some diseases do not need modern therapy, and as a result, when the children fall sick, they are only exposed to traditional therapies. Such information was indicated to originate from their ancestors or grandparents (supplement 3). It was also indicated that, in some instances, the children are taken out of the health facilities to traditional and religious healers (Appendix 6.2).

> *"There is when the child is suffering from biwala*[20] *and you know that it is biwala, there you don't go to the hospital, and you go to these others [traditional healers]."* **FGD Female participant**

Another participant emphasised.

> *"Yes. That person must not be injected",* and another one interjected, *"at the health centre if the child is injected, it dies."* **FGD female participant**

I also identified drug shops as important facilities in the communities (supplement 4). All participants indicated that they mostly use the drug shops to buy treatment for children since they are close to the community and the owners can provide the medicine at a credit (Supplement 3). Another exciting reason was that drug shops could provide treatment depending on the available money (Appendix 6.3). For instance, they can provide half dose.

> *"You find a person who may have their 500/= and they ask for some Panadol, some coartem, and they mix for them like that. Even when they do not get the full dose, but they get a quick relief as they wait for the morning."* **FGD men participants**

6.5.3. Theme 3: Health services system factors

The major identified health services system factors were those that affect the trust and responsiveness of the health facility to provide services adequately and appropriately. The factors that affect the trust of the type of health service provider are respectful care, service availability, customer care, patient experience with the health service provider, and perceived health workers' experience or skills (Appendix 6.3). Participants in both interviews indicated how the poor health workers' attitude and negligence at the health facilities contribute to women opting to deliver at the traditional birth attendants' homes or accessing treatment for sick children from drug shops. In terms of negligence, most women and men interviewed

[20] Was described by participants as a disease condition with symptoms of acute diarrhoea, fever, convulsion and sores

indicated that in addition to other health facility rules, the caretakers/patients have to line up (queue) based on a "first come – first serve" basis without triaging. As a result, some death cases have been indicated at the facility before patients receive the required services. The following interview narratives exemplar illustrate the health workers' negligence experienced by several participants.

> *"I have ever experienced a child who died while at the health facility because of health workers' delays and negligence. I got this child from this village of ours who was aged 3 years. we reached the health facility and they just told us to queue up and later took us to a small room but before entering, another patient was being worked on. We were then sent to another room where a health worker was working on a patient. We were told to wait, and this took along. We were in the facility and the baby died in our hands without seeing anybody to work on us."* **FGD male participant (Community transporter)**

> *"But then I was handled badly when I went for delivery. A health provider told me that she wanted 20.000/= before she could work on me, yet I never had the money by then".* **IDI interview**

Similarly, women's experience at the health facility affects future access to health services. For instance, a woman who lost a new-born at a TBA's place indicated that she could not go back to the health facility because the health worker was apathetic.

> *"What prevents me from going to Facility A is that I went there when my stomach was paining thinking I was feeling labour pains, we stayed on the queue up and the health worker who found me there said you mean you are feeling more pain than the others you have found there? That is why when I went to labour went to TBA B's place, I never bothered myself with going there"* **IDI women who experienced new-born death.**

> *"What made me not to go back to Facility X was because the workers were proud. The way they look at a patient as though we were useless".* **IDI**

Another special interest group that suffers from the negligence of the health workers are adolescent mothers. One of the interviewed adolescent mothers who lost her child during delivery at a TBA's place indicated that when she reached the health facility that is close to her place of residence, the midwife never cared and told her that she should go and deliver from somewhere else. Indeed, she left and was taken back to the community to a traditional birth attendant, where she was exposed to traditional ways of delivery. She experienced delivery issues of shoulder dystocia because of a macrosomia birth who died in the process of delivery. As such, most adolescents, therefore, usually access obstetric services in communities under unskilled health personnel.

> *"Immediately (after feeling labour pains) we (with her mother) went to Madina (TBA within the village) but unfortunately she was not around. I and my mother then got a boda-boda and went to the health facility. Reaching the health facility, the midwife looked at me and she told me that since I am a teenager, she will not help me deliver in their health facility. She never even gave me a referral to another facility. Fortunately, the boda-boda rider knew a place (TBA) where his wife normally delivers – that is where he took us. When we reached, the woman (TBA) examined me and found that I had no blood. She then boiled the medicine that can give me the blood for me to be able to push. I took the medicines and later the labour pains increased, and I started pushing. I pushed but I was too tired. The child was born alive but was also too tired. The child was too heavy, and it was not breathing well. After like 10 minutes, it stopped breathing".* **IDI with an adolescent mother aged 15 years.**

Furthermore, the recurrent stock out of drugs at the health facilities makes women use other means of treating their pregnancies or children, such as using traditional practices and self-medication by buying drugs from the community drug shops. It was indicated that in most cases, when women and sick children are taken to health facilities, they are told to buy the drugs (Supplement 4). The study participants indicated that because of the known facility challenges such as stock out of drugs and health workers' absenteeism, they would rather buy the drugs from the drug shops or use traditional means instead of wasting their little money and resources going to the health facilities when they know they may not receive the required services.

> *"…. you reach them [health workers] there and they register you, ask you for a book, once they ask for a book and examine the child to see what they are suffering from, they tell you what to buy, you have to buy drugs, syringe, the canular and all the requirements just like the person giving treatment sometimes…most of the time they need some money because Uganda is a corrupt country so there is nothing free. If you don't have money, you can even lose your child, if you don't have money, thinking that I will go to a government health facility and get free drugs, they are not there."* **FGD woman participant**

6.5.4. Concurrent barriers

Based on this study's findings, I have identified key factors that concurrently occur to affect access to appropriate health services in a resource-constrained setting (Box 1). These factors are poor transport system, lack of financial support, unresponsive health facility system and lack of autonomy (Box 1). In most cases, the three identified themes interact with each other to generate different vulnerability levels. For instance, a poor woman living in a hard-to-reach community that is characterised by poor transport systems and a lack of civil societies or organisations is more vulnerable than a poor woman living in communities with better social resources.

Narrative 1 (Box 1) describes how a woman reached the health facility but was not attended to early because the health workers were not available. But later, one came and found when the woman had started pushing. The problem of the shoulder not coming out indicates shoulder dystocia, which needed advanced labour management such as the use of assisted instruments or caesarean section. The referral to the higher-level health facility was not prompt and safe as the woman's husband had to get his brother to help them with their truck. This narrative indicates the challenges of the health facility system in responding to emergencies. The intersection of the health facility capacity, availability of skilled health workers, poverty, and transport challenges affected the birth outcome. Narrative 2 (Box 2) describes how women fail to deliver in health facilities because of health workers' negligence and a lack of finances to pay for health services at the health facilities and transportation(Box 2).

Box 6.1: Selected participants' concurrent barriers narratives

Narrative 1

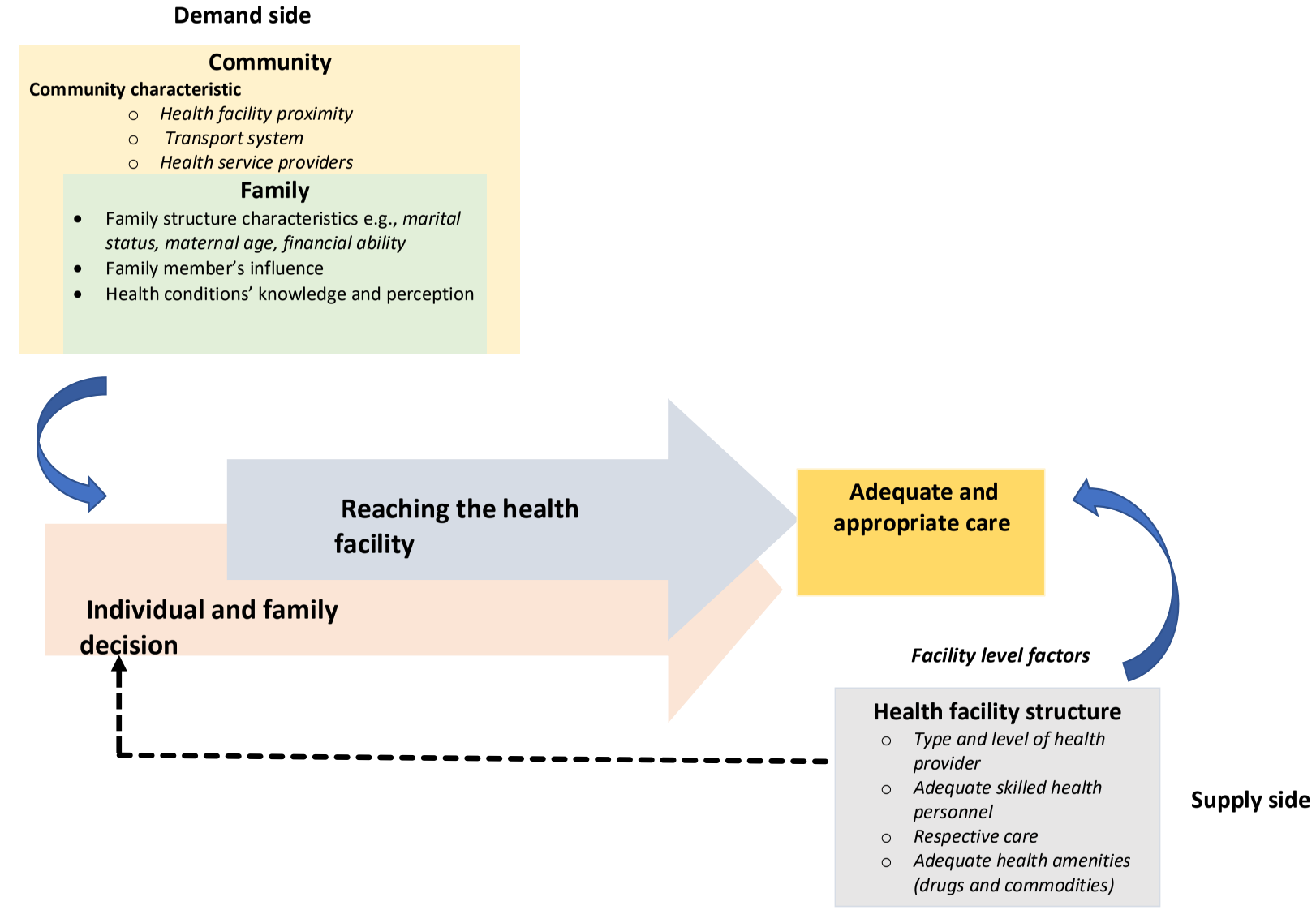
"She came and found when I was trying to push and she started encouraging me to push. However, the baby's head came out but the shoulders could not come out. I pushed as the midwife insisted I should until I lost energy. The midwife did not do anything to help and later the baby died while still in my legs. It never came out. Later, she told us to go to the higher-level hospital in Iganga but there was no means of transport. My husband had to call his brother who drives a truck which he brought and was put behind in the trial". ***IDI participant***

Narrative 2

" Some we fail to deliver from the health facilities because of our poor financial status. We have that fear that health workers will ask for money to pay for their services when we are not ready. We also fear being neglected by the health workers. When we go to the health facilities those health workers just look at us as if they don't know what we as mothers are going through. We, therefore, decide to remain at home where we know we would get some care from the relatives than going to the hospital to be neglected". ***Women's FGD participant***

Figure 6.1 is the framework that summarises how multiple barriers affect access to appropriate healthcare services. Even though the individual has decided to go to the health facility, the framework shows that community-based factors may curtail the person from receiving adequate and appropriate healthcare services. The framework also shows that reaching a health facility is not enough as a responsive health facility system is characterised by numerous factors, including adequate and skilled health workers, health providers' category, and respective care. These health facility factors affect trust, which ultimately affects individual and family decisions in accessing the health providers' services.

Figure 6.1: Healthcare access conceptual framework



6.6. Discussion

This study's novelty is that beyond the social factors, it uses evidence to holistically examine obstetric and children's health care access in resource-limited settings. The findings are based on the qualitative narratives that I gathered through in-depth interviews with women who experienced child loss during delivery or within one month after delivery, focus group discussions with the parents of children aged 0-5 years and key informant interviews with health workers. The approach provides an important insight into the understanding of how a set of social and health institutional system factors interact to hinder health services access equity. Drawing on the narratives gathered from children's parents, I demonstrate the multiple layers of health care access challenges that inhibit families' rights to access appropriate obstetric and child healthcare services. In an ecological system, I discuss how obstetric and child health care access is influenced by a set of multiple yet interacting factors that occur at the family, community, and health facility level. These factors do not operate in isolation but interact with each other, producing distinct pathways of health care access inequity relating to various domains of the health system, which I categorised as a poor transport system, lack of financial support, unresponsive health facility system and lack of autonomy.

In this study, while women indicated to have always planned to deliver in or take their sick children to the health facility, they are usually unable to access appropriate services because of multiple factors that interplay within and across individual, social and health facility system factors. The public health facilities known to serve the poor are located far from the communities in which most participants live. This intersects with other families, community, and health facility-level challenges to further curtail access.

The findings indicate the lack of autonomy women have in their decision to access obstetric and child health care. The influence of multiple people, including mothers-in-law and family friends in deciding on the type of therapeutic care for sick children and pregnant mothers has been well studied (Colvin et al., 2013; Haskins et al., 2017). The role and influence of the family network are complex. On the one hand, they may support financially and act as caretakers while at home and in hospital (Kerr et al., 2008; Scott et al., 2018). On the other hand, the family networks influence healthcare behaviour by providing traditional therapies, often as primary health care services, which also contributes to the delays or failures in accessing appropriate care in addition to other health consequences. Additionally, the family networks such as grandparents are custodians of traditional practices that may inhibit mothers from practising recommended health interventions such as exclusive breastfeeding (Kerr et al., 2008; Scott et al., 2018; Susin, Giugliani, & Kummer, 2005) and bathing of new-born immediately after birth (Gupta et al., 2015). I also found that grandparents may decide on what their sons should provide to their wives. The influence of the family support through social networks and power over resources means that the mother has to obey what their social support network, such as mothers-in-law, have suggested, even if it is contrary to the

recommended health practices(Aubel, Touré, & Diagne, 2004; Kerr et al., 2008; Gupta et al., 2015). This means that women must subordinate and thus tolerate family network abuses to ensure family solidarity and support.

The findings in this study have revealed that in a rural context, the facilities are not only too far to go to but also undesirable to go to. Such means that the community does not see the benefits of accessing health facilities' services, particularly the public institutions, given their persistent challenges of poor-quality services. High-level facilities, both public hospitals and private facilities, are often located in urban centres. Travelling to high-level facilities always located in urban centres necessitates money for transport, upkeep, and, in most cases, paying bills. Hence, the individual or family's ability to pay for health services and the transport was critical for families in prompt decision-making for obstetric and child health care access. In line with other studies (Colvin et al., 2013; Haskins et al., 2017), women in such settings depend on men for financial support as a traditional role. Thus, the absence of men at home contributes to delays or failures in accessing care. In such context and as this study confirms, traditionally, men are the custodian of financial and assets resources that facilitate access to the appropriate service. The social construct in such a rural setting is that men are the sole financial providers of their families as women are responsible for caring for children in addition to household chores. Such implies that women often do not participate in any income-generating activity and therefore lack autonomy in deciding where and when to receive treatment for themselves and their children. Because of the inability to pay for transport or health services, children and women usually delay or fail to access treatment. As alluded to earlier, such challenges expose them to other treatment alternatives and may result in life-threatening complications, particularly if the child is suffering from severe diseases such as pneumonia and malaria. On the one hand, such highlights how women's social and cultural norms depending on their husbands put the women in a more vulnerable position of violence. On the other hand, such indicates how single parents, particularly adolescents, may lack social support as in such a setting; unmarried adolescents always face sanctions resulting from their pregnancies ranging from inadequate family support to discrimination at the health facilities (Clark & Hamplová, 2013).

Issues of trust in the health providers due to the respectful care, service availability, customer care, patient experience with the health service provider, and perceived health workers' experience or skills were key in affecting formal health care access. In particular, public health facilities were dominated by irrespective care, poor customer care and recurrent stock out of drugs. Further, because of recurrent stock out of drugs in the health facilities, women usually use other treatment complements such as traditional practices and self-medication by buying drugs from the community drug shops. The effect of poor infrastructures and quality of healthcare services on the healthcare system's trust in a low-resource setting was reported in the study conducted in Mexico (Martínez-Martínez & Rodríguez-Brito, 2020). Furthermore, the previous health services experienced by the family member or women while at the facility influenced others to access services in the same facility. For instance, sharing the previous

experience of the health workers' rudeness or poor services stopped their colleagues from accessing the healthcare services in the same health facilities. Such indicates how the performance of the health facility affects the demand for services in the long run.

The poor transport system was vastly cited as the major causes of delays or failures in reaching the facilities. The rural communities in sub-Saharan Africa are characterised by poor road networks and inadequate transport services (Porter, 2002). In the study's setting, albeit being uncomfortable, motorcycles – commonly known as boda-bodas are the major means of transport. The community transporters (boda-boda riders) were potential actors who transport sick children and women and support them as caretakers in the absence of the husband and other family networks. In the study area, each household was found to have the transporter's contacts whom they would call whenever there is a sick person to transport to the health facilities. If the family has insufficient funds to cater to transport, the sick children and women would be transported on credit.

Additionally, the boda-bodas are used at the health facilities, particularly the lower ones, in referring the patients to other high-level health facilities. The importance of community transporters in improving access to health services is also indicated in the implementation research study that was conducted in a context similar to this study area (Ekirapa-Kiracho et al., 2016). However, as Ekirapa-Kiracho et al., 2016 indicate, the poor roads frustrate both the transporters and the community. In addition to long distances to the health facilities, the poor roads would lead to exorbitant charges, contributing to the delays and sometimes failures in reaching the health facilities. Further, boda-boda may be unsafe (Jones et al., 2016) not only for transporting critically ill patients but also transportation on poor roads, particularly during the rainy season, which may lead to accidents as was indicated in this study.

