RWANDA FURTHER ANALYSIS

Trends in Neonatal Mortality in Rwanda, 2000–2010

Further Analysis of the Rwanda Demographic and Health Surveys

Republic of Rwanda

Trends in Neonatal Mortality in Rwanda, 2000-2010

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Additional information about the RDHS can be obtained from the National Institute of Statistics of Rwanda, P.O. Box 6139, Kigali, Rwanda; Telephone: (250) 571-037, E-mail: info@statistics.gov.rw, Internet: www.statistics.gov.rw. Additional information about the DHS project may be obtained from ICF International, 11785 Beltsville Drive, Calverton, MD 20705, USA; Telephone: 301-572-0200, Fax: 301-572-0999, Email: reports@measuredhs.com, Internet: http://www.measuredhs.com.

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ABSTRACT

This further analysis examines levels, trends, and determinants of neonatal mortality in Rwanda, using data from the 2000, 2005, and 2010 Rwanda Demographic and Health Surveys (RDHS). The analysis begins with estimates of the neonatal mortality rate (NMR), overall and within each category of selected potential predictors of neonatal death, in the five years preceding each survey. Multivariate log probability models are then used to determine whether key indicators are independently associated with neonatal mortality in Rwanda, after adjusting for socio-demographic factors that could confound the association. Finally, multivariate decomposition procedures are used to determine the extent to which each selected indicator contributes to the observed reduction in neonatal mortality.

Between 2000 and 2010 a dramatic decline in under-five mortality in Rwanda was accompanied by a more modest reduction in the NMR. The improvement in the NMR was largely concentrated in rural areas, where coverage of maternal and delivery care services has increased most, with little improvement in urban areas, where coverage was already more widespread. This suggests that the improvement in NMR was driven by an increase in coverage of maternal and delivery care services, rather than an improvement in quality of care for those receiving services. The decomposition findings point to this same conclusion—that the reduction in NMR was driven by changes in the coverage of maternal and delivery care services and changes in the distribution of certain socio-demographic characteristics, rather than by changes in the effect of the interventions per capita. This finding highlights the need to build on the success in expanding coverage by paying increased attention to the quality of services, to ensure that their full benefits are realized.

The study identified several key indicators of maternal care and other interventions with improved coverage between the 2000 and 2010 DHS surveys, including delivery by a health professional, delivery in a facility, use of antenatal care (ANC) services, early initiation of breastfeeding, and mosquito net ownership. Three of these indicators—use of ANC services, early initiation of breastfeeding, and mosquito net ownership—were found to be associated with lower probabilities of neonatal death, after adjusting for socio-demographic factors.

The decomposition results provide further evidence that the increase in household mosquito net ownership, in particular, was significantly associated with the reduction in neonatal mortality in Rwanda, both between the 2000 and 2010 surveys and between the 2005 and 2010 surveys. Even after controlling for socio-demographic characteristics and the mother's use of maternal care services, mosquito net ownership remained independently associated with the reduction in neonatal mortality. This finding reinforces the importance of consistent and universal mosquito net use in areas with high prevalence of malaria.

ACRONYMS

ANC	Antenatal care
ACT	Artemisinin-based combination therapy
ASM	Agents de Santé Maternelle
BMI	Body mass index
CBHI	Community-based health insurance
CCM	Community case management
CHW	Community health worker
CPR	Contraceptive prevalence rate
CI	Confidence interval
DHS	Demographic and Health Surveys
HIV	Human immunodeficiency virus
IMR	Infant mortality rate
ITN	Insecticide-treated net
LLIN	Long-lasting insecticide-treated net
MDG	Millennium Development Goal
MOH	Ministry of Health
NISR	National Institute of Statistics of Rwanda
NMR	Neonatal mortality rate
PBF	Performance-based financing
PMI	President's Malaria Initiative
PMTCT	Prevention of mother-to-child (HIV) transmission
IPTp	Intermittent presumptive treatment for malaria in pregnancy
RAMA	La Rwandaise d'Assurance Maladie
RDHS	Rwanda Demographic and Health Survey
RR	Risk ratio
STI	Sexually-transmitted infection
TT	Tetanus toxoid
U5M	Under-five mortality
USAID	United States Agency for International Development

1. INTRODUCTION

1.1 Rationale for This Study

Rwanda has experienced a dramatic decline in under-five mortality since 2000. As is typically observed in other countries when overall levels of under-five mortality decrease, most of the improvement has been after the first month of life. As a result, the proportion of under-five deaths that occur during the first month of life—that is, neonatal deaths—has increased. To continue making gains in child survival in Rwanda, it has become increasingly important to understand and address the unique determinants of neonatal mortality, and to identify which interventions are effective in promoting neonatal survival.

This further analysis examines levels, trends, and determinants of neonatal mortality in Rwanda, using data from the 2000, 2005, and 2010 Rwanda Demographic and Health Surveys (RDHS). The findings are intended to inform ongoing neonatal survival programs and help allocate future resources.