Community health workers, drug shops, and traditional birth attendants were identified as primary healthcare providers; hence, the quality of services provided at these service points affects a child's life (Liow et al., 2016). In addition to mobilising and sensitising the community, the community health workers work with non-governmental organisations to provide treatment for sick children, provide nutrition guidance, and refer patients to health facilities. As alluded to earlier, most of the caretakers first try traditional means or buy drugs from drug shops before reaching the health facilities, which has been indicated in studies done in the same context (Källander et al., 2011; Kananura et al., 2020; Rutebemberwa et al., 2009; Waiswa et al., 2010). Buying drugs from drug shops was based on the flexibility of the drug shops in providing services on credits or depending on the money available. For instance, drug shops would give half treatment courses depending on the purchaser's financial ability – indicating the substandard health services that are provided by the community drug shops (Liow et al., 2016).

Additionally, as indicated earlier, the transport system's problem and lack of trust in high-level health facilities were cited as the reasons for using traditional means or buying from

drug shops. As indicated in a study by (Liow et al., 2016), because of the stock out drugs at the health facilities, the patients would be told to buy drugs (Liow et al., 2016); thus, the purchase of drugs depends on the financial ability. The findings also reveal that there are still existing community social constructs originating from family ascendants that inhibit the treatment of some diseases using modern medicine. However, from the description of these diseases, they exhibit common symptoms such as convulsion, diarrhoea, and malnutrition.

Civil institutions and political leaders were identified to complement the population's health. In the study area, the civil institutions were providing programs at a standard subsidised cost regardless of the family's wealth or financial status. For instance, one non-governmental organisation was providing vouchers for maternal and postnatal services at the cost of 1USD (4000 Uganda Shillings), while another was providing treatment for sick children (malaria, fever, pneumonia, and diarrhoea) at a subsidised price working through community health workers. I also found that in communities, the member of parliament had bought motor vehicle ambulances that were stationed at the health facilities for the referral; however, the patients must contribute fuel before they are transported. The "most vulnerable people", who include the poorest of the poorest, the unmarried and adolescents, may fail to fulfil the civil society and politicians' conditions of benefiting from some health interventions. For example, they may fail to acquire the minimum set amount needed to acquire the services.

6.7. Conclusion

The study findings have provided a set of variables that may be used to improve equity in the accessibility of appropriate obstetric and child health services. These variables categorised as a poor transport system, lack of financial support, unresponsive health facility system and lack of autonomy are nested within the demand and the supply side of the system and often interrelate to affect access to care for obstetric and child health care service. In areas with a poor transport system, access to finances plays a central role: paying for transport, upkeep and choosing the appropriate health service provider and treatment type. The lack of autonomy among women results from their dependence on their men and other family networks for financial support; thus, women cannot make their independent decisions on the choice of health services. Rural communities, particularly the poor, mostly go to public health facilities because they offer free services. However, because of the costs and other indirect burdens associated with the dyad of the poor transport system and long distances to the health facilities, the community may not see the benefit of going to the health facilities as they are aware of the persistent poor services the public health facilities always experience.

The findings highlight the ecological levels related to the identified themes. The *first* level highlights how the family structure, such as the family network members, marital status, age, caregiver's agency, and financial status, affect the decision in accessing healthcare services (Figure 1). The *second* level indicates that even though the decision has been made to go to the health facility, the community characteristics may control healthcare access (Figure 2). For instance, poor transport systems and long distances to the health facilities would make it

impossible for those with financial inabilities to access the services. This is worse in the communities that do not have civil institutions and local leaders with political will whom we found to address some of the access barriers. The *third* level indicates that even those who want to go to the health facilities (mainly public) find it worthless because of the known persistent poor services that are characterised by poor customer care and stockout of essential amenities (Figure 1). Thus, the community may prefer using other therapeutic alternatives such as traditional means or buying from drug shops. Hence, the type of healthcare services may affect the health conditions; for instance, receiving care from an unqualified health professional may deteriorate the health conditions and ultimately loss of life.

These findings suggest the need to concurrently address the individual, social, and health facility factors. Interventions should aim at attaining the quality of and respective healthcare services that are affordable and accessible. However, addressing such challenges may benefit from a multisectoral and life-course approach in designing and implementing child health and well-being interventions. The multisectoral approach is meant to involve the macro and meso decision-makers who include politicians, non-governmental organisations, civil societies, district and health facility level managers. The life-course is meant to involve those that influence children's health and well-being throughout their life cycle – from preconception, labour, postnatal and beyond.

This study has unmasked areas for further research. *First*, I note the "invisible vulnerable people" who include the poorest of the poorest, the unmarried and adolescents who may fail to fulfil the civil institutions' and other providers' conditions of benefiting from some of the health interventions. These may fail to acquire the minimum required amount to acquire the services. Therefore, I suggest an in-depth study of the distribution of pro-poor interventions. *Second,* given the substantial contribution of community transportation using boda-boda as gatekeepers amidst numerous challenges that range from poor roads to transporting women on credit, there is a need for studies on how the community transporters navigate such challenges and how they can be included as potential partners in healthcare. *Third,* there are still traditional perceptions regarding treating diseases using modern medicine, yet the description of the symptoms seemed known diseases such as malnutrition, diarrhoea, and pneumonia. Thus, I recommend an anthropological study on the causes and treatment of different diseases' typologies to guide behavioural change interventions. *Lastly,* access to the politicians' services may depend on the political affiliation of the beneficially and the politician's continued services in the office. Therefore, I recommend an in-depth analysis of how such affects service accessibility and sustainability in case the politician is voted out of office.

6.8. Strengths and limitations

The advantage is that the qualitative findings in this thesis complement the quantitative findings by providing a deeper insight into contextual issues that affect access to appropriate obstetric and child health services. The limitations of the qualitative findings are mainly related to generalisation as the findings are specific to the study area context. However, the qualitative findings could be applicable elsewhere due to certain social and health systems similarities that affect population health and well-being, mostly in poor-resource settings. The finding could also be helpful in other countries within sub-Saharan Africa since most communities share the same characteristics as this study's setting.

6.8. Appendices

Appendix 6.1: Interview quotation on family networks in maternal and child health

Network	Influence	Illustrative quotes
Mother-in-law	Place of care-seeking decision	"We went to the health facility in this villages [Lower health facility] and they [health workers] told us to go to Nakavule [referred to the higher-level hospital]. But when we were on our way, my mother-in-law changed and decided that we go to the TBA since there might be a possibility of operating us at Nakavule. We went to the TBA and that's where I delivered from." **IDI mother participant**
	Financial support	They buy soap, sugar, and help me with money once the child is sick, and at times they take the sick child to the hospital. **IDI mother participant**
	Enforcing other child health care behaviours	….. as we are in an extended family, the grandparents cannot allow her to stop breastfeeding before the child is 6 months no. They force her to breastfeed until the child grows up. **FGD men participant**
		"We are told that when the child is suffering from "Biwala" you take the child to the hospital because he or she will die when he is injected. **FGD women participant**
	Influence women husbands (their sons)	"Sometimes, my husband's first consult her mother how I should care for pregnancy. She gives him to advise that buy for her this and leave this". **IDI mother participant**
		"…. she used (Mother-in-law) to bring local herbs that I did not know". **IDI mother participant**
Family friends and neighbours	Friend's or neighbours' Previous experience effect	…… you may tell someone that I want to take the child to this health facility, but they then tell you that my friend has ever taken there a child, but the health workers there were unbothered or maybe she was given drugs from there that didn't match with the disease and I gave her and the child failed to get healed, so since your child is suffering from a similar disease, do you think it will get healed? And then you also get demoralised of going there. **FGD women participant**
		Even me it is like that, she [friend] can tell you that you are going to ADRA [name of the health facility]! The health workers at ADRA are very rude. That she can bark at you. She will tell you everything rudely. That for me I do not go there. for you, it is where you're going! You also say that I will also not go there. **FGD women participant**
	Support by escorting and financially by paying the health facility bills	…. She [neighbour] called me on phone and I woke my friend [wife] up, it was about 6:00 am then my wife took her to the health facility. But when they reached there, the health workers said she wanted 70000 shillings for discharge. I told him that give me the health worker on phone and talked to him that I had no money at that time, so give me a mobile number where to send the money.

Network	Influence	Illustrative quotes
		I sent him 80,000 and I told him to give the 10,000 to the patient to use. **FGD men participant**
		"…… I go to the neighbour and tell them that I have a sick child to help me with some money. Once I get money, I go to the drug shop and buy medicine".
	Provide care for children in the absence of parents	we also have neighbours but if we are going on a journey that requires me to go with my wife, we just leave the children there. They cook food and give them until we come back. **FGD men participant**
Community transporters	Taking women and sick children and sometimes on credit	"The work/roles we play to help them are these; there is someone calling you but when the situation they are in isn't good, but the money they are giving you may not be the right amount suited for the distance you are going to cover but because she is in a bad state of affairs/situation, you just help them and reach them to where they are going". **FGD men participant (working as a boda-boda rider)**
		"Sometimes you meet a woman who is not well and that she has not enough money, but you are forced to transport her to the health facility since she belongs in your community". **FGD men participant (working as a boda-boda rider)**
	Working as caretakers	"The work/roles we play for those patients when we reach the health facility, when we reach the health facility, sometimes you take others who have no caretakers, so you are told not to fast go but wait a little bit. So there is some work…. the health workers can send you to go and bring for us this, go bring that but sometimes they have their money which they are using. There are certain things she has forgotten home, you ride and come back home, sometimes you are transporting a pregnant woman and they say she has not come with the polythene, bring gloves, basin, jerrican, bring someone who will help us and you have to go and bring that person" **FGD men participant (working as a boda-boda rider)**
		"Secondly, recently I drove a patient who did not have money, I reached the health facility, and I am the one who struggled /suffered with her like her husband so I will have helped as a person". **FGD men participant (working as a boda-boda rider)**
		"Another, for instance, yesterday, I also took a woman to the health facility but unfortunately when I reached, the health facility, this woman had no money and also the facility needed her to buy some other items and therefore I ended working like her husband or caretaker buy going to the to buy what the health worker needed". **FGD men participant (working as a boda-boda rider)**
	Help them by looking for health workers while at the health facility	"At midnight, and when I knocked on the musawo's door, she did not open but remember everything hard already burst/poured out from the lady (bulikintu kyabiike). When she refused to open, I begged her, and the caretaker said let us go to Namukuve". **FGD men participant (working as a boda-boda rider)**
Husband	Social construct roles for men	"As a Musoga, let me say in Busoga because it is where I have lived, I know that it is mainly the men who have money, …. in Busoga t is known that the father is the supreme and most of the women just ask. I want this and then a man gives you, if a man says that they do not have, then it may be hard for me and my children to access treatment." **FGD women participant**
		"Sometimes they need money for transport and that transport is got from me the man. Looking for a solution comes from the man because he is the owner of the money the man at home, so if there is no money, the woman will not manage to go alone to the health facility. As I arrive, it is me to take care and do this and that, if they want tabs to be bought or syringes, it is me who is meant to do what? To buy it because she will not manage to buy it as she will be consumed in her child. So, I am overall in those ones." **FGD men participant**
		"We are the ones with authority because of the following; even if you are in the valley farming rice and a child gets sick, the woman comes there that you, the

Network	Influence	Illustrative quotes
		child is not fine. So, it is you to be creative and think where to take the child." **FGD men participant**
		"Sometimes they need money for transport and that transport is got from me the man. Looking for a solution comes from the man because he is the owner of the money the man at home, so if there is no money, the woman will not manage to go alone to the health facility. As I arrive, it is me to take care and do this and that, if they want tabs to be bought or syringes, it is me who is meant to do what? To buy it because she will not manage to buy it as she will be consumed in her child. So, I am the overall in those ones." **FGD men participant**
	Financial provider	"… Musawo [referring to the interviewer as a health worker], he [husband] can stop you from going to the health facilities in case he doesn't have money since most of us depend of them for financial support because he can say that "if you have the money, take the child but me I don't have and so if you don't have, that means that the child will not receive treatment at all." **FGD women participant**
		"When you come back home, your wife will tell you that my friend, while you were away, this child fell sick, so when you ask that what happened? She explains for you what transpired that time when you were not around. So as a father, you have the role to go to the clinic and bring tabs for the child to become better. If it requires taking him to the health facility, then they go". **FGD men participant**
		"it is the father you tell that I am taking the child to a health facility, but they need some money. They do not have time to see if the child has bathed, how they have stayed, they are there to support us financially". **FGD women participant**
		"I will not be so much different from what Sumaya has said, women have little income compared to men because if I go and they recommend a syrup which is 10,000/=, I may have only 2000/= it still needs me to ….that is why they say that a home needs to have a man and a woman, he supports us, he supports the bigger part. That is the authority they have over the health of children." **FGD women participant**
		"No, it started me at 2:00 am, my partner said now we don't have money for a motorcycle, let me put the bicycle out and I take you to deliver from there at Namukuve's (Traditional birth attendants) place." **FGD women participant**

Appendix 6.2: Interviews' quotation on community systems that affect assess to appropriate services.

Category	Challenges related to social infrastructures availability	Illustrative quotes
Responsive health facilities within the place of residence	Proximity	"The reason why children die, sometimes you get a child from home to the health facility, you reach the nearest health facility where you are meant to go and there are no necessary requirements for testing and treatment. So, when there are no drugs that are going to treat the disease, he/she is suffering from they refer you to a far place. In referring you to a far place/long distance, it is like you are using a motorcycle and the child dies along the way". **FGD men participant**
		"The situation I was talking about concerns the distance we have to the government health facility is a very long journey because it is in Busowoobi, and the other is at Bukwaya. To and

Category	Challenges related to social infrastructures availability	Illustrative quotes
		from you may be charged between 5000 - 6000/= for a person, which is expensive for us." **FGD women participant**
		"Yes, because the nearest health facility is private and it is in another village called Wairama, it is also a distance." **FGD women participant**
		"The situation I was talking about concerns the distance we have to the government health facility is a very long journey because it is in Busowoobi, and the other is at Bukwaya. To and from you may be charged between 5000 - 6000/= for a person, which is expensive for us." **FGD women participant**
		"We have challenges because a child falls sick but when you do not have a motorcycle at home. You have to look for one with it and you reach there, and they tell you, this night can I go to Iganga**?" **FGD women participant**
		"The health facilities are far, yet this is near [referring to the traditional attendant's place]. It's the transport situation to reach you to the far place if you have your bicycle". **FGD women participant**
Transport system	Status of the roads	"We have challenges because a child falls sick but when you do not have a motorcycle at home. You have to look for one with it and you reach there, and they tell you, this night can I go to Iganga**?" **FGD women participants**
Note.*** Iganga is a town centre which is located close to 8 Km from the village where the interview was conducted from*.		

Community diagnostic and therapeutic providers

Codes	Illustrative quotes
Existence of community health workers	"If the child has poor feeding, the VHT can call you and trains you on how to feed that child." **FGD men participant**
	"It is like this; here in villages we do not have where to treat worms from, we come here to VHTs and they give us tabs**." FGD men participant**
	"When my child develops diarrhoea, most of the time I bring her to "Musawo Hadijja" [Community health worker]. **FGD men participant**
	".. for me musawo [referring the interviewer as health worker] if the child has started having diarrhoea, I come to "musawo Hadijja [Community health worker, and tell her that the child has diarrhoea. And she gives me drugs that stop diarrhoea, but she first asks for how long had the baby had diarrhoea, is it a day or two? I explain to her if the baby has had let me say for a day, and she gives me tablets and she says go and give the child every tab until it clears." **FGD women participant**
	"We thank these health workers of ours so much who encourage/ tell us to sleep our children under the mosquito net. To help prevent malaria that is spread, when a child gets diarrhoea, you rush to the health worker who gives you drugs to treat the child." **FGD women participant**
	".....because those health workers emphasize /encourage that we take the children to health centres early if they fall sick and they also tell us to keep our homes clean, to give the children fluids all the time, they also tell us that if a child got a body temperature you should take them to the health facility, and also to go to them and tell them what has happened to the child. So they also help us in that way." **FGD women participant**
Existence of traditional birth attendants	"Women go to the TBA because of her good work and sometimes women escape from the hospitals when they are told that they will undergo the operation. For example, one lady last

Codes	Illustrative quotes
	month had her daughter whom they wanted to operate at the hospital, however, she had to carry her and escape the operation to the place of the TBA and they were helped them deliver. Of course, when other people get such information, they have to come to go to her". **FGD women participant**
	"At Mulerwa [Traditional Birth Attendant], we were not charged a lot of money as it would have been at the health facility. She only charged me 2000UGX which was for kuvunda nsiko (loosely translated as going to traverse the bush to look for herbs)." **FGD men participant**
	"They told us to go that you will first bring money first, so it pushed us on the wall, we left and went to the local Musawo [Traditional Healer or Birth Attendants]." **FGD men participant**
	"At the TBA we go there according to the situation has hardened when the pocket is empty." **FGD men participant**
	"What I got from Namukuve [TBAs] is that they care for those educated health workers is different from that of the TBAs we are talking about. A TBA will take care of a person and takes that responsibility, but those educated ones you find when they are less concerned." **FGD men participant**
	"It was shorter for me depending on my pocket, government charges a lot of money, they said that giving birth is free of charge, but when you reach there, they ask for money so it brings difficulty to me." **FGD men participants**
	"No, it started me at 2:00 am, my partner said now we don't have money for a motorcycle, let me put the bicycle out and I take you to deliver from there at Namukuve's [Traditional birth attendant] place." **FGD women participants**
	"I was saying that such beliefs cannot prevent us because even last month I had a child admitted I a far government health facility, but I managed to carry it from there, removed the drip and took it to church and they prayed and prayed for it. Then at the end, we carried it and took it back to the health facility. I also another one they brought suffering from bijadu [evil spirits/witchcraft] that needed traditional medicine, they carried them from the hospital and took it to a traditional healer, and in the end, they carried the person from the traditional healer's place back to the health facility". **FGD Women participants**
	"As for us Basoga [Tribe] we know that when a child is developing baby teeth, they develop some diarrhoea. I bought some drugs to treat diarrhoea, but it persisted and when I checked the child's behind, it had turned red. I realized that it was "Lwenyanja" and I went to get some herbs". **FGD Women participants**
	"There is when the child is suffering from "Biwala" and you know that it is "Biwala", there you don't go to the hospital, and you go to these others". **FGD women participants**
	"…they are not supposed to be injected! [respondent emphasizing]. Yes (another person interjecting) must not be injected. At the health centre if the child is injected, it dies (another respondent emphasizing)". **FGD women participants**
Existence of drug shops	"I had labour-like pains which were gradually increasing and I told my children that you tell your father that am feeling labour pains so he called a bodaboda and I was taken to the health facility…..but I had just reached the other trading centre where I got a clinic and delivered from…..because when I moved from home to the roadside to get onto the motorcycle, I felt the baby coming, so I told them I couldn't make to the place I was to deliver from. So I was taken to a clinic." **IDI women participant**
	"Are there children that you take to drug shops and buy them medicine?" the modulator asked. Mostly, that is where we go. Because It is the one nearest to me". **FGD men participant**
	"Yes, so when a child gets body temperature, I go and buy some Panadol and coarterm so that I bring, and he/she swallows. But if it fails, we transfer to the government health centres". **FGD men participant**
	"Another thing as to why we use those clinics is because you use/spend little money, and secondly, we also know one another. Even when you don't have money, they give you treatment and a day or two days after, you can sell your chicken and go to clear." **FGD men participant**

Codes	Illustrative quotes
	"You find a person who may have their 500/= and they ask for some Panadol, some coartem, and they mix for them like that. Even when they do not get the full dose, but they get a quick relief as they wait for the morning." **FGD men participant**
	"..I was on my way to a government health facility and I couldn't make it so I delivered from a clinic". **IDI woman participant**

Leadership and community will

Category	Codes	Illustrative quotes
Service delivery	Ambulance	"…..they (politicians) are better positioned for some issues like when we needed an ambulance and you approach the member of parliament, he offered one". **Health facility worker**
		"…we are a beneficiary of a committed member of parliament for this county. He provided us with two ambulances. However, we have to contribute fuel and therefore those with no money to contribute towards fuel may be transported". **Men's FGD participant**
		"…we are a beneficiary of a committed member of parliament for this county. He provided us with two ambulances. That is a positive impact. But still, politics has had some interference in the health services". **Health facility worker**
		"Of course, they have affected. One, they create awareness, secondly, they lobby for us. Like we have had some good moments in MCH services because of the ambulance. It is easy to refer. Means of transportation is easy. So, all those are results of politicians. And then, when there are challenges with the health care providers, the community members find it easy to run to politicians. So, politicians help to give us feedback that there is information from the community to help us do some changes here and there. **Health facility worker**
Enforcement	Mobilization and sensitization	"…. so they helped us in mobilization because people trust them. People believe in them. So, they can easily obey to there, to whatever they tell them. So, we had a good turn up partly because of, so they have a very positive influence in certain behaviours at the community level. And then still at health service level, these people help us in lobbying". **Health facility worker**
		"…. at the community level, others said before, they advocate they give us feedback messages from the community so to help us do changes here and there. So, they equally, you know they have an influence on, they advocate like improving the rural transport network for easy accessibility to the health facilities". **Health facility worker**
		"It has like for example in some areas we have been able to put outreaches because of their effect. Yes. In this district, we have few health centres threes. The majority are health centre twos. There are sub-counties without a health centre three. And many of them have come up and demanded services. Demanded services like HIV services, like immunization services where they are not. And you sit as a team, either at the district level or what level and you decide. So, some of the outreaches that have put have come because of their demand". **Health facility worker**
	Community Rules and norms	"When the LC1 come at your home when you do not have a latrine, they tell you to build one but if you fail, they arrest you, but they first warn you". **FGD women participant**
		"It has greatly helped because you could find little children here in ponds [swimming contaminated water]; it was a war for parents to have latrines at home, in a home sweeping or clearing the nearby bush, to keep away mosquitoes was not easy. But right now, when you tell him that the chairman has said that tomorrow the health workers are coming here for the

Category	Codes	Illustrative quotes
		issue of pit latrines. That day a person will look for a worker to dig for them a latrine so that they don't find any faecal matter in anyone's compound. In so doing, the chairman has already prevented that situation because If flies remain in the latrine, they will not come and drop on a child's food which they are going to eat". **FGD men participant**

Appendix 6.3: Interviews' quotation on health systems services factors that affect appropriate care services.

codes	Illustrative quotes
Stockout of amenities including drugs	"…. you reach them [health workers] there and they register you, ask you for a book, once they ask for a book and examine the child to see what they are suffering from, they tell you what to buy, you have to buy drugs, syringe, the canular and all the requirements just like the person giving treatment sometimes…most of the time they need some money because Uganda is a corrupt country so there is nothing free. If you don't have money, you can even lose your child, if you don't have money thinking that I will go to a government health facility and get free drugs, they are not there." **FGD women participant**
Respect	"They photographed a woman giving birth and they used to show those that had come to take medicine (antenatal) that are you seeing how this colleague of yours is dirty! You should also not come here when you're dirty." **FGD women participant**
Health facility needs	"There are also many needs at the health facilities like gloves, and drugs that the patients have to buy before they are worked on, which makes them deliver from the community, in particular, the TBA who sometimes don't ask such items." **FGD women participant**
	"They told us to go that you will first bring money first, so it pushed us on the wall, we left and went to the local Musawo who has no much experience". **FGD men participant**
	"..you buy things such as toilet paper and if you fail to buy them, my dear, they do not work on you even if the child is dying." **FGD women participant**
Facility rules	"…but those things made me fed up I said that I will never go back to X [which was public health facility]. For me, I no longer want to go to the health facilities." **FGD women participant**
	"When the time for giving birth came, I pushed the baby and when they checked my handbag, there were old baby clothes because you prepare after the child grows up, you keep them after using them for another one. That your husband has never bought you new clothes ever since you got pregnant? What kind of woman are you? Things like that, but I never listened to others since I was in a lot of pain." **FGD women participant**
	"Others tell us that you go with only new baby clothes, they don't want old ones. And if you go with old ones, they abuse you, you dog, have you been sleeping with an animal! Things like that." **FGD women participant**
	"Yes, I went to Nakavule for consultations. That is where I wanted to obtain ANC services from, but when I reached there the situation was not good. What made me not go back to Nakavule was because the workers were proud. The way they look at a patient as though we were useless." **IDI woman participant**
	"What I saw, health workers could look at you as if you are useless. Some could abuse some women that "these women who do not want to stop producing" That "they keep coming to our hospital to disturb us all the time" **IDI woman participant**
	"What I got from \Namukuve (TBA) is that the care for those educated health workers is different from that of the TBAs we are talking about. A TBA will take care of a person and takes that responsibility, but those educated ones you find when they are less concerned. You tell someone that "osisinaile ebino nani eyakutuma" (you are opening your teeth, who sent you)? **FGD participants**
	"Some health providers abuse and are proud and arrogant on us so if you are once abused you may not wish to go back to the facility". **IDI woman participants**
	"…Sometimes you take a child who is very sick and when you reach the health facility, they just tell you to line-up without checking the child. For instance, I took a child who was convulsing and had pneumonia, but when we reached the health facility, they just told us to line-up. The health

codes	Illustrative quotes
	workers told us that she will not work on us until we join the queue and indeed, we had to wait in the line until the child was worked on". **FGD men participants (working as boda-boda riders)**
	"I have ever experienced a child who died while at the health facility because of health workers delays and negligence. I got this child from this village of ours who was aged 3 years. we reached the health facility and they just told us to queue and later took us to a small room but before entering, another patient was being worked on. We were then sent to another room where a health worker was working on a patient. We were told to wait, and this took too long. We were in the facility and the baby died in our hands without seeing anybody to work on us". **FGD men participants (working as boda-boda riders)**
	"….. We were then referred to the hospital but when we reached the health workers were around but very proud and never attended to us. It was Sunday. The one we got made us sit and wait for long and never appeared. The mother of the child said., my child seems to be dying in my hands and so she suggested that we take her to a private health facility. I carried the child and took her to the private where the child was immediately received, worked on and later improved. Otherwise, if we had remained at that government health facility, the child would have died". **FGD boda-boda (men) [7162:7989]**
	"I went to the council [first level health facility] when my child had contracted pneumonia, the other health worker barked at me instead of telling me that right now for us we will not manage that one, take him/her to Nakavule, she told me that but did you study? Do you have knowledge? Do you understand? Getaway and you just go to Nakavule now". **FGD women participants**
Negligence	"..the mother had twins and all the children were delivered under the assistance of caretakers. We were 3 caretakers for that mother. The first one went and begged the health worker, she refused to come from the counter with a head like this (participant demonstrates a bent head). The second one went and begged her but she was on the counter like this….<<demonstrates bent head>>.There was nothing she was doing, then I walked there myself and told her Musawo. its after seeing the head that I ran and begged the health worker. But by the time I went back the mother to be would not get up from where she was, the baby fell in my hands. I ran back and told her that Musawo, the woman has given birth, come and help because the baby has dropped, after a very long time, even after the second child had dropped, then the Musawo got up from where she was. So, such things put our lives at risk, if I have come to you as a health worker, and you are a truthfully a qualified health worker, and I come to you saying am badly off, you must take responsibility and do your work especially when you are just seated doing nothing. If I come calling you when you are working on another person, you can tell me that let me finish here very fast, then I come and see what's going on, but if you are just seated, just seated". **FGD women participants**
	"What I saw, health workers could look at you as if you are useless. Some could abuse some women that "these women who do not want to stop producing" That "they keep coming to our hospital to disturb us all the time". **IDI woman participants**
	"Sometimes you meet them, and they look at you as if you are a stranger. They can decide to shout at you". **IDI woman participants**
	"They didn't act very fast, because even the time I gave birth I was alone without the presence of a health worker". **IDI woman participants**

CHAPTER SEVEN
DISCUSSION AND CONCLUSIONS

This thesis has applied life-course and systemic approaches to understand child health and survival in resource-poor settings. The studies conducted as part of the thesis examined questions relating to under-10 mortality, new-born mortality including stillbirths, child morbidity, and health care access. The focus was on Uganda as a case study. This thesis was motivated by four reasons: 1) the stagnation in new-born mortality in most of the sub-Saharan African countries, 2) the continued largest share of global child and new-born mortality by sub-Saharan African countries; 3) the lack of reliable under-10 mortality; and 4) the need for rethinking the available frameworks that have been used in the studies of child mortality and implementation of child health survival interventions in light of a life course and systemic approaches. Guided by the concepts of interdependence, social interactions and health service delivery systems' drawn from social and health systems and life-course perspectives, the thesis' specific objectives were to: 1) determine the under-10 mortality age-specific estimates; 2) assess the epidemiological shift in the under-10 mortality risk factors and causes of death; 3) assess the role of Low Birth Weight (LBW) in mediating the new-born mortality risk factors and the role of institutional delivery in new-born mortality; 4) identify key community and household predictors of suspected pneumonia and diarrhoea, and 5) examine how multiple factors concurrently affect access to appropriate health care services.

In light of the thesis's motivations and objectives, I applied multiple data sources and multiple analysis approaches to investigate multiple outcomes that can illustrate several aspects affecting healthcare access and children's survival. The four sub-studies underscore the importance of applying life-course and systemic approaches in addressing child health issues in low-resources settings by highlighting the critical and sensitive periods of survival and the vulnerable groups. The vulnerability is explicated by the continued effect of socioeconomic, maternal or demographic, and intrinsic factors that continue to affect the children's survival and health (morbidity) and various barriers at different levels that interact to inhibit women in labour and sick children from accessing appropriate health services.

First, I use a decade of cohort data collected between 2005 and 2015 on 22385 births and 1815 deaths collected by Iganga-Mayuge HDSS in Chapter 3, to examine the mortality patterns, mechanisms, and risk factors among children aged 0-9. Building on the life-course *principle of life span development and Timing of the outcome and life-source and systems framework for child health and survival (Figure 1.4),* Chapter 3 articulates how the socioeconomic, maternal, and intrinsic factors at birth continue to affect the survival of children thereby indicating the critical period of survival over the life cycle. Similarly, Chapter 3 describes the age-specific causes of death and how the causes of death vary across the age groups. Furthermore, in addition to the description of maternal morbidity, Chapter 3 describes the timing of healthcare access for sick children and during delivery to provide an insight into survival mechanisms.

Second, I used HDSS data collected between 2005 and 2015 on 10,758 birth in Chapter 4 to assess how LBW mediates factors associated with new-born mortality and the role of institutional delivery in moderating the relationship between low birth weight and new-born survival. Building on the

life-course *principle of life span development and Timing of the outcome as well as life-source and systems framework for child health and survival (Figure 1.4),* Chapter 4 describes the timing of new-born death, thereby providing an insight into the critical period of new-born survival. Additionally, Chapter 4 highlights how some of the risk factors continued to affect the survival of new-borns in the later stage.

Third, after identifying pneumonia and diarrhoea as the major causes of mortality in Chapter 3, I moved on to investigate the community and household predictors of suspected pneumonia and diarrhoea and how these differed across the place of residence in Chapter 5. Building on the life-course *principle of Time and Place as well as the life-course and systems framework for child health and survival (Figure 1.4)*, I show how the predictors of suspected pneumonia and diarrhoea differ between places of residence.

Finally, after assessing at what point sick children and women in labour access health care services, I moved into examining how multiple factors interacted to affect access to obstetric and child health care services in Chapter 6. Building on the life-course *principle of agency and linked lives as well as life-source and systems framework for child health and survival (Figure 1.4)*, Chapter 6 examines how the social network ties, the structure of the community and the organization of the health services shape access to the appropriate services. The chapter illustrates how access to appropriate services is shaped by the choices and actions taken within the opportunities and constraints of social circumstances. Additionally, the Chapter explains the influence of different networks on healthcare access choices and actions.

This concluding chapter summarises the findings and synthesises these in line with available evidence and the global agenda. Before discussing the policy implication in the context of Uganda and beyond, I summarise the strengths, limitations, methodology and conceptual contribution of the thesis. Finally, I indicate the areas for future research.

7.1. Overview of the findings

The first paper presented in Chapter 3 of this thesis explains age-specific mortality estimates, causes of death, and mortality risk factors among children aged 0-9 years old. With the notion of illustrating the mortality mechanisms, Chapter 3 also presents the timing of obstetric health access for women in labour and health care access for sick children. Additionally, the chapter presents data on morbidity in pregnancy among women who had experienced stillbirth and new-born mortality. To the best of my knowledge, this is the first study that comprehensively assessed children's survival beyond 5 years of age in Uganda and sub-Saharan Africa. Based on the new datasets used here, I found that the probability of a new-born child dying before reaching the age of 10 was 99 per 1000, and the probability of a child aged 5 years dying before reaching the age of 10 was 11 per 1000. The probability of a child aged 0-1 and 1-5 years dying before 10 years was 46 per 1000 live births and 45 per 1000 children. These estimates are consistent with the global reports on sub-Saharan Africa estimates (Masquelier et al. 2018; UN IGME 2018, 2019). The external consistency indicates how health demographic and surveillance data may contribute to monitoring health events, particularly in countries with weak or no civil and vital registration systems. Various

studies have indicated how HDSS data could be used to monitor health events in countries with no civil and vital registration systems (Bocquier et al., 2017; de Savigny et al., 2017; Sankoh & Byass, 2012; Ye et al., 2012).

The association of adolescent motherhood, lower wealth status, lower levels of education, rural residence, low birth weight and multiple birth status with child mortality and morbidity was studied in Chapter 3, Chapter 4 and Chapter 5, where their association shifted with age bands. However, the association was much higher among children aged 0-3 years. In light of a life course perspective, such evidence indicates how the age of 0-3 remains a critical period for reducing child mortality. Although there has been a call for nutritional interventions that target child development within 1000 days of life – from conception to 2 years old and beyond (Kattula et al., 2014; Ritte et al., 2016), these findings reveal a need for an extension of 1500 days – from conception to 3 years. Especially, the vulnerable groups identified in both studies that should be targeted with the 1500 interventions are adolescents and those living in poorer socio-economic families or communities such as rural and perhaps slums. Indeed, enormous evidence shows how adolescent women and those with poor socioeconomic positions are more likely to experience adverse maternal, new-born, and post-natal health outcomes (Kattula et al., 2014). Adolescents and women from poor socio-economic status usually experience various challenges that typically concurrently occur to affect their access to better maternal and child health care services. Furthermore, this thesis has revealed that regardless of demographic and socio-economic status, low birth weight babies and those born as multiple should be targeted with special health care until at least 3 years of age (WHO, 2003, 2006, 2015c). Certainly, in line with a life course perspective, a pregnancy, labour, and post-natal package for improving health and survival, and the critical point at which these services should be provided, are well known (Kattula et al., 2014).

Furthermore, using the HDSS data in Chapter 3, I was able to study the causes of death and how they differ by age group. I found that the causes of death also shift by age. Low birth weight and prematurity, antepartum, and intrapartum complications accounted for 94% of all causes of death among new-borns. Malaria, malnutrition, acute respiratory and diarrhoea infections accounted for 88% of all causes of death among children aged 0-5 years. Injuries and gastrointestinal diseases emerged among the top four causes of death in the 5-9 age group, with malaria and malnutrition remaining. In line with the life-course perspective, the epidemiological shift of diseases and risk factors between age bands indicates the need for age-specific prevention and protection interventions. Noteworthy is that the reporting on the causes of deaths in Uganda is usually based on the health facility reports, which are limited to those who died at the health facility (Amouzou et al., 2013; Uganda Ministry of Health. Moreover, health facility reporting completion issues affect the reliability of the results (Amouzou et al., 2013; Kiberu et al., 2014; Maïga et al., 2019). Further, the health facility reporting does not allow disaggregation of data according to several age groups since the data is heaped in the form of under-5 and 5+ years old (Diaz et al., 2021). While the results on the causes of death in this thesis come from one region, the fact that the child mortality estimates match the estimates reported in other external reports, the causes of death estimates may represent the national estimates. Moreover, these estimates provide an insight into the distribution of mortality causes across the age groups, thus guiding the design and implementation

of age-specific interventions. While I did not study how the morbidity in pregnancy is associated with child mortality because of data limitations, Chapter 3 revealed that 80% of women who experienced new-born mortality had experienced morbidity in pregnancy.