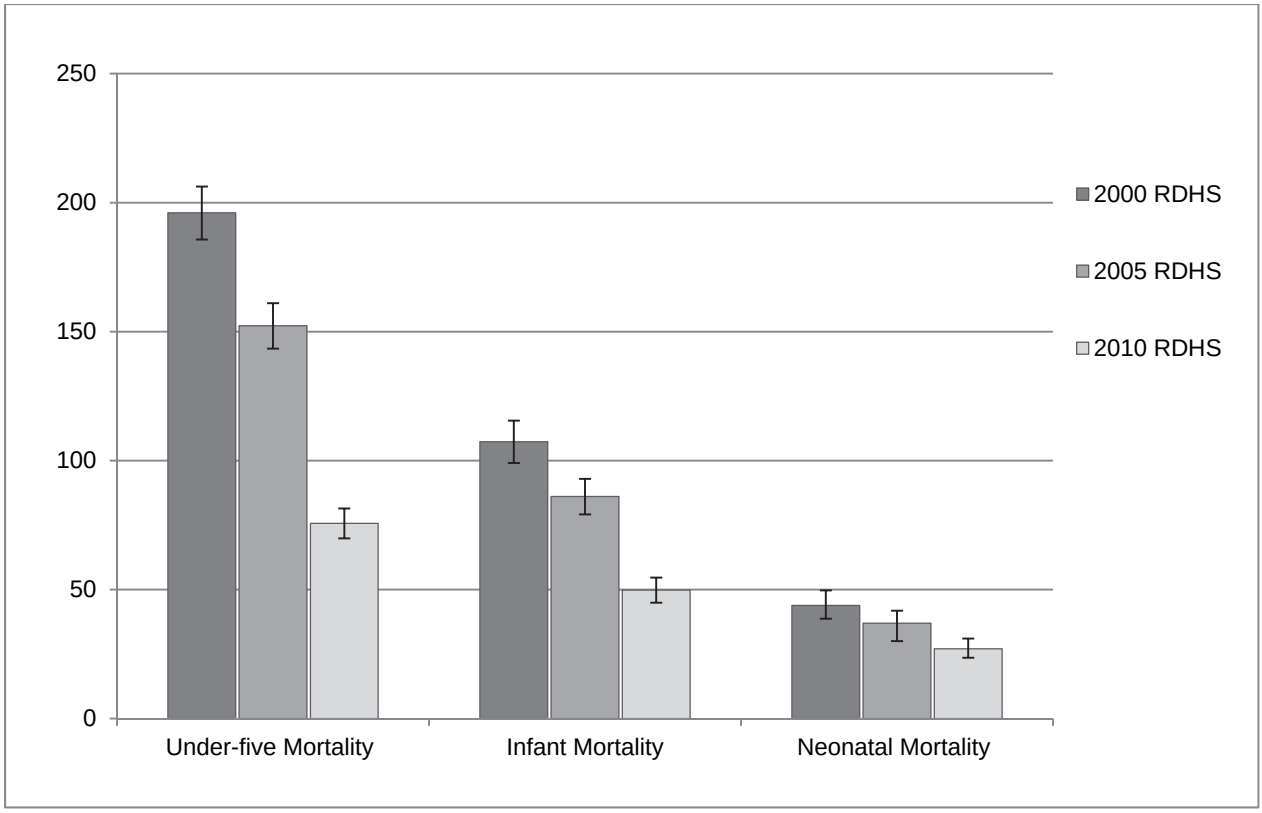
Chapter 1 provides background information on causes of neonatal mortality, as well as an overview of key health interventions underway in Rwanda that could affect neonatal survival. Chapter 2 describes the data and the methodology of the study, defines all variables, and presents study limitations. Chapter 3, on results, has four sections: first, trends in the prevalence of potential determinants of neonatal mortality between 2000 and 2010; second, neonatal mortality rates (NMRs) disaggregated by each selected determinant; third, log probability models to identify which of these potential determinants are independently associated with neonatal mortality; and fourth, findings from a multivariate decomposition analysis to determine which indicators are significantly associated with the observed decline in neonatal mortality. Chapter 4 provides overall conclusions and policy implications.

1.2 Background

Millennium development goal four (MDG 4) established the target of a two-thirds reduction in under-five mortality between 1990 and 2015. Global estimates from 2010 show that approximately 40% of all deaths to children under age 5 occur during the neonatal period, although in regions with higher child mortality neonatal deaths account for a somewhat lower percentage (Liu et al. 2012). In Africa, for example, an estimated 30% of childhood deaths in 2010 occurred in the neonatal period. Many countries have made progress in reducing deaths among children under age 5, but these gains have been predominantly among children age 1-4. Far less progress has been made in reducing the mortality risk for children under age 12 months, especially for neonates, in the first month of life. As a result, as total under-five morality decreases, the proportion of those deaths that occur during the neonatal period increases (Lawn, Cousens, and Zupan 2005).

Between the 2000 and 2010 RDHS, under-five mortality fell substantially in Rwanda. The under-five mortality rate in the five years preceding the 2000 RDHS was 196 deaths per 1,000 live births, and a decade later the rate had fallen to 76 deaths per 1,000 live births in the five years preceding the 2010 RDHS. Using DHS surveys and other evidence, the UN Inter-agency Group for Mortality Estimation calculated an average annual rate of reduction of 5.1% in under-five mortality in Rwanda from 2000 to 2011, compared with 2.4% in sub-Saharan Africa as a whole, putting Rwanda on track to be one of the few sub-Saharan countries to achieve MDG 4 (You, New, and Wardlaw 2012).