The findings presented in Chapter 4 of this thesis complement Chapter 3 by providing perinatal and new-born mortality trends. As of 2016, the perinatal mortality was estimated at 32 per 1000 birth, and the estimates had not significantly reduced. Similarly, new-born mortality reduced by 14% from 22 per 1000 in 2011 to 19 per 1000 live births in 2015. Importantly, perinatal mortality and new-born mortality within the first day of life remained unchanged – the first day of life perinatal mortality is estimated at 26 per 1000 births. These findings showcase how Uganda has stagnated in reducing new-born mortality and thus the need for more efforts if the country is to meet the global targets of reducing neonatal mortality to 12 per 1000 and less. Intrapartum maternal diseases such as hypertension, haemorrhage and other infections accounted for 85% of stillbirths, while 10% was due to obstructed labour. Similarly, 33% of the new-born causes were attributed to birth asphyxia and obstructed labour, 26% to unclassified perinatal causes, and 27% to preterm and low birth-related conditions. These causes of perinatal and new-born mortality have been consistently highlighted in various studies, including MDG monitoring reports, as the major contributors of new-born mortality in low- and middle-income countries (Amouzou et al., 2014; Lawn et al., 2009, 2011; Lawn et al., 2005; Mathers, 2014; Mbonye et al., 2012; Savage et al., 2008). In line with the life-course framework, these results highlight the critical period the country needs to address in reducing new-born mortality to accelerate progress.

Furthermore, Chapter 4 findings highlight how health facilities could not significantly reverse the association between low birth weight and new-born mortality, which could perhaps explain the inadequacies in interventions for most-at-risk new-borns in health facilities. Studies in the areas with the same setting have indicated the insignificant contribution of institutional delivery in reducing new-born mortality (Konje et al., 2020). In light of a systemic approach, access to appropriate health facility interventions is complex because of multiple barriers that occur (concurrently) at both community and health facilities. This premise is supported by the qualitative work in Chapter 6 that examined how multiple factors concurrently affected access to obstetric and child health care services. Multiple factors that span from financial inabilities, and poor transport systems to unresponsive health facility systems hindered access to obstetric and child healthcare services. Because of financial inabilities and expected health facility system challenges, women usually access services from unqualified health workers, who later refer them to the health facilities whenever they anticipate poor health outcomes. The financial inabilities and poor transport systems explain the delays and failures in accessing appropriate health care services reported in Chapter 3. Chapter 6 also indicates that women usually depend on social-network agents for advice on therapeutic care and financial support, which affect their agency in accessing healthcare. As Chapter 6 confirms, various studies in a similar context (Kerr et al., 2008; Gupta et al., 2015; Susin et al., 2005) have indicated how men and mothers-in-law as resources holders influence when and how to access obstetric services.

Consistent with other studies, community health workers and community drug shops were found as the first primary health services providers (Awor et al., 2015; Kalyango et al., 2013; Kitutu,

Mayora, et al., 2017; Liow et al., 2016; Mukanga et al., 2012; Rutebemberwa et al., 2012). The critical finding that this study unveiled was that self-administered medication was common. Mothers and fathers knew which antibiotics to buy or give, including traditional drugs in case a child presents ill symptoms. Moreover, the parents would buy drugs – usually half dose – from the drug shops. Various studies have indicated an alarmingly high proportion of people accessing drugs over the counter without clinical prescription (Anyama & Adome, 2003; Kagashe et al., 2011; Mbonye et al., 2016) and sometimes drug shops or pharmacies providing incomplete doses (Kagashe et al., 2011). The provision of inappropriate antibiotics, including incomplete doses, has been indicated as the key driver for antibiotic resistance (Shallcross & Davies, 2014).

Chapter 6 showcased how social marketing through working with community health workers and health facilities was key in addressing access barriers. First, an organization known as "Living Goods" that was providing treatment for children through social marketing – was working with community health workers to provide treatment for children at a subsidised price. Additionally, Marie Stopes Uganda was providing subsidised maternal and new-born healthcare services through a voucher scheme. The importance of social marketing, including conditional cash transfers in improving the population's health, has been indicated in many studies done in developing countries (Elmusharaf et al., 2015; Lagarde et al., 2009; Rasella et al., 2013; Rivera et al., 2004). However, what is not clear is if these strategies reach the "poorest of the poor" given the conditions applied in accessing the services. In Chapter 6, community transporters (boda-bodas) and ambulances were identified as the available transportation means that help the community. Some politicians had bought ambulances to transport patients from the community to the health facilities and between facilities in some areas. While these transportation services were very important to the community, the charges were indicated to be high because of poor roads and long distances to the high-level health facilities. For the families to use the politicians' ambulances, they are supposed to contribute money for buying fuel before being transported, which may affect those from low-income families.

7.2. Conceptual and methodological contribution

Methodologically, the thesis applied multiple analysis techniques and multiple data sources to investigate multiple outcomes for a deeper and thorough understanding of child health and mortality in resource-poor settings of sub-Saharan countries such as Uganda. The six methodological contributions are based on the analysis techniques applied in the sub-studies of this thesis. Particularly, the analysis approaches contribute to the health systems' methodological approaches that seek to understand vulnerability in health care access, mortality, and morbidity.

First, Chapter 3 shows the application of lifetables to estimate age-specific child mortality using a decade of data on a cohort of children born between 2005 and 2015. The Royston-Parmar model was also applied to the same data to assess how different mortality risk factors change with children's age. To my knowledge, this is the first analysis approach that has been applied to measure the under 10 and 5-9 mortality rates in sub-Saharan Africa. This analysis approach can be replicated to study child mortality in the different HDSS and DHS. Additionally, disaggregating the study of new-born into two outcomes (perinatal and late neonatal) has helped us understand how different factors affect these groups differently, which helps in the design of age-specific interventions.

Second, in Chapter 4, while the aim was not to study causation, the approach provides an insight into how birth weight moderates the association of numerous factors with new-born mortality. Moreover, I have provided a simple approach to generating an indirect effect that can be replicated in other mediation studies. While this approach is rarely applied in health science research, it may unmask the health outcome's underlying risk factors or root causes. This approach contributes to the novel approaches of analysing non-experimental data for causal mechanisms. Further, examining how institutional delivery moderates other health outcomes such as low birth weight is important in understanding its role in reversing the risk of mortality among most-at-risk groups – this was also assessed in Chapter 4. Overall, this study contributes to understanding mediation and moderation analysis in health and social science research.

Third, I applied multiple imputations to address the missing data gaps for some variables in Chapters 3 and 4, particularly birth weight. In the dataset, birth weight was missing among 64% of registered birth records, and therefore, the analysis of such data with a lot of missing gaps may lead to an elusive conclusion. The application of the multiple imputation method has been indicated as an important approach for minimising the missingness bias (Graham et al., 2007), which does not depend on the magnitude of missingness (Lee & Huber, 2011; Madley-Dowd et al., 2019). Nonetheless, the multiple imputations approach is not extensively used in many health studies, perhaps because of limited skills in the application. The method's subsection of multiple imputations may guide the replication of the approach.

Fourth, machine learning techniques have been shown to be effective in classification, regression, clustering, or dimensionality reduction tasks of large sets of especially high-dimensional input data (Breiman, 2001; Schmidt et al., 2019). However, the application has been limited largely to clinical research (Correa et al., 2018; Delen et al., 2010; S. Gupta et al., 2014; Huang et al., 2018; Naydenova et al., 2016; Rose, 2013; Silterra et al., 2017) and only a handful studies have applied ML on cross-sectional population health data (Daoud et al., 2019; Luo et al., 2015). Yet, Machine Learning (ML) models such as lasso, random forest and deep learning have been indicated to perform better than the traditional linear and non-linear models on high dimensional datasets or correlated variables and datasets with too many variables than observations (Breiman, 2001; Luo et al., 2016). Indeed, using the area under the ROC curve (AUC) for model selection in Chapter 5, ML models performed better than the logistic regression model. The ML modelling idea lets the algorithm determine how the outcome and independent variables are linked (Breiman, 2001; Song et al., 2004). ML modelling techniques have not been extensively applied to the available cross-sectional data in LMICs. In Chapter 5, I applied machine learning (artificial intelligence algorithm) techniques to understand the most vulnerable groups at high risk of suspected pneumonia and diarrhoea.

Fifth, while the frameworks by Andersen and Newman, 1973; Mosley and Chen, 1984; and Thaddeus and Maine, 1994 have been crucial in understanding the barriers to and determinants of health care access (Andersen and Newman, 1973; Mosley and Chen, 1984; Thaddeus and Maine, 1994), they suggest a linear pathway of care-seeking that is out of step with the multiple overlapping factors. These frameworks do not comprehensively highlight how access to appropriate health care is concurrently affected by the multiple interactions within and across the social structural context, individual behaviours and health facility systems. Beyond the available

linear health access frameworks, I use qualitative data to comprehensively understand obstetric and child health care access mechanisms. These findings resulted in a multisectoral implementation conceptual framework that recognises the simultaneous effect of multiple factors.

Last, throughout all sub-studies, the thesis has showcased the need for a life course and multisectoral approach to child health interventions by highlighting the critical and sensitive periods of survival and the vulnerable groups. Although the life course and multisectoral approaches have been emphasised in international and local policies (Aagaard-Hansen et al., 2019; Bundy et al., 2018; Chan et al., 2016; Uganda Ministry of Health, 2016; Kuruvilla et al., 2018; Richter et al., 2017; United Nations, 2016; WHO, 2015a; WHO, 2015b), the emphasis usually falls short of empirical evidence. Thus, conceptually, this thesis contributes to providing a life-course and multisectoral framework that can be used to design and implement child health programs. The broad spectrum of adverse circumstances and risk factors that affect child health and survival and the epidemiological shifts in the mortality causes, mortality risk factors, and the magnitude of death emphasises the need for a life course approach in designing and implementing the intervention.

7.3. Strengths and limitations

7.3.1. Strengths

The major strengths of this thesis are that in the light of life-course and systemic perspective, it uses multiple data sources in the analysis and interpretation of data to describe various vulnerability categories across childhood's life span. More importantly, the thesis evidence contributes to the current call for redesigning child health programs (Requejo & Strong, 2021) in resource-poor settings. Each sub-study provides new insight into the mechanisms and determinants of child mortality in resource-poor settings. Together, the use of different data sources and analysis approaches help us build a stronger life-course framework on child health and survival.

First, HDSS data that was used in Chapters 3 and 4 of the thesis is that the HDSS have the capacity to link the health events data to the other socio-economic, maternal demographic, structural and biological factors (Cunningham et al., 2019; Utazi et al., 2018; Gerritsen et al., 2013; Helleringer et al., 2018; Jia, Sankoh, and Tatem 2015; Mbondji et al. 2014; Sankoh & Byass, 2012), which helped (Chapter 3) to assess how these factors pattern the health outcomes over the life course. The HDSS data comprehensively describe the population. Since the data is collected over time on the same individuals, it was possible to understand how the socioeconomic and individual intrinsic factors at birth continued to affect children's survival. The results show how supporting the HDSS may not only help in monitoring the health events but also the economic and population transition. There are at least four HDSS in different regions in Uganda and others collecting disease-specific longitudinal data like HIV. Therefore, supporting such sites to harmonise the data collection system could represent the national longitudinal data system. Second, the strength of findings based on the analysis of DHS data presented in Chapter 4 is that although the cross-sectional nature of the DHS cannot be used to infer a causal relationship between risks and outcome, contrary to other approaches, the algorithmic modelling approach employed in this study provides important risk factors from a set of variables that may suggest the direction of predicted pneumonia and

diarrhoea. Finally, the qualitative findings in this thesis complement the quantitative findings by providing a deeper insight into contextual issues that affect access to appropriate obstetric and child health services.

7.3.2. Limitations

Several limitations relate to the generalization, data collection approaches and data sources.

Generalization: Chapters 3, 4 and 6 findings are based on event history (Chapters 2 and 3) and qualitative data (Chapter 6) that are generalisable to the two-district covered by HDSS and perhaps central-eastern Uganda. The findings based on the HDSS may not be extrapolated beyond the areas under surveillance; however, due to certain similarities of social and health systems that affect population health and well-being, mostly in poor-resource settings, the HDSS qualitative findings could be applicable elsewhere. Furthermore, both HDSS and qualitative results contribute to designing health systems interventions that address both mortality causes and risk factors. The finding could also be helpful in other countries within sub-Saharan Africa since most communities share the same characteristics as this study's setting.

Missingness and incomplete birth and death registration in Chapters 3 and 4: While the registration and follow-up of pregnant women until the end of pregnancy is expected to improve the estimation of birth outcomes, the inconsistency in registered births over the years and the inconsistencies between deaths reported in the verbal autopsy and birth registration datasets shows the limitation of HDSS data in registration of all births, which affects the reliability of HDSS in the estimation of child mortality. Studies done in the same setting have shown the limitation of HDSS in the documentation of stillbirths and new-born mortality (Akuze et al., 2020; Kadobera et al., 2017; Nareeba et al., 2021), which could be the result of the data collection approach (Akuze et al., 2020; Nareeba et al., 2021). For instance, in their study, Akuze et al., 2020 indicate how the reporting of SBR was 127% higher and the NMR 16% lower in Iganga-Mayuge HDSS when using full pregnancy history (FPH) than when a full birth history (FBH) was used (Akuze et al., 2020). However, it is surprising that the NMR reported in FPH tool was lower than the reported estimates under FBH tool (Akuze et al., 2020), which affirms that neither source is a "gold standard" as both tools may miss some events (Nareeba et al., 2021). Barriers and enablers to reporting pregnancy and adverse pregnancy outcomes that have been reported in the study done in the same setting include interview tools and processes, socio-cultural and spiritual beliefs, woman-specific factors, the value placed on a baby's life and the terminology and psycho-social (Kwesiga et al., 2021).

Additionally, there was a considerate proportion of missingness for some variables, particularly birth weight. For instance, consistent with other studies (Biks et al., 2021; Blanc & Wardlaw, 2005; Blencowe et al., 2019; Channon et al., 2011; Hutcheon & Platt, 2008), birth weight information was missing for most births in all years of data collection, but this reduced with the increase in the year of data collection. Furthermore, consistent with studies done in the same setting (Biks et al., 2021; Blencowe et al., 2021), the likelihood of not having a birth weight record was associated with the timing of new-born death, place of delivery and maternal education. To minimise the bias that could result from missingness, I performed multiple imputation, which has been recommended (Madley-

Dowd et al., 2019; Sullivan et al., 2018; van Ginkel et al., 2020) regardless of the proportion of missingness for missingness at random (Madley-Dowd et al., 2019).

Furthermore, consistent with other studies (Blencowe et al., 2021; Channon et al., 2011), the heaping of birth weight in the HDSS was observed in multiples of 1000g with high frequencies observed for 2000g (14%), 3000g (63%), 4000g(21%) and 5000g (3%). Indeed, the heaping of birth weight data has an impact on the classification of children's birth weight categories (Blencowe et al., 2021; Channon et al., 2011). The health facilities should be strengthened with weighing machines and health workers trained on the need for taking birth weight measurements accurately. Furthermore, the community health workers can be supported to take birth weight measurements for new-borns whose birth weight was not recorded.

Recall bias: The HDSS verbal autopsy data used in Chapter 3 are not based on clinical or laboratory evidence and are thus subject to a high degree of misclassification errors that have a profound effect on the cause of mortality specific estimates (Amek et al., 2018; Anker, 1997; Chandramohan et al., 2001; Herrera et al., 2017). The causes of death are based on the child's mother's narrative of the signs and symptoms recognised before death and the final codes assigned by the physicians. For instance, the death attributable to malaria could be misclassified since malaria is usually based on fever as a major symptom that is also a diagnostic symptom for other morbidities such as diarrhoea and respiratory infections. While the HDSS uses the two physicians to review all the same verbal autopsy data independently to determine the causes and chain of events that lead to death, the classification of the diseases based on the individual narratives may have led to underestimation or overestimation of the true mortality cause-specific fraction.

Furthermore, the limitation of DHS used in Chapter 5 relates to the nature of cross-sectional studies on retrospectively collecting information on human behaviours and events. For instance, the occurrences of diarrhoea and measures of suspected pneumonia and birth weight in the DHS rely on women's ability to recall. However, the DHS consideration of children born in the last five years preceding the survey may minimise such bias. Further, the DHS consideration of collecting data on occurrences of suspected pneumonia and diarrhoea episodes and symptoms that occurred in the two weeks preceding the day of the interview may also minimise the reporting bias of the morbidities' symptoms and occurrences. Additionally, the reporting of diarrhoea and suspected pneumonia occurrences are subject to the symptoms and thus may not provide accurate information as it would have been if clinical notes were available (Ayede et al., 2018; H. Campbell et al., 2013). However, for suspected pneumonia, the questions on if the child had short, rapid breathing, which was chest-related or difficult breathing, are asked as a measure of the occurrence of suspected pneumonia, which may increase the accuracy in the estimation of suspected pneumonia prevalence. Further, the analysis of data in this study only considered children that were staying with the parents or caretakers at the time of the interview, which could have reduced the reporting bias (under-reporting) as caretakers or parents may not know the health status of the children they do not live with.

Limited variables: The analysis of HDSS data in Chapters 3 and 4 of the thesis was limited to the available data variables. For instance, the birth registration data did not have information on the

gestation period at birth, which could have been used to generate the preterm births, full-term births, and macerated stillbirths' cutoffs. Some other inexpensive ways yet effective in estimations of pregnancy gestation, such as a pregnancy calendar, could be utilized. The estimation of the gestation period based on the last menstruation period has been indicated to give better estimates (Gernand et al., 2016; Hoffman et al., 2008; Neufeld et al., 2006; Rosenberg et al., 2009). Therefore, the HDSS can train their community data collectors on this method of attaining pregnancy gestation period. Additionally, community-level pregnancy testing for suspected pregnancies can also be used to fill the gap (Comfort et al., 2016, 2019).

7.4. Implications for child health policies in Uganda and other countries with similar context

The fact that the child mortality rates in Uganda are commensurate with the sub-Saharan African estimates, the findings and recommendations that this thesis has identified could potentially be applied in other countries within the region. Furthermore, sub-Saharan African countries share similar health and social systems challenges that affect children's health and survival. Beyond the science-driven interventions, the thesis has indicated the need for intensive synergetic efforts that address social, structural, and health systems challenges. Thus, the thesis results inform us that to accelerate progress in achieving the global commitment to improving health and well-being, there is a need to address child health problems beyond the health sector. Notably, the thesis highlights how optimising the life course framework's potential impact may lead to high coverage, equity and quality of child health care services. The evidence on how multiple factors affect survival and access to appropriate health care services in this study emphasises the need for a paradigm shift in clinical practices, community social and behavioural programs, and public policies. In particular, my recommendations emphasise six faceted domains: 1) task shifting, 2) multisectoral approach, 3) behavioural change innovations, 4) referral systems, 5) community health systems, and 6) bringing and enforcing relevant policies from different sectors. These have been shown to work in the fight against covid-19 in most countries, including developed countries, and were shown to have facilitated progress in countries that have dramatically reduced child and maternal mortality (WHO & UNICEF, 2010).

Why life-course and systemic approach?

- *It corresponds to the SDG 3 calls for holistic, people-centred, and multisectoral approaches to human health and development.*
- *The need for rethinking new approaches that improve health and wellbieng for all children*

What does the thesis results mean?

- *The thesis findings underscore the importantance of addressing social, structural, and health systems challenges throughout the all stages of child development.*
- *The thesis recommendations emphasise six faceted domains: 1) task shifting, 2) multisectoral approach, 3) behavioural change innovations, 4) referral systems, 5) community health systems, and 6) bringing and enforcing relevant policies from different sectors.*

Aligning the recommendation with the life course approach and the need for age/stage-specific interventions, I discuss these shifts for each stage of development along the life course (pre-

conception, pregnancy, day 0, post-natal and beyond) in relation to sub-studies findings in the subsequent subsections. In light of life course and systemic perspectives, Figure 7.1 is a holistic framework that summarises vulnerability and some of the suggested interventions at each stage of development. For example, the framework shows the list of interventions that are needed during preconception to address unplanned and unwanted pregnancies. Similarly, the frameworks provide a list of pregnancy and birth interventions that would address adverse pregnancy and birth outcomes. Beyond labour and birth interventions, the framework also includes the list of interventions needed for children to continue surviving and thriving. Importantly, the framework indicates the need for integration, task shifting, multisectoral, referral system, and social or behavioural change as critical health systems interventions throughout the stages of child development.

7.4.1. Preconception

Chapter 3 and Chapter 4 of the thesis identified essential segments of the children at risk of adverse birth outcomes. Maternal age of 10-19 and 30+ years and mothers' previous new-born death experience were new-born mortality risk factors. These factors were also indicated to affect low-birth weight. The high likelihood of newborn mortality among women in extreme age groups (adolescents and advanced aged women) and those with previous child mortality experience suggests preventive interventions targeting these risky groups. High impact pre-conception interventions such as family planning services, better nutrition and immunization primarily targeting adolescents, and proper screening for risk factors before pregnancy (Dean et al., 2014b, 2014a; Gee et al., 2017; Hadar et al., 2015; Hemsing et al., 2017; Lassi, Imam, et al., 2014; Mason et al., 2014) could help in the identification and modification of these risk factors. Usually, pregnancies among advanced aged and adolescent women are unwanted.

What is known?

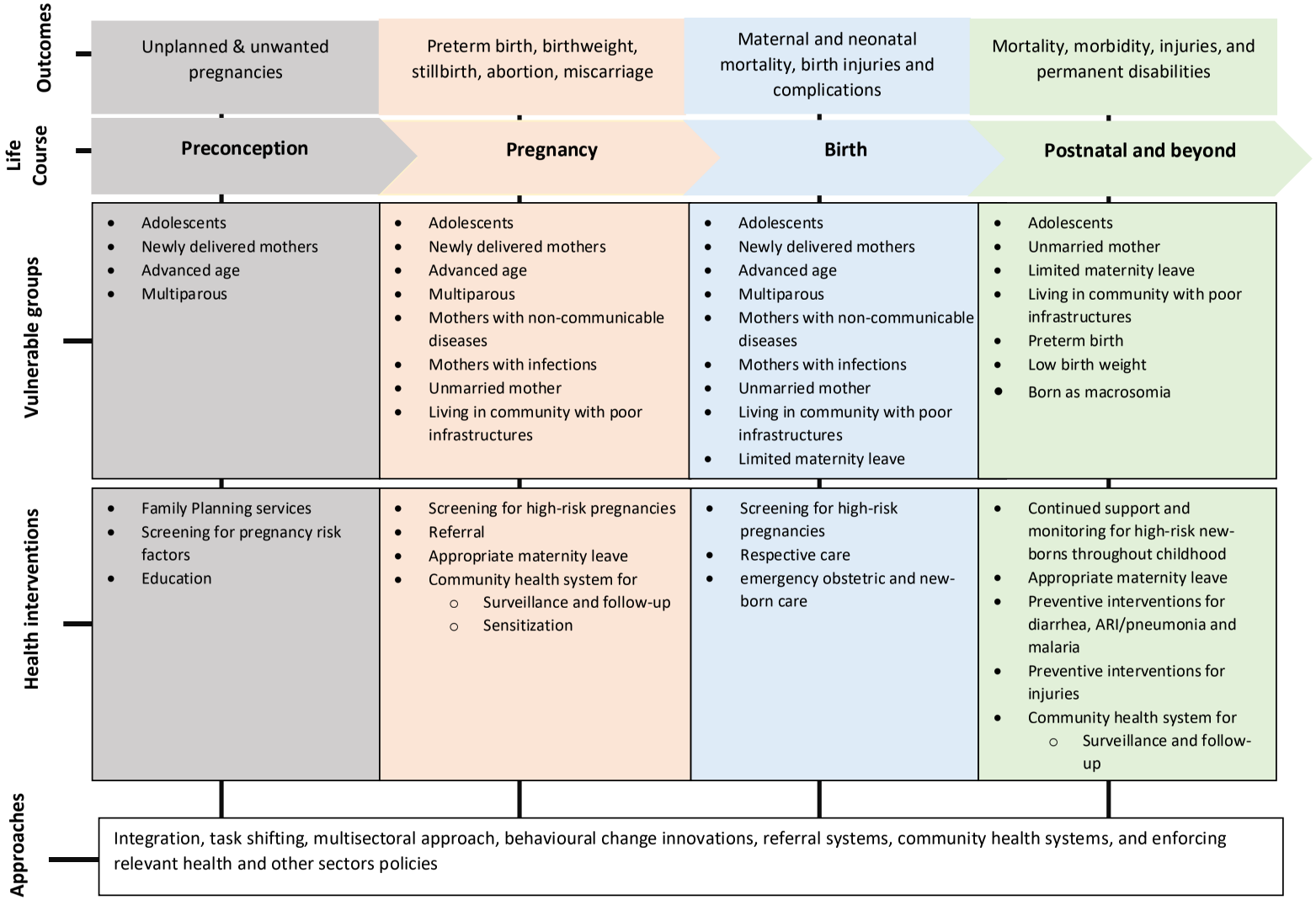
- *High impact preconception interventions include family planning, better nutrition and immunization services targeting women and girls and screening for risk factors before pregnancy.*
- *The interventions are not universally implemented in low resource settings.*
- *In Uganda, there are consistent high unmet need for family planning and high teenage pregnancies.*

What do the thesis findings add?

- *The association of LBW with adolescent age and the association of newborn mortality with advanced age presented in Chapter 4 underscores the need for preconception interventions that prevent pregnancies among such high risky groups*
- *The relationship between the mothers' experience of childbirth with birth outcome and child survival reported in Chapter 3 and 4 highlights the need for intensifying preconception screening for maternal risk factors.*

Thus, the thesis recommends birth control interventions that target adolescents, multiparous women in the advanced age, and newly delivered women, particularly those that target women who have experienced new-born loss.

Figure 7.1: Life course and systemic interventions for improving child health



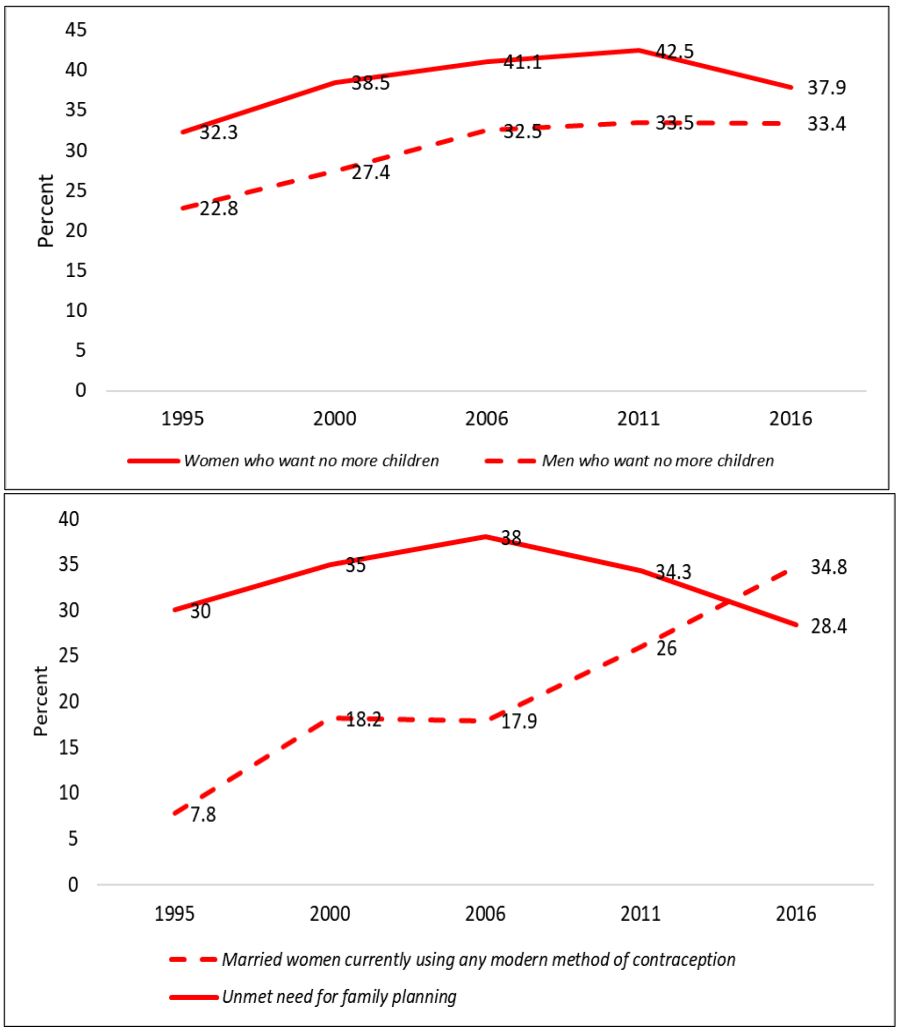
Source: Author

Effective use of family planning has been indicated as the most effective measure of preventing unwanted pregnancies, including adolescent pregnancies (Blumenthal & Voedisch, 2011; Dean et al., 2013; Kopp, 2016; Norton et al, 2017; Tsui et al. 2010). Reaching women with pre-conception family planning interventions contributes to the increased knowledge and awareness of avoiding unplanned pregnancies (Dean et al., 2014a, 2014b; Lassi, Imam, et al., 2014; Mason et al. 2014). Furthermore, pre-conception interventions on family planning encourage women, including couples, to have a reproductive plan, which provides freedom for women to decide how and when to have children (Dean et al., 2014a, 2014b; Lassi, Imam, et al., 2014; Mason et al., 2014). Such indicates that pre-conception family planning interventions may bring multiple effects, including reduced low birth weight, improved child survival and reduced fertility. Available studies have indicated that reproductive health planning may avert 71% of unwanted pregnancies (Dean et al., 2014b). In addition, pre-conception interventions that target adolescents have been indicated to reduce adolescent pregnancy by 15% and repeat adolescent pregnancy by 37% (Dean et al., 2014b).

Uganda's inadequate family planning services are evidenced by the consistent high unmet need for family planning and the current unwanted births among women and men (Figure 7.2). Noteworthy is the enormous evidence on factors that impede access to family planning services that need to be addressed. These factors are identical to obstetric and childcare access barriers identified in Chapter 6. Consistent with other studies (Dean et al., 2013; Nelson et al., 2019; Norton et al, 2017; Tsui et al., 2010), the factors are inadequate staff to provide family planning services, inadequate supplies, family influence, cultural and societal norms, and financial constraints.

Addressing these challenges needs a strong collaboration with other sectors (Subedar et al., 2018). First, there is a need to target the community social agents, such as religious leaders and cultural leaders, with the information on the need for reframing the existing norms on family planning (Dean et al., 2013). Second, to increase access to family planning services at the community level, there is a need to put in place or strengthen the existing community health service points in providing family planning services (Blumenthal & Voedisch, 2011). On the one hand, there is a need to collaborate with community health workers, whom this study indicated as critical primary healthcare givers to provide emergency contraceptives in the communities (Blumenthal & Voedisch, 2011), particularly targeting the hard-to-reach areas and poorer communities, including adolescents and referral for those in need of long-acting methods. Various studies have indicated how emergency family planning services through community health workers have been effective (Chin-Quee et al., 2016; Comfort et al., 2016; Prata et al., 2013). On the other hand, like HIV and immunisation services, the government can provide family planning services through private-public partnerships at affordable prices, particularly targeting the small-scale health service providers, including maternity homes and drug shops or clinics that usually serve the poor communities: rural and urban slums.

Figure 7.2: Unmet need for and access to modern family planning



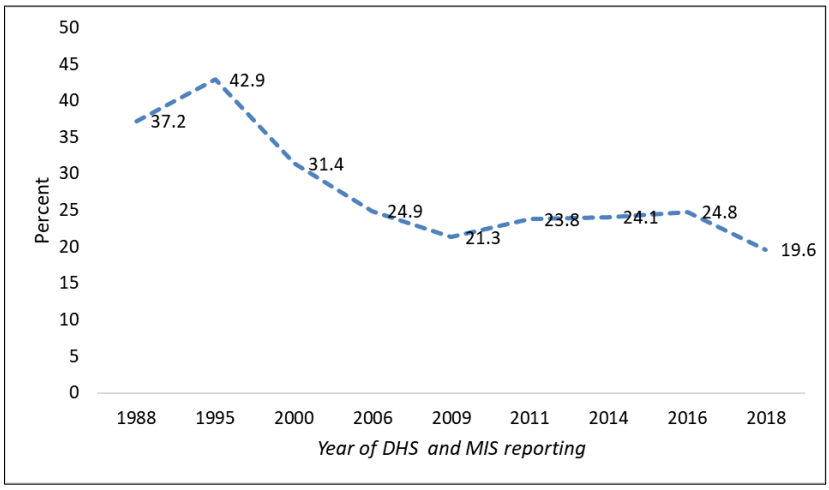
Source: *Demographic Health Surveys STAT Compiler*

Third, specifically for adolescents, there should be programs and policies that empower them to reduce early and repeated pregnancies. The adolescents should be empowered through education by identifying the most at-risk adolescents and providing them with youth empowerment services (Dean et al., 2013). In addition, laws and dissemination of information that build the girls' self-esteem in denying and reporting coerced sex and demanding safe sex through various channels are crucial. The stagnation in the high proportion of motherhood among adolescents in Uganda highlights a need for such intervention (Figure 7.3).

Lastly, integrating family planning interventions within the routine maternal and child health services and community health programs has been shown to effectively address short birth spacing (Cooper et al., 2017; Nelson et al., 2019; Pradesh et al., 2016). The risk assessment interventions should be integrated with counselling that should be used to prepare women for pregnancy. These assessments may include screening for non-communicable diseases, sexually transmitted infections, and genetics (Dean et al., 2013). While preconception risk

assessment is a new concept in Uganda, including in other sub-Saharan African countries, there is a need to have a tailored package on the importance of preconceptions disseminated through various communication channels.

Figure 7.3: Teenagers who have begun childbearing.



Source: *Demographic Health Surveys STAT Compiler*

7.4.2. Pregnancy

The high prevalence of morbidity in pregnancy, low birth weight, and the highest new-born mortality causes and stillbirths attributed to antepartum causes presented in Chapter 3 of the thesis suggest the need for adequate and appropriate pregnancy interventions. Therefore, strengthening antenatal care services for proper screening of the risk factors and providing preventive services is crucial. While attending antenatal care visits creates the avenue for early identification of pregnancy danger signs and access to preventive intervention (Adam et al., 2005; Bhutta et al., 2009; Ghosh-Jerath et al., 2015; Haws et al., 2009; Lawn et al., 2009; Lincetto et al., 2013; Piso et al., 2014); usually, health facilities lack enough capacity to provide antenatal care services appropriately and adequately (Arsenault et al., 2018; Benova et al., 2018; Kanyangarara et al., 2017; Owili et al., 2019). Moreover, the services in the low-resource setting do not match the technological advancement. For instance, current effective technologies for screening pregnancies, such as ultrasound scanning, are not universal – they

What is known?

- *Foetal growth restriction is usually a consequence of maternal nutrition and morbidity in pregnancy.*
- *Early screening of pregnancy complications leads to access to appropriate lifesaving services.*
- *Current effective technologies for screening pregnancies are not universal.*

What do the thesis findings add?

- *The high prevalence of morbidity in pregnancy reported in Chapter 3 and low birth weight presented in Chapter 3 and 4 highlights the need for pregnancy preventive and screening interventions.*
- *The new-born mortality causes and stillbirths attributable to antepartum causes reported in Chapter 3 demonstrates the need for pregnancy interventions that identify, monitor, and manage high risky pregnant women.*

are usually in hospitals and urban specialized health facilities. Yet, such could be used to identify high-risk women, for instance, multiple births, fetal malposition and malpresentation. WHO recommends that every woman should have access to an ultrasound before 24 weeks gestation for gestational age estimation and detection of multiple pregnancies and fetal anomalies (WHO, 2016). Therefore, the health workers, particularly those in the rural communities, could be supported to provide advanced screening, for instance, ultrasound screening for examining maternal complications. Fortunately, there are portable and cost-effective ultrasound equipment in the market that have been tested to work well in low-resource settings.