Figure 1.1. Under-five, infant, and neonatal mortality rates for five-year intervals preceding the survey, Rwanda 2000, 2005, and 2010

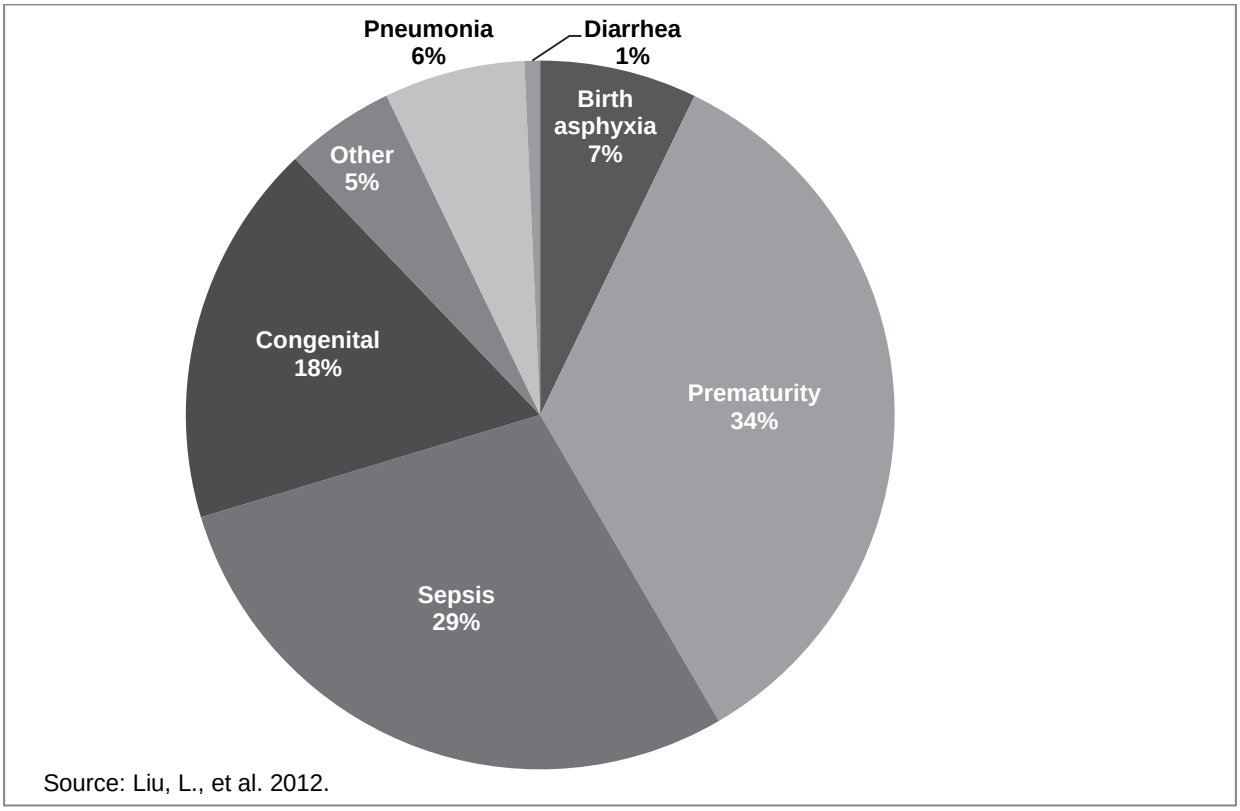


Consistent with the pattern described, the reduction in under-five mortality in Rwanda has resulted primarily from fewer deaths occurring after the first month of life (see Figure 1.1). There was a much more modest reduction in the probability of dying during the first month of life. While in 2000 an estimated 22% of under-five deaths occurred in the first 28 days of life, by 2010 that percentage had increased to 34% (Liu et al. 2012). In order to continue making improvements in under-five mortality in Rwanda, the focus needs to include the unique, complex causes of neonatal death.

Causes of neonatal death

Approximately three-quarters of neonatal deaths take place in the first seven days of life (Lawn et al. 2005). Unlike older children, who often die of infections, newborns most often suffer from complications of preterm birth, intrapartum-related complications (such as birth asphyxia), and congenital conditions. After the first week, sepsis and other infections play a major role during the first month of life. Figure 1.2 summarizes the causes of neonatal mortality in Rwanda (Liu et al. 2012). (See Table A.1 for the distribution of neonatal deaths by age at death in days and by survey year in Rwanda.)

Figure 1.2. Causes of neonatal death in Rwanda, 2010 estimates



Source: Liu, L., et al. 2012.

Table 1.1 describes the most common direct causes of neonatal death globally (Liu et al. 2012), and the most commonly recommended interventions at the community/family, health facility, and policy levels (Darmstadt et al. 2005, Partnership for Maternal Newborn & Child Health 2011). The table does not include the indirect causes of neonatal mortality, of which low birth weight is the most important, leaving newborns more vulnerable to infection and other stressors. Low birth weight is often closely related to prematurity, but can also be caused by complications in babies born at term, such as intrauterine growth restriction (Blencowe et al. 2012). In sub-Saharan Africa low-birth-weight infants are three times more likely to die before reaching age 1, and nine times more likely to die in the first month of life compared with infants born with a normal weight (Guyatt and Snow 2001).

Factors contributing to low birth weight include infections such as malaria and HIV, short birth intervals, poor maternal nutrition, the mother's age (under age 18 or over age 34), and smoking and alcohol abuse. The incidence of low birth weight would be reduced by many of the same interventions aimed at addressing the direct causes of neonatal death: prevention or screening and effective treatment for infection or anemia; early detection of problems and risk factors during the pregnancy; counseling for pregnant women on nutrition and self-care; and family planning to prevent unwanted pregnancies among adolescents and older women and to ensure optimal birth spacing (Lawn et al. 2005).