Furthermore, we know that foetal growth restriction (small for gestation age and prematurity) is usually a consequence of maternal nutrition and morbidity in pregnancy. Therefore, interventions such as enhancing the community health workers' work to identify pregnant women and assess malnutrition at the community level may contribute to pregnancy interventions. Beyond community sensitization and mobilization, the community health workers could be used to identify the newly pregnant women, particularly those that the study identified to be at high risk of child mortality, and if they have attended antenatal care and need to be referred. Usually, women are uncertain about their pregnancy in the first trimester – contributing to the delays in accessing ANC services (Morroni & Moodley, 2006; Pell et al., 2013). Thus, early pregnancy tests have been indicated to increase early access to ANC services (Morroni & Moodley, 2006). However, these services are often not available in facilities close to the community. In their study, Comfort et al. 2019 indicate how community health workers could offer pregnancy tests in the community, which increased access to early ANC services (Comfort et al., 2019). Additionally, the community health workers may be involved in supporting women and their families in their birth preparedness and identifying women who may need extra support to ensure that required services have been addressed. The work of community health workers in supporting pregnant women has been widely documented in Uganda and other countries with similar contexts (Ekirapa-Kiracho et al., 2017; Nalwadda et al., 2013; Namazzi et al., 2017; Rutebemberwa et al., 2012; Waiswa et al., 2015).

Lastly, the findings on the high prevalence of morbidities in pregnancies and child mortality presented in Chapter 3 suggest interventions that target women, families, and the community with information on pregnancy and child danger signs that affect pregnancy outcomes and child survival as well as child well-being. The transmission of information can be through media such as radio, WhatsApp, telephone messages, and community health workers. Building on covid experience (Bashshur et al., 2020; Betancourt et al., 2020; Galle et al., 2021; Monaghesh & Hajizadeh, 2020; North, 2020; Reynolds, 2020; Smith et al., 2020), there is a need to leverage digital technologies for telemedicine or telediagnosis or telemonitoring and sensitizing the community on pregnancy danger signs. In fact, available research indicates how telehealth has been effective in reducing hypertension and obesity in pregnancy and

monitoring high-risk pregnancies (DeNicola et al., 2020; Ohannessian et al., 2020; Shannon et al., 2019; Van Den Heuvel et al., 2020; Xie et al., 2020).

7.4.3. Birth and postnatal

The largest share of perinatal and new-born mortality attributed to deaths within the first day of delivery that was presented in Chapters 3 and 4 highlights challenges of quality obstetric and new-born healthcare access. Stillbirth and new-born death due to intrapartum, preterm/low birth weight-related conditions and obstructed labour, including other unspecified perinatal conditions, emphasise the challenges of accessing quality care (Wall et al., 2010). Additionally, the problem of accessing appropriate health care services is further underscored in Chapter 4, which indicates the insignificant effect of health facility delivery on the association between low birth weight and perinatal mortality. Certainly, the delays or failures in accessing obstetric and child health care services highlight the community challenges. These challenges as comprehensively studied in Chapter 6 include financial costs associated with health facilities and transport, and an unresponsive health facility system. These results suggest concurrent interventions that empower women and health facilities to access and provide appropriate health care.

What is known?

- *The largest share of perinatal and new-born mortality in low resource settings occur within 24 hours of life*
- *Stillbirth and new-born death due to intrapartum and low birth weight related conditions result from poor healthcare services*
- *Access to appropriate health services is affected by both community and health facility services' system factors*
- *Enormous interventions that address health access barriers in low resource settings are known but usually not replicated.*

What do the thesis findings add?

- *The highest share of death within 24 hours of life presented in Chapter 4 indicates how the day of delivery remains critical period for addressing newborn mortality*
- *The insignificant inverse moderation effect of health facility deliveries on LBW survival reported in Chapter 4 highlights the health system challenges in addressing the highly risky new-borns.*
- *The existence of multiple factors that inhibit pregnant women and children from accessing adequate and appropriate healthcare services highlight the need for innovates approaches that address the identified barriers concurrently.*

First, building on the pregnancy interventions, the identified women with maternal danger signs and sick children should receive emergency care in highly equipped facilities. The key barriers to address that this study identified in Chapter 6 are poor referral transport systems at the community level and poor health facility services. Capitalising on existing social systems, the thesis suggests innovative ways of putting up a community transport system that should transport women and sick children to the health facilities at the community level. These may include financing

schemes and community transport schemes (Alaofe et al., 2020; Esssien et al., 1997; Nwolise et al., 2015). For instance, we know that there are already existing community schemes that could be leveraged to integrate emergency finances for obstetric and child health care services. These schemes can benefit from the government or donors' capital funds that could be conditioned to maternal and child health care transportation. Further, boda-boda riders are well known as key transporters in low-resource settings (Pariyo et al., 2011). In Chapter 6 of this thesis, I found that each family had contact with a *boda-boda* who could be contacted for transportation in case of an emergence. Thus, community transport can be enhanced by supporting the communities to have an organized transport system at the village level (Elmusharaf et al., 2015). Such could be embedded within the existing community groups with the fund set aside to maintain the community transport system. Chapter 6 indicated how providing vouchers to pregnant mothers contributed to health care services access. Enormous evidence indicates how health conditioned vouchers have improved access to health care services (Bellows et al., 2011; Bhatia & Gorter, 2007; Brody et al., 2013; Engmann et al., 2016; Grainger et al., 2014; Njuki et al., 2015; Potts, 2011; Rob et al., 2011). However, for sustainability, the distribution of these vouchers can be integrated within the existing social groups.

Second, in the view of the total market approach, Chapter 6 of the thesis identified drug shops and community health workers as important resources that should be leveraged to provide primary health care services. To optimise community health workers and drug shops' role in supporting child health care, they should be supported to provide quality care services. Such should be through integrating them within the health system with routine mentorship, training, and monitoring support. I also suggest mechanisms for accrediting and certifying the community drug shops that provide quality services and sensitising communities on the importance of accessing treatment from accredited and certified drug shops. Further, the paper also indicated how integrating triage, testing and treatment for malaria, diarrhoea and pneumonia within the community health workers' routine work improved access to health care services for children. This model complements the integrated community case management, whose enormous significant contribution has been extensively published (Awor et al., 2012; Kitutu, Kalyango, et al., 2017; Kitutu, Mayora, et al., 2017; Nanyonjo et al., 2019). Learning from available evidence of working with community drug shops and community health workers to test and treat common children's diseases in Uganda and similar context (Awor et al., 2012, 2014; Kitutu, Kalyango, et al., 2017; Kitutu, Mayora, et al., 2017; Nanyonjo et al., 2019; Valimba et al., 2014) there is need to extensively spread these interventions to cover all the district.

Lastly, there is a need to ensure the availability of essential emergency obstetric and childcare services at the first-level facilities. Learning from the past, strengthening maternal and child health care at the primary healthcare level was indicated as a key priority for achieving Millennium development goals (Bhutta, A. et al., 2008). The health facilities should be supported to respond to emergencies through proper medical procedures such as triage,

which may facilitate prompt and appropriate treatment as well as referral. Furthermore, simple yet effective interventions such as the use of partograph for labour progress, Apagar score assessment, and Kangaroo mother care for preterm/low birth weight children should be emphasized in lower health facilities.

7.4.4. Beyond birth and early postnatal

The shift in the causes of death, mortality and morbidity risk factors presented in Chapters 3-5 of the thesis highlight the need for age-specific health interventions. The continued high risk of suspected pneumonia, diarrhoea, and mortality up to the age of 3 years presented in Chapter 5 emphasises the need for a post-natal treatment and care package for mothers and health workers throughout the new-born life-course. In particular, these interventions should target children born as LBW, including multiple birth and those whose mothers or caretakers are adolescents. Some of the family and community level postnatal interventions include supporting economically disadvantaged women and families with a post-natal package that includes information on newborns' appropriate care practices, and routine monitoring throughout their infancy. Other post-natal interventions that should be given to children throughout their development stages are appropriate immunisation, maintaining good sanitation and hygiene, and proper parental care for injuries (Bhutta et al., 2013; Lassi et al., 2010; Rudan et al., 2007; Were et al., 2015).

What is known?

- *Postnatal remains the weakest of all reproductive and child health programmes in resource-poor settings.*
- *Interventions for targeting under-five children are well known but not universally implemented*
- *Evidence on the survival of children aged 5-10 in remain elusive.*

What do the thesis findings add?

- *The shift in the causes of death reported in Chapter 3 and risk factors reported in Chapter 3 and 4 suggest for the age specific interventions*
- *The high occurrence of common morbidities among under-3 aged children reported in Chapter 5 and the high effect of the mortality risk factors among the same groups reported in Chapter 3 show how 1000 days of life remains a critical period for child survival.*
- *The continued effect of mortality risk factors and occurrence of common morbidities among under-five aged children reported in Chapter 3 and 5 suggest for postnatal care packages including policies.*

Furthermore, we know that the laws governing access to maternity and paternity leave are weak. Usually, women have inadequate time to practice recommended interventions such as exclusive breastfeeding. Yet, maternal leave enables mothers to access appropriate healthcare services, recover from childbirth, and provide adequate care to their new-borns. We also know that other caretakers who look after children in their parents' absence are usually illiterate about proper childcare. As a result, children are usually exposed to feeding

before the recommended age, leading to low immunity and early exposure to infections that may lead to long-term consequences such as stunting. Although not sufficient, the government should strengthen the existing maternity leave employment policy (Government of Uganda, 2006) to make sure that all pregnant women and mothers who have recently delivered, working in formal and informal sectors, acquire adequate maternity leave to access appropriate services and practice recommended post-natal childcare services. The current Uganda employment policy articulates that:

> *A female employee shall, as a consequence of pregnancy, have the right to a period of sixty working days leave from work on full wages hereafter referred to as "maternity leave", of which at least four weeks shall follow the childbirth or miscarriage* (Government of Uganda, 2006).

However, such an employment act may not apply to those engaged in the informal sector. Furthermore, the government and civil society organizations can also invest in campaigns promoting maternity rights and breastfeeding practices at workplaces of work.

Additionally, while the mortality among children aged 5-9 years seemed lower, the thesis indicated that the group remains at the risk of getting sanitation and hygiene-related diseases and injuries. We know that usually, by the age of 5-6 years, almost all children are already in school and spend most of their time with the schoolteachers and caretakers. Therefore, the school is a big opportunity to improve the health of children by influencing health-related practices such as deworming, immunisation, handwashing behaviours and preventing injuries (Bhutta et al. 2013; Bundy et al. 2006; Luong 2010). The health and education sectors should collaborate to supervise schools regularly and ensure schools have a conducive environment for children. The school policy on promoting better health for children should be designed.

7.4.5. Implications for strengthening surveillance data

The use of the Iganga-Mayuge HDSS data has highlighted some of the important data collection gaps, which may strengthen data collections in DHSS sites. In particular, there is a need to strengthen the documentation of pregnancies, births, and perhaps migration. In addition, FPH has been recommended to provide better estimates than the FBH approach applied in the HDSS (Akuze et al., 2020). Since the DHS has considered having FPH as a core module in the subsequent phases (Demographic and Health Survey, n.d.), it is recommended that HDSS consider

What is known?

- *Stillbirths, birth weight, pregnancy gestation data remain a documentation challenge in HDSS*
- *HDSS have potential in linking health events to economic and behavioural indicators.*

What do the thesis findings add?

- *The problem in data collection such as inconsistences in stillbirths and newborns between verbal autopsy and birth registration and birth weight heaping shows the need for innovative ways of improving data quality.*

using the same approach for harmonisation and comparison. Additionally, the use of Iganga-Mayuge HDSS data has shown the potential of HDSS in monitoring health events, and economic and behavioural indicators in countries with limited national longitudinal data systems (Ngom et al., 2001). Given that health service interventions and events are time-conditional since the impact of services is a function of the timing of interventions and their timing relative to specific episodes of illness and seasonal patterns of morbidity, HDSS provide a unique opportunity for providing longitudinal household and population data that could be used to measure the possible correlations between social and economic status and health outcomes (Ngom et al., 2001). However, there is a need to support the HDSS on data interoperability and linkage of datasets of different levels: household and events registration, health service point, social and verbal autopsy.

Furthermore, given the weak civil and vital registration system in Uganda, there is a need for an innovative way of documenting birth and mortality based on available structures (Amouzou et al., 2013). Uganda has community health workers and local leaders at village levels who are part of the health systems and administrative structures. There is a need to optimise their work to report on birth events such as death and births. In addition to tracking mortality, morbidity and health service delivery, the community health workers could help track the vulnerable groups and ensure that the required health care has been received. The use of community health workers in collecting data on health events has been documented in various studies done in sub-Saharan Africa (Amouzou et al., 2015, 2014; Bryce et al., 2016; Joos, Amouzou, et al., 2016; Silva et al., 2016). Leveraging the existing technologies, the reporting can be linked to the national registration system through smartphone or text reporting. Available studies have indicated how leveraging text messaging to report health events through working with community representatives has been effective (Bangura et al., 2016; Bryce, 2016; Joos, Silva, et al., 2016; Nichols et al., 2019). Furthermore, based on their implementation learning (Amouzou et al., 2015, 2014; Bangura et al., 2016; Bryce, 2016; Bryce, Amouzou, et al., 2016; Joos, Amouzou, et al., 2016; Joos, Silva et al., 2016; Nichols et al., 2019; Silva et al., 2016), these reports also provide the recommendations for setting up effective community-based surveillance systems, that we can build on to strengthen the national civil and vital registration system.

7.4.6. Operationalising the implementation of suggested recommendations

It is important to note that the suggested recommendations are implemented at different levels: family, community, health facility and policy and decision-making levels. For the family, community, and facility-level implementation recommendations to be effective, there is a need for strengthening multisectoral planning and collaboration (Figure 7.4).

Figure 7.5: Operationalizing the implementation of suggested recommendations

Multisectoral and collaboration	**1. Strengthen intersectoral collaboration** **2. Involve multiple stakeholders that affect community structural, social, behavioural, and health services changes.** a. *Politicians* b. *district administration team and health facility managers* c. *Civil society and non-governmental organizations* d. *Transporters* e. *Cultural leaders*
Family	**1. Develop a surveillance system that maps out all pregnant women and children, including birth outcomes** **2. Identify the most vulnerable groups** • *Unmarried women* • *Married but not living with husbands* • *Poor families and those with unresponsible husbands* **3. Support vulnerable women to join social support** **4. Support integrated health campaigns targeting risky groups of women and families**
Community	• **Organise social support groups** • *Financial* • *Behavioural change* • *Transport* • **Ensure integrated community outreaches** • *Malnutrition mapping and management* • *Immunization including deworming* • *Sensitization* • *Family planning* • **Strengthen integrated community case management** • *Working with community health workers* • *Working with private clinics and drug shops* • **Implement health campaigns that address cultural values**
Health facility	**7. Ensure availability of resource** • *appropriate personal* • *financing (including operational and core funding)* • *availability of material resources (infrastructure, drugs, equipment)* *8.* **Ensure integrated health screening** *9.* **Enhance capacity building and task shifting** *10.* **Emphasise respectful care practices**

Source: Author

7.5. Further research

- *Care practices for low birth weight, including preterm and multiple birth:* Given the high burden of low birth weight and multiple births on child mortality, I recommend research on the burden of caring for low birth weight and multiple birth children. Additionally, I recommend more research on care practices for low birth weight and multiple birth children at community and health facility levels. Particularly for twins, there are traditional practices that are performed that usually inhibit the recommended new-born care practices, such as immediate breastfeeding and delayed bathing (Beattie, 1962; Mtaku, 2016). These studies will be important in designing a post-natal care package for children with low birth weight and multiple births children.
- *Regional distribution of low birth weight, including preterm:* I recommend studies on the geographical distribution of low birth weight and multiple births. In particular, there is a need to understand how regional birth weight estimates relate to other geographic-specific health indicators such as children and women stunting, malaria, diarrhoea and anaemia.
- *Obstetric and childcare practices in health facilities:* I recommend clinical studies that assess obstetric and childcare practices. While Chapter 6 tries to provide health facility-based hindrances that affect access to obstetric health care services, it leaves out health facilities' capacity in delivering services. Therefore, a comprehensive clinical study that assesses health facilities' capacity in terms of health workers' skills and availability of amenities that facilitate their performance is crucial. The assessment could focus on labour services, care for most at risk (for instance, women presenting shoulder dystocia, preterm), care for preterm and low birth weight children, and other essential care for new-borns, such as resuscitation.
- *Child health and care practices in an urban setting:* The study area was majorly rural, so I recommend studies focusing on maternal and child health care in purely urban areas (cities and towns). Notably, studies on understanding the people involved in caring for children and childcare practices are needed. We know that the urban health care system is composed of various players targeting specific groups of people. However, there is a paucity of information on the urban context's obstetric and child health care services' mechanism. Besides, the involvement of different groups of people in childcare and how they affect their health and survival in an urban context is elusive. In particular, the type and level of employment in an urban context can profoundly shape children's health at different levels of development.
- *Coverage of vouchers and subsidised maternal and child health interventions:* There is a need to understand the coverage of vouchers and subsidised maternal and child health interventions. Although these interventions are mainly designed to target the poor communities, the extremely poor families may be left out given the conditions of first paying for the voucher or services. Information on who could be left out and those benefitting and the mechanisms for generating money to purchase the vouchers

may contribute to the reframing of an inclusive voucher system. Such would also contribute to designing the upcoming health insurance scheme's packages to match the rural population's income.

7.6. Conclusion

In conclusion, the thesis has highlighted the critical and sensitive period for children to survive and has discussed age-specific (preconception, pregnancy, delivery, postnatal, infancy, and childhood) interventions that can be applied to improve the health and survival of children. The thesis findings underscore the importance of addressing social, structural, and health systems challenges throughout all stages of child development. *First,* the thesis has shown how Uganda has stagnated in reducing perinatal and newborn mortality and how death within 24 hours of life has remained a challenge. These results show the need for more efforts if Uganda is to achieve its commitment to reducing new-born and under-five mortality to less than 12% and 25%, respectively. The insignificant inverse effect of institutional delivery on newborn mortality gives us an insight into the need for strengthening the responsiveness of the health system in addressing new-born mortality. The key issues to address are the healthcare access barriers that include poor health facility services, poor referral transport systems, and women empowerment. *Second,* because of the association of low birth weight with adolescent age, the association of newborn mortality with advanced age and the association of mothers' childbirth experience with the birth outcome and child survival, the thesis recommends preconception interventions that prevent pregnancies among such high-risk groups. *Third,* the high prevalence of morbidity in pregnancy and low birth weight can be addressed through pregnancy preventive and screening interventions that are usually included in the antenatal care package.

Furthermore, to address death due to antepartum causes, the thesis recommends the need for strengthening community health systems to identify, monitor and refer high-risk pregnant women and use digital technologies for screening and prevention including behaviour change and follow-up. *Lastly,* the shift in the causes of death risk factors highlights the need for age-specific interventions and how the risk factors and morbidities remain high among children aged 0-3 years. Malaria and protein deficiency, including malnutrition, appear as the major causes of death with gastrointestinal and injuries emerging among the top mortality causes, suggesting health interventions that target the 5-10 age group.

For the optimal implementation of life-course approaches recommended in this thesis, key areas have been considered: task shifting, multisectoral approach, behavioural change innovations, referral systems, community health systems, and bringing and enforcing relevant policies from different sectors. Indeed, learning from Covid-19 responses, this approach might be the most effective in addressing maternal, reproductive, and child health services, including adolescent health. For instance, the fight against Covid-19 in countries that have succeeded was beyond biomedical interventions of treatment, in which promotive and preventive public health strategies were integrated. Globally, the fight against the pandemic

has required various stakeholders across disciplines to have collective goals and action plans of organizing, spreading, and implementing public health standards and supply of health personnel and amenities to the most deserving area. This approach is needed to address most of the challenges that affect health care access. For instance, we need the transport sector to improve the roads indicated to be critical in the women's movement to health facilities. We also need social service and legislative sectors to address social norms that affect human rights. The education and judicial systems should be revitalised to deliver interventions that contribute to delayed early pregnancies.

Notably, the pandemic taught the country leaders the need for a robust health system that is responsive. A responsive and trusted health system is composed of a robust, coordinated referral system and equipped health facilities in the form of staff and necessary amenities. Lastly, the monitoring and surveillance system optimised the digital technologies for early testing, contact tracing, diagnosis, and tracking of the spread by identifying hotspots.

In the context of maternal and child health and borrowing from Covid-19, digital technology can be applied for prompt birth and death registration, including causes of death at the community level. In fact, some platforms such as U-reporter, mTrack, educTrack, and FamilyConnect, all implemented by the Government of Uganda and UNICEF, have been indicated to be critical in prompt reporting community and health facility issues such as drug stock-outs and disease outbreaks (UNICEF - Webpage, n.d.-a). For instance, the FamilyConnect mobile phone application sends targeted lifecycle-based messages on maternal and child health to pregnant women and children's caregivers (UNICEF - Webpage, n.d.-b, n.d.-a). These should be optimised further for integrated health and economic events' reporting.

CHAPTER EIGHT
THESIS APPENDICES

8.1. Qualitative data collection tools

8.1.1. Interview consent form

Study title: Child health and survival in Uganda

Name of the Researcher: Kananura Rornald Muhumuza

Institution: Department of International Development, The London School of Economics and Political Science; and Department of Health Policy Planning and Management, Makerere University School of Public Health

Information for participants

Information about the study

Good/morning/afternoon. I am _____ and on this study I am working as_____. **Mr Kananura Rornald Muhumuza** is a study team leader and he is affiliated with Makerere University School of Public Health and London School of Economics and Political Science in the UK. The study is investigating the accessibility of maternal and health services – a cornerstone for child survival, with a focus on how the community and health facility factors contribute to child mortality in this community. This study will be conducted collecting information from women and health facilities from October 2018 to December 2018. This information sheet outlines the purpose of the study and provides a description of your involvement and rights as a participant if you agree to take part.

Participants' involvement

You are being asked to join because you are a recent newly delivered mother. We would want to seek your experience while pregnant and during labour. You will be asked questions related to the services received at the health facility and any other care you did for while pregnant and during delivery. You do not have to take part if you do not want to. You can withdraw at any point of the study, without having to give a reason. If any questions during the interview make you feel uncomfortable, you do not have to answer them, and you can withdraw from the interview at any time for any reason. Withdrawing from the study will have no effect on you. If you withdraw from the study, we will not retain the information you have given thus far unless you are happy for us to do so. However, we hope you will give us your time until the end because your views are crucial in improving maternal and child health services in this community. If you do decide to take part I will ask you to sign a consent form which you can sign and return in advance of the interview or sign at the meeting.

How information will be used

The collected information collected will contribute to the understanding of the maternal and child health services in Uganda and how such could be used to prevent the child mortality not only in Uganda but other countries.

Confidentiality

The records from this study will be kept as confidential as possible. Only me and my supervisor will have access to the files and any audio tapes. Your data will be anonymised – your name will not be used in any reports or publications resulting from the study. All digital files, transcripts and summaries will be given codes and stored separately from any names or other direct identification of participants. Any hard copies of research information will be kept in locked files at all times.

Participation reward

We will not pay you for your participation in the survey. However, at the end of the survey, we shall give you a non-monetary gift as an appreciation for your participation.

Addresses for questions or complaints

If you have any questions regarding this study, please contacts **Kananura Rornald Muhumuza** via: Email: mk.rornald@musph.ac.ug or r.m.kananura@lse.ac.uk, Tel: **UG-256705151722 or UK-447576682644**. In case of any concerns or complaints regarding the conduct of this research, please contact the **LSE Research Governance Manager** via research.ethics@lse.ac.uk Or **Dr Suzanne Kiwanuka** Makerere University School of Public Health Email. skiwanuka@musph.ac.ug, Tel: **256701888163 or 256312291397**

To request a copy of the data held about you please contact: glpd.info.rights@lse.ac.uk

If you are happy to take part in this study, please sign the consent sheet attached on the next page.

PARTICIPATION IN THIS RESEARCH STUDY IS VOLUNTARY.

Please tick the appropriate boxes	**Yes**	**No**
I agree to take part in the study		
I understand that I am free to decline to participate in this research study, or I may withdraw my participation at any point without penalty. My decision whether or not to participate in this research study will have no negative impacts on me either personally or professionally.		
I confirm that I have read and understood the information sheet provided for the above study. I have had the opportunity to consider the information and ask any questions I have.		
I understand that my data will be kept safe and will not be shared with anybody outside this study.		
I understand that my words may be quoted in publications, reports, web pages, and other research outputs.		
I agree to the interview being audio recorded		

Please retain a copy of this consent form.

Participant name:

Signature: _____ Date _____

Interviewer name:

Signature:_____ Date _____

For information please contact:

Kananura Rornald Muhumuza

Email: mk.rornald@musph.ac.ug or r.m.kananura@lse.ac.uk,

Tel: UG-+256705151722 or UK-+447576682644.

Dr Suzanne Kiwanuka

Institutional Review Board Chair,

Makerere University School of Public Health

Email. skiwanuka@musph.ac.ug,

Tel: 256701888163 or 256312291397

8.1.2. Focus Group Discussion interview guide for Women with children aged 6 moths-5 years.

Eligibility: The interview will be conducted with women with children aged 1-5 years. The group should not be more than 7 participants and less than 5.

1. What do you say about the health of women and children in this community?
2. How do pregnant women in this community access maternal services?
    a. Probe – let each participant talk about how she did access the maternal services for her current child
3. How sure were you that you and your child would survive during labour and why?
4. How do young children in this community access health services?
5. What are the common childhood diseases in this community?
    a. Probe – ask each participant to talk about the diseases that their children experienced
6. How are the diseases mostly treated and who are the people involved in the provision of treatment?
    a. Tell me what happened to your child when she/he fell sick (ask at least five group members to describe what treatment was given to the child and how, who was involved, and why)
7. Who are the people in this community that have authority over the health of women and children?
    a. How has the authority of such groups affected the health of women and children?
8. What is your view on the involvement of husbands in caring for their pregnant women?
    a. Probe for their experience while pregnant
9. What is your view on the involvement of women partners/husbands in caring for their care for children?
    a. Probe for each partners involvement in caring for children
10. As mothers, what has been your role in the health of your children?
11. How do women in this community care for children?
    a. Probe for how each mother in the group cared for the child
12. How is breastfeeding done in this community?
    a. Probe – for each of the participant to tell how she practices or practiced breastfeeding and for how long
13. Why do you think children die in this community?
14. How do you think the authority of different groups could have contributed to the death of children in this community?
    a. Family members authority
    b. Local leaders' authority
    c. Health workers authority
15. What do you think could not be working well in regard to the health of mothers and children in this community?
16. How have you been involved in making the health programming and decision making that could help your community?
17. What is your views concerning the health workers perception?

    Probe for:

    1. Respectful *(and why through scenarios)*

2. Disrespectful *(and why through scenarios)*
3. Listened to me and sought my views *(and why through scenarios)*

18. Whom would you blame for child mortality and poor health services in this community and why?

8.1.3. Key Informant Interview Guide for women who experience prenatal deaths

Individual ID	
Village	
Household GPS coordinates	

The Research Assistant must make sure that this is an eligible participant. The eligible participant is the woman who delivered in the last 4 months, and who experienced stillbirth or new-born death. The woman must be a resident of the HDSS and must have accessed services within the HDSS catchment area.

Is the participant eligible?
Yes [ ] No [ ]
If no, thank her and end the interview otherwise proceed with the consent form.

The Research Assistant must read a consent form in local language highlighting the objectives of the study, risks involved, benefits, and the responsible parties. The participant should be informed that her participation is voluntary and that she was chosen by chance. However, the participant will be given a non-monetary gift as an appreciation for her participation. Two copies of the consent forms should be signed, one for the researchers and the other for the participants. In the instance where the participant is not able to write, a thumbprint may be used.

Use the smartphone of tablet to capture the following information

Individual ID		
Village		
Household GPS coordinates		
Place of delivery		
Name of the health facility		
Marital status		
Education level		
Mothers age		
Maternal occupation		
Religion		
The position of the pregnancy (including miscarriage or abortion)		
Age of the last child the deceased follows		
Number of children		
Deceased age in days		
Deceased pregnancy gestation age		

Child MUAC indicator		
Mothers MUAC indicator		

1. Prenatal care seeking behaviours

The interview must inform the participant she will ask you questions related to the experience throughout her pregnancy. The following are the guiding questions.

1.1. How did you care for your pregnancy?

Probe

- Used traditional methods (herbs and any other means)
- Place (traditional birth attendant, family member, self)
- Sought care from the medical health centre

1.2. If she sought care from the medical health facility;

- what type of the facility *(Note that the community might consider a drug shop or nursing home as a health facility, the question should be asked to know which category of the facility).*
- When you went to the health centre, what did the health provider tell you about your pregnancy and what kind of services did you receive
- how do would describe the services and why
- how many times did you go to the health facility while pregnant?

1.3. If the woman never sought care from the health facility, ask for the reasons?

1.4. Ask if the woman sought care from traditional or a community or family member?

Probe

- What kind of care did you receive?
- What forms of traditional medicine did you take, for how long and why?
- how would you describe the services received from the traditional attendant and why?

1.5 In this community, who are the people that have authority over the health of women and children? (list all the people involved in the health of women and children).

Probe to make sure to check if the following categories have authority in case there are not mentioned

1. Husband
2. Parents (In-laws, and women parents)
3. Sisters and brothers (In-laws and mothers' side)
4. Local leaders
5. Community health workers
6. Community transporters
7. Traditional healers
8. Etc

1.6 For each of the group's category mentioned (check the list) how could they have contributed to the health of your pregnancy?

1. Husband
2. Parents (In-laws, and women parents)
3. Sisters and brothers (In-laws and mothers' side)
4. Local leaders

5. Community health workers
6. Community transporters
7. Traditional healers
8. Etc

1.8 In this community, what kind of traditional and cultural aspects do pregnant women do to keep healthy and deliver healthy children? (Use of traditional medicine, what type, who provide, and at what cost)

1.9 Could you tell me what the traditional and cultural aspect you did to keep your recent pregnancy and child healthy? (Let the woman describe on how it was done, from where and at what cost).

1.10 How did your family members or partner support you while pregnant?

1.11 How were you able to do household chores?

Probe

- what kind of work did you do throughout your pregnancy?

1.12 How did you prepare for the birth of the deceased?

2 Skilled assisted delivery and postnatal care access

The interviewer must inform the participant that she will be asked questions related to the experience throughout her labour and delivery experience

2.8 In this community, what are traditional and cultural practices that are done to quicken the labour progress?

2.9 For each of the practice, ask the woman to mention the people and the cost involved?

2.10 Did you take any medicine to quicken labour progress? If yes, where did you get it from, what was the name, how was it taken and for how long?

2.11 Tell me a story about your labour and delivery experience *(The story should capture on how the **labour started** including the **time the labour started**, **the time she left home,** to all places where you went for care. **Note that**, for each place, let her estimated time of arrival, the time took at the place)*

Probe

- Who was involved in deciding where to go (Husband, family member, Transporter)
- Let the woman ask if she was aware of where she was going and if she was involved in the decision
- When you reached the place of delivery, what was your experience *(health provider response, had she developed any complications, was the health provider timely available. Note that this question should be asked for each of the places where the woman went)*
- How were you handled at the place (each) were you sought care? Let the woman describe the treatment and care received at each place
- At the place of delivery, what services did you receive to help the baby and you survive?
- How was the delivery conducted?

2.12 What do you think could have resulted to the death of the child?

- The baby was to small (preterm/low birth weight)
- The baby was too big

- Health workers negligence
- Delays in reaching the health facility
- Others

2.13 What is your views concerning the health workers perception?
Probe for:

4. Respectful *(and why through scenarios)*
5. Disrespectful *(and why through scenarios)*
6. Listened to me and sought my views *(and why through scenarios)*

2.14 How did you travel from home to (each) place of delivery?

2.15 Why do you think sometimes women refuse to deliver in health facilities?

2.16 Could you share with me the experience you had at the health facility from the time you reached the gate, to the time you exited (Let the woman explain the time reception received by Security guards, receptionist, health workers, congestion on the facility and general environment (light, sanitation etc))

3 Care for the new-born practices

The participant will be asked on how the new-born was cared for immediately after birth while at the place of delivery and henceforth

3.8 What happened to the new-born immediately after delivery?

3.9 What were you told about the health of the new-born?
Probe

- The New-born had a problem with breathing
- The new-born was low-birth-weight or premature
- The New-born was very big

3.10 What was done at the place of delivery regarding the health conditions of the new-born?

3.11 How much time did you spend at the health facility and what did the health worker tell you before leaving?

3.12 In this community, what are some of the traditional and cultural things that are done for new-born immediately after birth to improve their health? Probe for Bathing, applying something on the umbilical cord, delayed breastfeeding, feeding the child with some other things (let her mention) etc?

3.13 For the traditional and cultural practices mentioned above, what was done on the child immediately after birth to improve its health?

1. Immediate bathing with traditional herbs
2. Applying traditional substances on the umbilical cord
3. Delayed breastfeeding
4. Fed the child with traditional herbs,
5. Anything else

3.14 Who was involved in the practice of the mentioned traditional and cultural practices? (For each of the practice done, let the woman mention the person involved)

3.15 Was there anything wrong with the cord? what was that and how was it cared?

3.16 Tell the experience you went through while caring for your child before death

Probe

- Did a child develop any complication and at what age?

- Tell what was done to treat the child and who provided the treatment?
- Did you seek care from the health facility, if yes at what stage did you go to the health facility?
- What traditional ways or medicine did you apply before taking the child to the hospital?
- If you did not go to the health facility, why?

3.17 Whom would you blame for child mortality and poor health services in this community and why?

4: Community sensitization

1. How do you get information regarding maternal and child health in this community?
   1.1. Health workers
   1.2. Community health workers
   1.3. Media (radio, etc)
   1.4. Community dialogue meetings
2. Probe ask the woman if she has ever heard of information regarding maternal health and let her mention, the sources, type of information and how she participated?

8.1.4. Ethics – LSE approval letter

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www.lse.ac.uk

Research Division

Rornald Kananura
Department of Social Policy
r.m.kananura@lse.ac.uk

25th June 2018

Dear Rornald

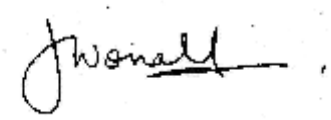
Re: 'Child health and survival in Uganda: an application of system thinking' [REC ref. 000731]

I refer to the above research proposal which you recently submitted for review by the Research Ethics Committee. Having considered your ethics review application and supporting documents, I am satisfied that you have properly addressed the ethical issues raised by your proposed research. I am thus able in my capacity as Chair of the Committee to approve the application. Please note, however, that ethics approval is contingent upon approval of the travel outline/risk assessment by the Health and Safety team for the individual researchers.

Please note that any significant changes to the research design must be reported to the Research Ethics Committee. Amendments to the research design that may affect participants and/or that may have ethical implications must be reviewed and approved by the Research Ethics Committee before commencement (or recommencement) of the project. The Research Ethics Committee may periodically conduct a selective audit of current research projects.

I would like to take this opportunity to wish you well with your research project.
If you have any further queries, please feel free to contact Lyn Grove, Research Division.