Table 1.1. Causes of neonatal mortality and globally-recommended interventions

Category/cause of mortality	Community/family interventions	Health service interventions	Policy/health system interventions
Intrapartum-related complications (birth asphyxia)	birth preparedness planning, demand for skilled delivery services, rapid transportation or "waiting homes"	24-hour skilled care, including C-section, newborn resuscitation, thermal care	assure financial and geographic accessibility of services, general health system strengthening (ensure adequate human resources for health, hold providers accountable for quality, infrastructure, and supply chain)
Preterm birth complications	delay of first pregnancy, maternal nutrition, optimal birth spacing, kangaroo care, breastfeeding	eclampsia and pre-eclampsia prevention, intermittent presumptive treatment for malaria, detection and treatment of asymptomatic bacteriuria, antenatal steroids, PMTCT	above, plus provide access to family planning services, ensure services are accessible to adolescents
Sepsis/ meningitis/ tetanus	demand for ANC, breastfeeding, clean home delivery, handwashing, hygienic cord care, thermal care	immunization, antibiotics for premature rupture of membranes, support for early and exclusive breastfeeding, postnatal evaluation	same as for intrapartum-related complications, plus support for community-level interventions
Congenital abnormalities	self-care behaviors (smoking, alcohol)	folic acid	support for community-level interventions, food fortification
Other neonatal disorders (including severe malnutrition)	early and exclusive breastfeeding, support for improved nutrition of mother	support for early and exclusive breastfeeding, postnatal care	support for community-level interventions
Pneumonia	care seeking for sick newborns, community case management of pneumonia	facility supervision of CHWs, integrated management of childhood illness	support for community-level interventions, community case management
Diarrhea	care seeking for sick newborns, exclusive breastfeeding, handwashing and other hygiene behaviors	facility supervision of CHWs, integrated management of childhood illness, routine immunization against Rotavirus	support for community-level interventions, community case management

Source: Table compiles information from Darmstadt et al. 2005, Liu et al. 2012, and Partnership for Maternal Newborn & Child Health 2011.
Note: Not all interventions included in this table are recommended or being implemented in Rwanda.

1.3 Health Policy Interventions in Rwanda

In the years since the 1994 genocide, the government of Rwanda has made a strong commitment to improving the lives of its people. It has worked to improve access, quality, and utilization of health services through a variety of policies and strategies, many of which have contributed to the decline in under-five mortality. While most Rwandans are still poor and depend largely on farming for their livelihood, the economy has grown rapidly. Health systems management functions have been decentralized and efforts have been made to distribute facilities geographically, although given limited public transportation, physical access to health facilities remains a challenge (Huerta Munoz and Kallestal 2012).

This report focuses on specific policy and programmatic initiatives that can be linked to improved health outcomes for newborns. Between 2000 and 2010 the most significant relevant policy interventions undertaken in Rwanda include 1) a national reproductive health policy emphasizing family planning and maternal health care services; 2) the implementation of performance-based financing at the facility level to improve the quality of services; 3) the creation of a community-based health insurance system to reduce the financial burden of health services; 4) aggressive efforts to reduce malaria incidence and to provide effective treatment for those infected; and 5) the establishment of a community health worker program in every village of the country. Substantial progress has also been made in extending services to prevent mother-to-child transmission of HIV, resulting in an infection rate of just 3.5% among exposed infants at six weeks (MOH 2011). HIV infection therefore contributes relatively little to the neonatal mortality rate. Table 1.2 summarizes the major policy milestones.

Table 1.2. Major national policy milestones related to neonatal health in Rwanda, 2000-2010

Year	Policy
2000	Pilot project of community-based health insurance; standard DHS survey
2001	Pilot projects on performance-based financing (PBF) of health services in two districts
2003	National reproductive health policy published
2004	First policy on community-based health insurance (CBHI) elaborated
2005	Rwanda health sector policy, including sexual and reproductive health; standard DHS survey
2006	Facility-based childbirth policy, TBAs trained to support facility deliveries; PBF introduced in all districts; CBHI extended to all Rwandans; national family planning policy issued
2007	Family planning declared a development priority; establishment of Community Health Desk and scale up of community case management of childhood illness by community health workers (CHWs)
2008	Maternal death reviews institutionalized; CBHI subsidies for the indigent established
2009	Community PBF for CHWs instituted
2010	Pilot of community-based provision of family planning; pilot of mobile phone reporting system for pregnancy complications in the community; nutrition and family planning added to community health system; standard DHS survey

Source: Table draws from Bucagu et al. 2012.

Reproductive health policy

Reproductive health, including family planning and maternal health services, has received a great deal of attention in Rwanda during the past decade. Family planning can reduce neonatal mortality by preventing adolescent and other high-risk pregnancies and by enabling optimum birth spacing. The 2003 reproductive health policy set an objective of 15% coverage for modern methods of contraception for women of reproductive age (age 15-49) by 2010. That figure has been exceeded; according to the 2010 DHS, 29% of all women of reproductive age and 45% of married women reported currently using a modern method of contraception (NISR, MOH, and ICF International 2012).

Maternal health services are essential for preventing, identifying, and responding appropriately to complications of pregnancy and childbirth. Rwanda has adopted the World Health Organization (WHO) approach to focused antenatal care (ANC), recommending four ANC visits during the pregnancy, starting in the first trimester (MOH 2003). Services should include tetanus vaccination; provision of iron and folate; screening for syphilis, anemia, HIV, and asymptomatic bacteriuria; assessment of danger signs and pregnancy risk factors; counseling on danger signs; safe delivery; nutrition; breastfeeding; prevention of HIV and other STIs; and postpartum family planning.