Yours sincerely,



Professor John Worrall
Chair of the Research Ethics Committee

cc. Dr Lyn Grove, Research Division

8.1.5. Ethics – Uganda National council for Science and Technology approval letter

Uganda National Council for Science and Technology

(Established by Act of Parliament of the Republic of Uganda)

Our Ref: HS395ES **6th August 2019**

Mr. Kananura Muhumuza
Principal Investigator
Makerere University Kampala
Kampala

Dear Mr. Muhumuza,

I am pleased to inform you that on **06/08/2019**, the Uganda National Council for Science and Technology (UNCST) approved your study titled, **Child Health and Survival in Central Eastern Uganda**. The Approval is valid for the period of **06/08/2019** to **06/08/2020.**

Your study reference number is **HS395ES**. Please, cite this number in all your future correspondences with UNCST in respect of the above study.

Please, note that as Principal Investigator, you are responsible for:

1. Keeping all co-investigators informed about the status of the study.
2. Submitting any changes, amendments, and addenda to the study protocol or the consent form, where applicable, to the designated local Research Ethics Committee (REC) or Lead Agency, where applicable, for re-review and approval prior to the activation of the changes.
3. Notifying UNCST about the REC or lead agency approved changes, where applicable, within five working days.
4. For clinical trials, reporting all serious adverse events promptly to the designated local REC for review with copies to the National Drug Authority.
5. Promptly reporting any unanticipated problems involving risks to study subjects/participants to the UNCST.
6. Providing any new information which could change the risk/benefit ratio of the study to the UNCST for final registration and clearance.
7. Submitting annual progress reports electronically to UNCST. Failure to do so may result in termination of the research project.

Please, note that this approval includes all study related tools submitted as part of the application.

Yours sincerely,

Hellen Opelot
For: Executive Secretary
UGANDA NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

LOCATION/CORRESPONDENCE

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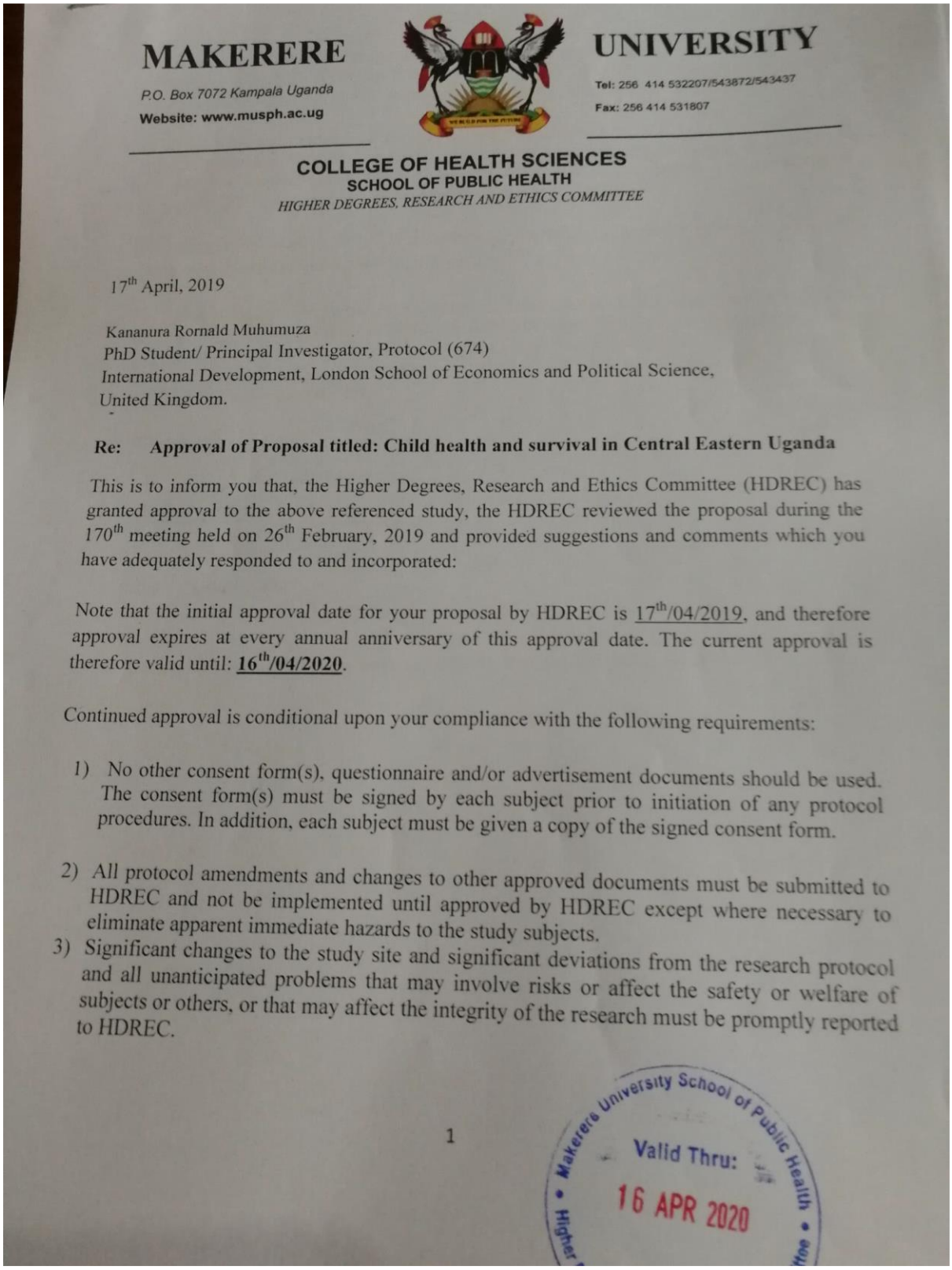
FAX: (256) 414-234579
EMAIL: info@uncst.go.ug
WEBSITE: http://www.uncst.go.ug

8.1.6. Ethics – Local Institutional Review Board approval letter



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COLLEGE OF HEALTH SCIENCES
SCHOOL OF PUBLIC HEALTH
HIGHER DEGREES, RESEARCH AND ETHICS COMMITTEE

17th April, 2019

Kananura Rornald Muhumuza
PhD Student/ Principal Investigator, Protocol (674)
International Development, London School of Economics and Political Science,
United Kingdom.

Re: Approval of Proposal titled: Child health and survival in Central Eastern Uganda

This is to inform you that, the Higher Degrees, Research and Ethics Committee (HDREC) has granted approval to the above referenced study, the HDREC reviewed the proposal during the 170th meeting held on 26th February, 2019 and provided suggestions and comments which you have adequately responded to and incorporated:

Note that the initial approval date for your proposal by HDREC is 17th/04/2019, and therefore approval expires at every annual anniversary of this approval date. The current approval is therefore valid until: **16th/04/2020**.

Continued approval is conditional upon your compliance with the following requirements:

1) No other consent form(s), questionnaire and/or advertisement documents should be used. The consent form(s) must be signed by each subject prior to initiation of any protocol procedures. In addition, each subject must be given a copy of the signed consent form.

2) All protocol amendments and changes to other approved documents must be submitted to HDREC and not be implemented until approved by HDREC except where necessary to eliminate apparent immediate hazards to the study subjects.
3) Significant changes to the study site and significant deviations from the research protocol and all unanticipated problems that may involve risks or affect the safety or welfare of subjects or others, or that may affect the integrity of the research must be promptly reported to HDREC.

1

Makerere University School of Public Health
Valid Thru:
16 APR 2020

4) All deaths, life threatening problems or serious or unexpected adverse events, *whether related to the study or not,* must be reported to HDREC in a timely manner as specified in the National Guidelines for Research Involving Humans as Research Participants.

- Please complete and submit reports to HDREC as follows:

a) For renewal of the study approval – complete and return the continuing Review Report – Renewal Request (Form 404A) at least 60 days prior to the expiration of the approval period. The study cannot continue until re-approved by HDREC.

b) Completion, termination, or if not renewing the project – send a final report within 90 days upon completion of the study.

- Finally, the legal requirement in Uganda is that all research activities must be registered with the National Council of Science and Technology. The forms for this registration can be obtained from their website www.uncst.go.ug. Please contact the REC Administrator at wtusiime@musph.ac.ug or telephone number (256)-393 291 397 or +256772496136 if you encounter any problems.

Yours sincerely

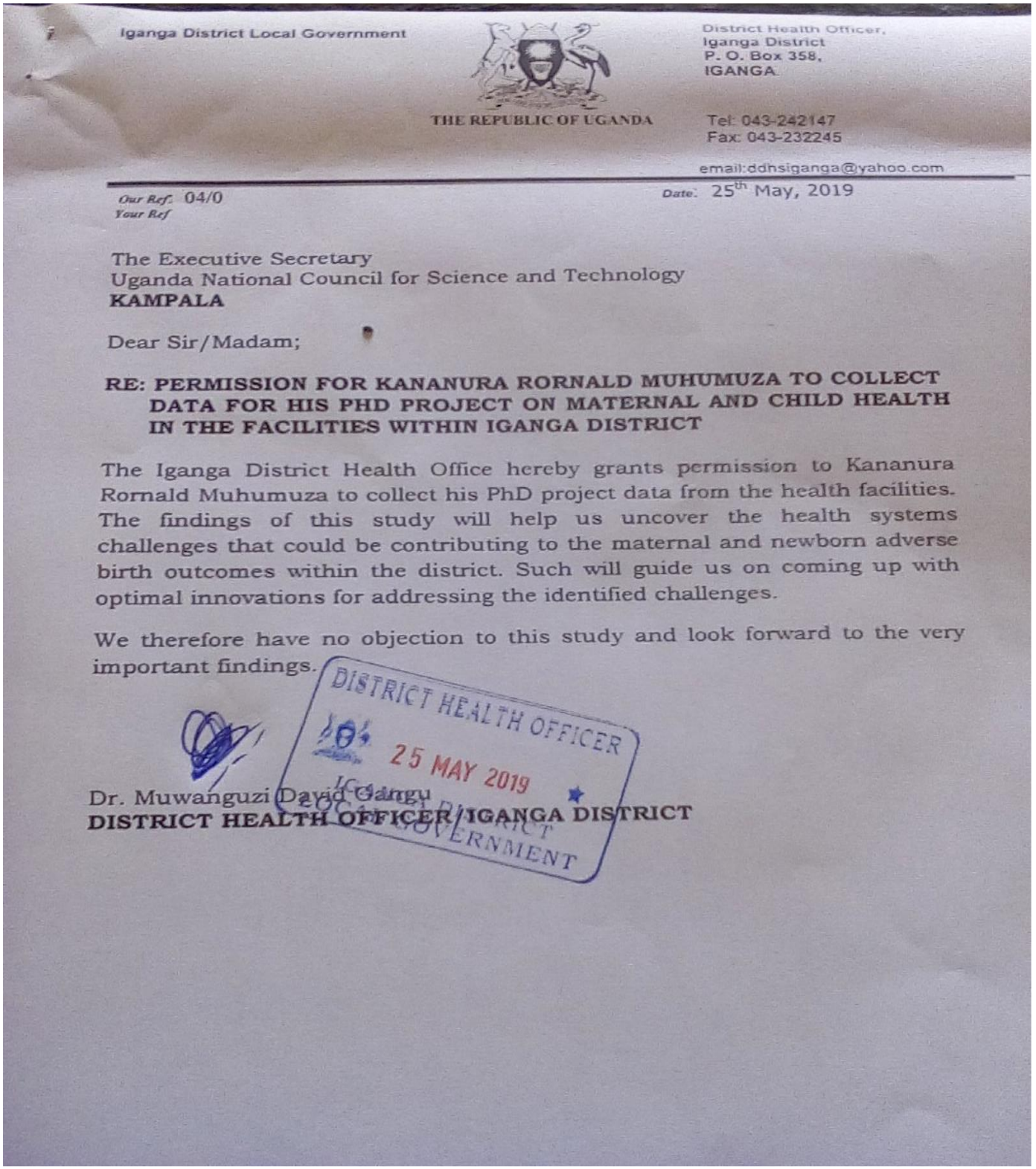
Makerere University School of Public Health
Valid Thru:
16 APR 2020
Higher Degrees, Research and Ethics Committee

Dr. John C. Ssempebwa
Ag. Chairman: Higher Degrees, Research and Ethics Committee

Enclosures:

a) A stamped, approved study documents (informed consent documents):

8.1.7. Ethics – Iganga District approval letter



Iganga District Local Government

THE REPUBLIC OF UGANDA

District Health Officer,
Iganga District
P. O. Box 358,
IGANGA

Tel: 043-242147
Fax: 043-232245

email:ddhsiganga@yahoo.com

Our Ref: 04/0
Your Ref

Date: 25th May, 2019

The Executive Secretary
Uganda National Council for Science and Technology
KAMPALA

Dear Sir/Madam;

RE: PERMISSION FOR KANANURA RORNALD MUHUMUZA TO COLLECT DATA FOR HIS PHD PROJECT ON MATERNAL AND CHILD HEALTH IN THE FACILITIES WITHIN IGANGA DISTRICT

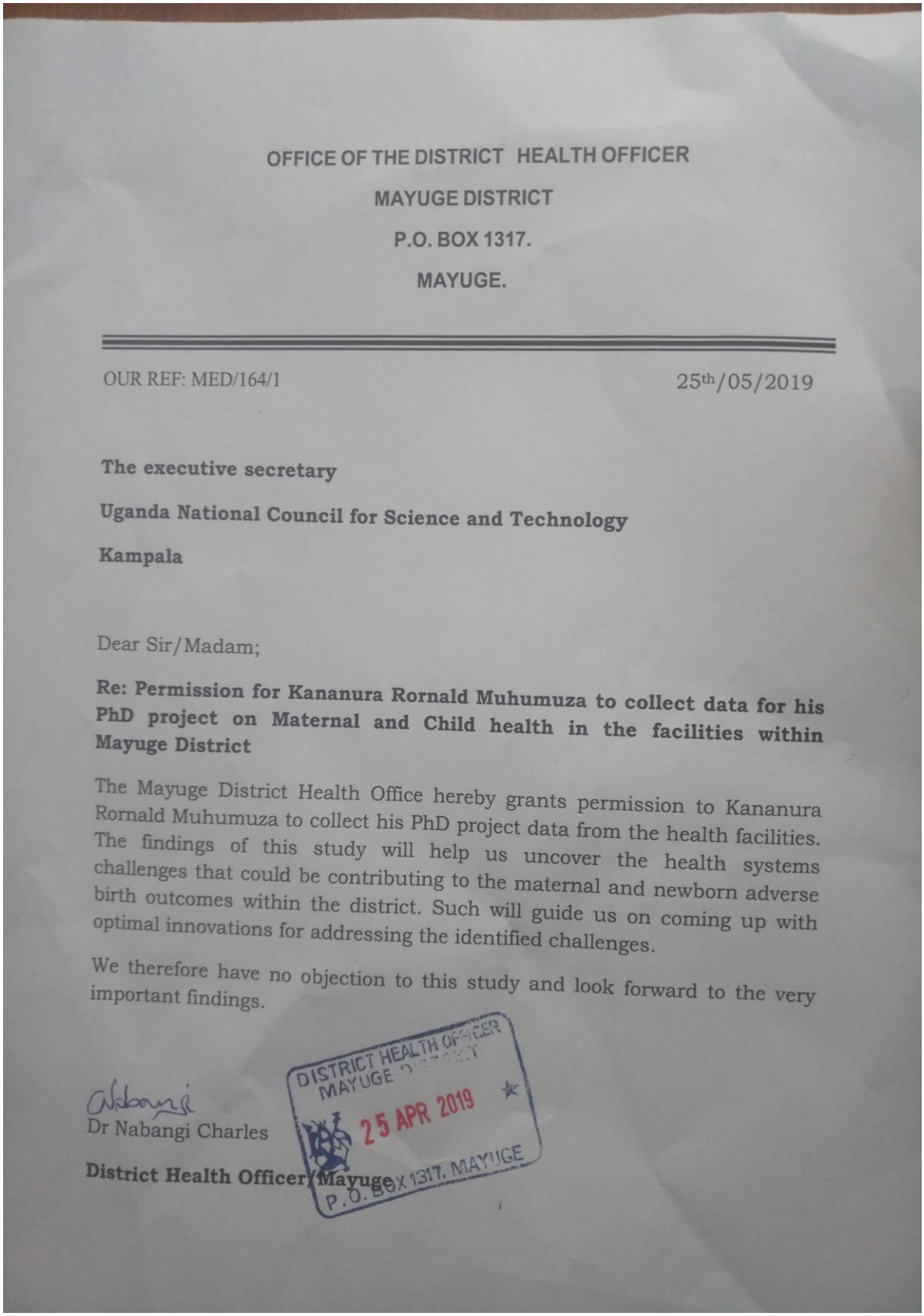
The Iganga District Health Office hereby grants permission to Kananura Rornald Muhumuza to collect his PhD project data from the health facilities. The findings of this study will help us uncover the health systems challenges that could be contributing to the maternal and newborn adverse birth outcomes within the district. Such will guide us on coming up with optimal innovations for addressing the identified challenges.

We therefore have no objection to this study and look forward to the very important findings.

DISTRICT HEALTH OFFICER
25 MAY 2019
IGANGA DISTRICT
LOCAL GOVERNMENT

Dr. Muwanguzi David Gangu
DISTRICT HEALTH OFFICER/IGANGA DISTRICT

8.1.8. Ethics – Mayuge district approval letter



OFFICE OF THE DISTRICT HEALTH OFFICER

MAYUGE DISTRICT

P.O. BOX 1317.

MAYUGE.

OUR REF: MED/164/1 25th/05/2019

The executive secretary

Uganda National Council for Science and Technology

Kampala

Dear Sir/Madam;

Re: Permission for Kananura Rornald Muhumuza to collect data for his PhD project on Maternal and Child health in the facilities within Mayuge District

The Mayuge District Health Office hereby grants permission to Kananura Rornald Muhumuza to collect his PhD project data from the health facilities. The findings of this study will help us uncover the health systems challenges that could be contributing to the maternal and newborn adverse birth outcomes within the district. Such will guide us on coming up with optimal innovations for addressing the identified challenges.

We therefore have no objection to this study and look forward to the very important findings.

DISTRICT HEALTH OFFICER MAYUGE DISTRICT 25 APR 2019 P.O. BOX 1317. MAYUGE

Dr Nabangi Charles

District Health Officer/Mayuge

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