Assisted delivery by a health professional is essential to preventing stillbirth and neonatal death and disability; it does so by enabling a rapid and effective response to danger signs. This care should include routine use of the partograph to determine the need for emergency intervention and timely referral for emergency services when necessary. Rwanda Ministry of Health (MOH) norms state that all health centers should be able to provide basic emergency obstetric care and all district hospitals should be able to provide comprehensive emergency obstetric care. Findings from a recent assessment of the quality of care, however, show that actual availability is much lower (Ngabo et al. 2012).

Similarly, postnatal care plays an important role in identifying sick newborns and ensuring timely treatment. The availability of postnatal care in Rwanda appears to be quite low. In 2007 just 16% of facilities offered postpartum care (NISR, MOH, and Macro International 2008), although the government has made this area a priority. Because of changes in how the DHS survey collected information regarding postpartum care for women and infants between 2000 and 2010, the present analysis does not examine children's receipt of postpartum care.

Performance-based financing

In conjunction with health insurance coverage, performance-based financing (PBF) has been credited for much of the progress in increasing coverage of skilled delivery services in Rwanda. PBF was first piloted in 2001 and then, after positive results, rolled out countrywide in 2006. The aim of PBF is to increase the utilization of health services by offering financial incentives to providers to perform the intended services. PBF also encourages facility-level problem solving to improve performance, and it increases the financial resources available to fund those services (Basinga et al. 2011). To address concerns about potential biases in the data, the government of Rwanda instituted rigorous monitoring and evaluation, including audits of facility reports and modification of the indicators or payment levels when problems are identified (Management Sciences International 2005).

Since its inception, PBF in Rwanda has included indicators of key maternal health care services that greatly improve outcomes for newborns. These include indicators of both completeness and quantity of antenatal care and delivery services at health centers (Box 1.1). District hospitals have a different but complementary set of PBF indicators also emphasizing maternity care. Several researchers have looked at the association between PBF and service utilization. The most extensive study, by Basinga and colleagues (2011), found that quarterly supervision of visits by the district hospital supervision team were associated with a significant increase in the probability of institutional delivery, with the probability of a woman receiving a tetanus vaccination during a prenatal visit, and with an improvement in the facility quality score. However, there was no increase in the utilization of ANC services, a result the authors attribute to inadequate financial incentives for antenatal clinic attendance, a situation over which the health providers have relatively little control (Basinga et al. 2011).

Box 1.1 Rwanda PBF indicators related to neonatal health outcomes

Number of…

- first prenatal care visits
- women who completed four prenatal care visits
- deliveries in the facility
- women who received appropriate tetanus vaccination during prenatal care
- women who received a second dose of malaria prophylaxis during prenatal care
- high risk pregnancies referred to district hospital
- emergency transfers to hospital for obstetric care during delivery

Source: Box draws from Basinga et al. 2011.

Health insurance

The government of Rwanda has assigned the highest priority to universal access to health care services. Rwanda began implementing health insurance in 2001 with a mandatory scheme for public sector workers, known as La Rwandaise d'Assurance Maladie (RAMA). Subsequently, a more broad-based program of community-based health insurance (CBHI) was implemented. This program has evolved to include a mechanism to provide coverage free of charge to indigent families (MOH 2008, Sekabaraga, Diop, and Soucat 2011). According to the 2010 RDHS, 78% of households have some form of health insurance, and 98% of these are covered by CBHI (NISR et al. 2012).

Using data from the 2005 RDHS, Hong and colleagues (2011) found that having health insurance was significantly associated with women's birth-care-related health-seeking behaviors. Women with health insurance, compared with women without, were 29% less likely to deliver at home and 25% less likely to deliver with an unskilled birth attendant or to have no assistance at delivery, after adjusting for likely confounders (Hong et al. 2011). As part of the current analysis, we replicated that analysis using the 2010 RDHS and found a similar but stronger effect. In 2010, being insured was significantly associated with a 43% reduction in the odds of home delivery, a 41% reduction in the odds of having an unassisted birth (or delivery by an unskilled attendant), and a 15% reduction in the odds of having fewer than four ANC visits for the most recent birth, after adjusting for likely confounders. (See Table A.2 for additional detail.)

Malaria control program

Malaria during pregnancy is associated with substantial risk for both the mother and infant. Infection with malaria during pregnancy can cause severe maternal anemia and intrauterine growth retardation, leading to low birth weight (Guyatt and Snow 2001, Takem and D'Alessandro 2013). Placental malaria, in fact, has been shown to double the infant's risk of being born with a low birth

weight. Guyatt and Snow (2001) estimate that infection with malaria during pregnancy is responsible for 6% of infant deaths and 11% of neonatal deaths in malarious regions of sub-Saharan Africa.

Previous studies have shown protection against malaria during pregnancy to be associated with lower levels of neonatal mortality. In a recent study using DHS data from 25 countries in Africa, Eisele and colleagues (2012) found that children whose mothers were fully exposed to malaria prevention during pregnancy had a lower risk of neonatal death, and lower odds of being born with a low birth weight, compared with children whose mothers were not fully exposed, after controlling for likely confounders (Eisele et al. 2012). (Exposure to prevention was defined as either having received full intermittent presumptive treatment for malaria in pregnancy (IPTp) or having had an insecticide-treated net (ITN) in the household during the pregnancy.[1])

Since 2005 Rwanda has rapidly scaled up its interventions to reduce morbidity and mortality caused by malaria, and has set a goal of achieving pre-elimination status by 2017 (President's Malaria Initiative 2013). In 2006 Rwanda began distributing ITNs through mass public health campaigns and during routine ANC visits. During 2006 and 2007 alone, more than three million ITNs were distributed in campaigns specifically directed to pregnant women and children under age 5. An additional 6.1 million nets were delivered during 2009-2011 in a broader campaign aimed at universal coverage (one net per two persons) (Karema et al. 2012).

In terms of treatment for children with malaria, in 2004 Rwanda began piloting home-based management of malaria (HBM) among children under age 5 with artemisinin-based combination therapy (ACT) provided by community health workers. Rwanda transitioned to ACT in all health centers in 2006 (Otten et al. 2009). With regard to pregnant women, the standard of care changed during this period. Although still recommended by WHO, Rwanda discontinued intermittent presumptive treatment for malaria in pregnancy in 2008. In 2012 it began piloting a new strategy of intermittent screening and testing of pregnant women with rapid diagnostic tests (President's Malaria Initiative 2013).

Community health workers

To implement many of the above policies, the MOH has relied on community health workers (CHWs) to mobilize and sensitize community residents, to act as intermediaries between the community and the health facility, and to extend the reach of preventive and curative services. Every village has four elected CHWs. Two of them are trained and equipped to provide community case management (CCM) of common childhood illness, including malaria, diarrhea, and pneumonia. They are not authorized to provide treatment to newborns, but they are trained to encourage care-seeking and to rapidly refer any sick infants that come to their attention.

More significantly for neonatal health, a cadre of specialized CHWs, called Agents de Santé Maternelle (ASM), focus specifically on women in communities, including pregnant women and their newborns. The ASM identify pregnant women early, distribute a first dose of iron, folic acid, and mebendazole for anemia prevention, and promote mosquito net use, ANC, and breastfeeding, among other activities (President's Malaria Initiative 2013). Many are former traditional birth attendants who have been reoriented and trained to fill this new role; home births are severely discouraged, with fines

[2] ITN ownership at the time of pregnancy was approximated using information collected in the household net roster, including the reported date that the household obtained the net, and the timing of treatment of the net with insecticide.

sometimes levied against both traditional birth attendants and women who use their services. Conversely, the ASM are encouraged to accompany women to the health facility for delivery and often help support the mother during delivery, sometimes receiving a small payment for their services. Beginning in 2009, the ASM also received cell phones specially programmed to help them track pregnant women in the community and call for assistance in case of an emergency (MOH 2011). This system helps to track pregnant women and children during the first year of life.

2. DATA AND METHODS

2.1 Data

The study examines trends and determinants of neonatal mortality in Rwanda, using data from the Rwanda 2000, 2005, and 2010 standard DHS surveys[2]. These are nationally representative, population-based household surveys that monitor demographic trends; reproductive health behaviors, attitudes, and outcomes; and socio-demographic characteristics of women and men of reproductive age. All data are collected in face-to-face household interviews, and a standard core questionnaire is included in each survey, enabling comparisons across countries and over time.

Table 2.1 presents information on the three surveys included in this analysis, including dates of fieldwork, sample sizes for households, women, and births, and the approximate reference period for neonatal mortality estimates generated in each survey.

Table 2.1. Summary of Rwanda Demographic and Health Surveys included in the analysis

Year	Date of fieldwork	Reference period for five-year neonatal mortality estimates	Number of households interviewed	Household response rate	Number of women age 15-49 interviewed	Eligible women response rate	Number of live births reported, lifetime	Number of live births, five years preceding interview	Number of most recent births, five years preceding interview
2000	June-Nov, 2000	1996-2000	9,696	99.5	10,421	98.1	28,965	8,249	5,095
2005	Feb-July, 2005	2001-2005	10,272	99.7	11,321	98.1	30,376	8,768	5,347
2010	Sept 2010-March 2011	2006-2010	12,540	99.8	13,671	99.1	33,039	9,229	6,395

The study population was restricted to live births that occurred during the five years preceding each survey (60 months preceding the month of interview). Two additional restrictions should be noted. First, for some maternal and delivery care indicators, information is only available for women's most recent birth in the five years preceding the survey. Second, indicators related to maternal and delivery care are only available for 59 months; that is, they are not available for the 60th month preceding the interview. Indicators that are limited to the most recent births and indicators limited to months 1-59 (rather than months 1-60) before the month of interview are noted as such in the tables in this report.

2.2 Definitions of Indicators

The key outcome examined in this report, neonatal death, is defined as a death that occurred in the first month of life (days 0-29). We examine determinants of neonatal mortality at four distinct levels of influence: characteristics of the household, the mother, the child, and fourth, the maternal and delivery care received, along with coverage of other interventions that could affect neonatal survival. Household-

[2] The analysis did not include the Interim DHS conducted in 2007-08.

level indicators are expected to impact mothers' access—access to health care, access to economic resources, access to social and familial support—and could also capture geographic variation in the quality of available services. Characteristics of the mother and of the child primarily identify higher-risk pregnancies and births. With the fourth level of indicators—characteristics of maternal and delivery care and other intervention-relevant indicators—we hope to gain a better understanding of which maternal/delivery services and neonatal survival interventions are associated with lower levels of neonatal mortality.

These same four levels of indicators, defined in detail below, are used throughout this study in both the descriptive and multivariate analysis.

Characteristics of the household – all measured at the time of interview:

Place of residence. Urban or rural. It is expected that children born in urban households have a lower risk of neonatal death. Urban is used as the reference category in regression analysis.

Province[3]. The five political provinces of Rwanda created in 2005 are used in this analysis: Kigali City, South, West, North, and East. Kigali, the capital, is the reference category.

Household wealth index terciles. The composite wealth index constructed by DHS is based on household-level data on assets, services, and amenities, and ranks households according to their level of wealth. These ranks were divided into terciles: low, middle, and high. It is expected that children from wealthier households have a lower risk of neonatal death. The highest tercile is the reference category.

Household size. The number of household members is grouped into three categories: fewer than five, five to seven, and eight or more members. We expect larger household size to be associated with higher risk of neonatal mortality, as large household size is often associated with rural residence, poverty, higher fertility rates, and shorter birth spacing. The smallest household size category is the reference category.

Household access to an improved water source. A household is defined as having access to an improved water source if it has any of the following: piped water into the dwelling, yard, or plot; a public tap or standpipe, tubewell, or borehole; a protected dug well or protected spring; rainwater; or bottled water. Studies have found access to an improved water source to be associated with infant survival (Fuentes, Pfütze, and Seck 2006). We test for an association with neonatal survival, as well. Having access to an improved water source is the reference category.

Household access to an improved toilet. A household is defined as having an improved toilet if it has any of the following types of facilities, and if this facility is not shared with another household: a flush or pour flush to piped sewer system, septic tank, or pit latrine; a ventilated improved pit latrine; a pit latrine with a slab; or a composting toilet. Household access to improved sanitation is associated with lower levels of infant mortality (Fuentes et al. 2006). We test whether, in Rwanda, it is also associated with lower levels of neonatal mortality. Having access to an improved, non-shared toilet is the reference category.

[3] This provincial breakdown was not available in the 2000 survey, but GPS data in that survey were used to reconstruct provincial lines and assign each cluster to one of these five provinces. In 2000, 145 births came from households from a sampling cluster that could not be located geographically. These births were excluded in the analysis.

Characteristics of the mother:

Mother's age at child's birth is divided into three categories: under age 18, 18-34, and 35 or older. Mother's age is expected to have a U-shaped relationship with the risk of neonatal death, such that children born to women of younger and older ages are at elevated risk. Age 18-34 is the reference category.

Mother's marital status is divided into two categories: currently married or in union, and not currently married or in union. Note that this information refers to women's status at the time of interview, as a proxy for marital status at the time of the child's birth. Children whose mothers are not currently married are expected to have an elevated risk of neonatal mortality. Married women are the reference category.

Mother's education is grouped into three categories: no education, primary education, and secondary or higher education. Women's education is expected to be inversely associated with the risk of neonatal death. Women with secondary or higher education are the reference category.

Mother's body mass index (BMI) was calculated using height and weight measurements taken on the date of interview, according to the formula (height/weight^2). BMI scores were divided into quartiles, which were then reduced to three categories: the lowest quartile, the middle two quartiles, and the upper quartile. Undernutrition, measured by low maternal BMI, is expected to be associated with poorer neonatal survival. Women in the middle two quartiles (i.e., within the inter-quartile range) are used as the reference category. Height and weight information was collected in every household in the 2000 RDHS but was collected in every other household in the 2005 and 2010 RDHS, so this indicator is only available for half of all births in the 2005 and 2010 surveys.

Mother's stature was divided into quartiles. Children whose mothers are in the lowest height quartile are compared with children whose mothers are in the upper three quartiles. Short stature, which reflects the mother's nutrition from the fetal period through adolescence, and which also captures environmental exposures such as infection, illness, and economic hardship during this period, has been associated with higher levels of neonatal mortality (Christian 2010). Women in the upper three quartiles are the reference category (labeled "not short"), while women in the lowest quartile are labeled "short." Like the BMI, this indicator is only available in the 2005 and 2010 surveys for half of all births.

Characteristics of the child:

Sex of child. Male or female. Female is the reference category.

Multiple birth. Whether the birth was single or multiple. Multiple births are known to have a higher risk of neonatal death. Single births are the reference category.

Birth order. This indicator is grouped into four categories: first births, second births, third births, and fourth or higher-order births. Birth order is expected to have a U-shaped association with neonatal mortality, such that first births and high-order births have increased risk of death during the neonatal period. First births are the reference category.

Preceding birth interval. Birth intervals are grouped into three categories: intervals of less than 24 months, 24-35 months, and 36 or more months. The preceding birth interval is expected to have a U-shaped relationship with neonatal mortality, such that births with either short or long preceding intervals are at elevated risk. Since first births do not have a preceding birth interval, they are included as a

separate, fourth category in the regression analysis. The optimal birth interval, 24-35 months, is the reference category.

Characteristics of maternal and delivery care, and coverage of other interventions that may have influenced neonatal mortality:

Mother received ANC from a health professional (for most recent birth). Health professionals include doctors, nurses, midwives, and medical assistants. Neonatal mortality is expected to be lower among children whose mothers received ANC from a health professional. In regression analysis, children whose mothers received at least one ANC check-up from a health professional are the reference category.

Number of ANC visits (for most recent birth). This indicator has five levels, comparing children whose mothers had 0, 1, 2, 3, and 4 or more ANC visits from any provider. Neonatal mortality is expected to be inversely associated with the number of ANC visits received. Children whose mothers had 4 or more visits are the reference category.

Mother received tetanus injections (for most recent birth). This indicator is grouped into three categories: women who received no tetanus toxoid vaccination injections, women who received one injection, and women who received two or more injections for the most recent birth. Neonatal mortality is expected to be inversely associated with the number of tetanus injections the mother received. Children whose mothers had two or more injections are the reference category.

Delivery by a health professional. Births that were attended by a doctor, nurse, midwife, or medical assistant are compared with those that were not. Children whose births were attended by a health professional are expected to have a lower risk of neonatal mortality, and are the reference category.

Delivered in a health facility. Children who were delivered in any public or private health facility are compared with those that were not. Children delivered in a health facility are expected to have a lower risk of neonatal mortality, and are the reference category.

Early initiation of breastfeeding (for most recent birth). For a woman's most recent birth, the DHS asks how long after giving birth the mother initiated breastfeeding. Children for whom the mother initiated breastfeeding within the first hour of delivery are compared with those for whom breastfeeding was initiated later or not at all. Early initiation of breastfeeding is expected to be positively associated with neonatal survival (Edmond et al. 2006). It will be noted below that there may be ambiguity in the direction of causation. Children for whom breastfeeding was initiated early are the reference category.

Mother has health insurance. As part of the 2005 and 2010 surveys, respondents were asked whether they had health insurance. Children born to mothers who responded that they had health insurance at the time of interview are compared with children whose mothers responded that they did not. We hypothesize that insurance status may be associated with neonatal survival, but note the possibility that a woman who had health insurance at the time of the survey might not have had it when the child was born. Children with insured mothers are the reference category.

Household owns a mosquito net. This indicator identifies households that own at least one mosquito net of any type *at the time of interview* (untreated mosquito nets are very rare in Rwanda). It should be noted that the date of interview is always *after* the survival or death of the child during the neonatal period; however, we use this information as a proxy for mosquito net ownership during the pregnancy. Malaria during pregnancy can cause intrauterine growth retardation and preterm delivery,

leading to low birth weight and neonatal death (Takem and Allesandro 2013). Children born into households that own a net are expected to have a lower risk of neonatal mortality, and are the reference category.

Mother slept under a mosquito net the previous night. All respondents are asked whether they slept under a net the night before the interview. We use this information as a proxy for the mother's net use during her pregnancy and during the neonatal period. Children whose mothers slept under a net the night before the interview are expected to have a lower risk of neonatal mortality, and are the reference category.

2.3 Methods

The analysis begins with estimates of neonatal mortality rates, overall and within each category of each potential predictor of neonatal death, for the five years preceding the 2000, 2005, and 2010 surveys—that is, in months 1 to 60 before each woman's month of interview. A log probability model was used to estimate the probability of dying in the first month of life.[4]

To further test the association between key indicators of interest and neonatal mortality, multivariate versions of the log probability model were used to determine whether key indicators are associated with neonatal mortality in Rwanda, after adjusting for socio-demographic factors that could confound the association. Stata 12 was used to make the calculations. In order to inform our understanding of the extent to which each selected indicator contributed to the observed reduction in neonatal mortality, multivariate decomposition procedures were also used.

Multivariate decomposition provides a way to analyze differences in the outcome between two groups or, as in this case, between two points of time. In Equation 1, this difference is represented by $Y_A - Y_B$. This study used the mvdcmp procedure in Stata, which is comparable to the Oaxaca-Binder Method but provides flexibility to use non-linear models. The decomposition procedure divides the total decline in neonatal mortality into two portions: the portion that can be attributed to the change in composition or the prevalence of a set of indicators (referred to as the *endowments* portion, and represented by X_A and X_B in Equation 1), and the portion that can be attributed to the change in the effect of these indicators (referred to as the *coefficients* portion, and represented by β_A and β_B in Equation 1) (Powers, Yoshioka, and Yun 2011).

[4] The model agrees exactly with the DHS software normally used to calculate neonatal mortality rates, along with all the other standard under-five mortality rates, and follows the standard DHS mortality estimation protocol (Rutstein and Rojas 2006), but has several advantages. Because it falls within the framework of generalized linear models (with binomial error and log link), it can easily incorporate information on sample weights, survey stratification, and clustering of households, and it easily produces standard errors, confidence intervals, and test statistics. This model was first applied to DHS data in a study of child mortality in West Africa by Bal et al. (2004).

Equation 1:

$$Y_A - Y_B = F(X_A\beta_A) - F(X_B\beta_B)$$

$$= \underbrace{F(X_A\beta_A) - F(X_B\beta_A)}_{\textbf{Endowments}} + \underbrace{F(X_B\beta_A) - F(X_B\beta_B)}_{\textbf{Coefficients}}$$

The decomposition procedure relies on two key pieces of information: the prevalence of all selected indicators at both points in time, and the coefficients derived from multivariate regression models predicting neonatal death run separately at both time points. The mvdcmp procedure assumes additivity of the components for composition and effect (Powers et al. 2011). Two decompositions were performed: one to examine the decline in neonatal mortality between the 2000 and 2010 surveys, and one to examine the decline between the 2005 and 2010 surveys, since the mortality decline was concentrated between these two surveys. The reduction in the NMR between the 2000 and 2005 surveys was not statistically significant, so we did not decompose this reduction. Because key variables related to maternal and neonatal care are available only for the most recent birth, it was necessary to restrict the sample to the women's most recent birth in the five years preceding each survey, for both decompositions.

2.4 Study Limitations

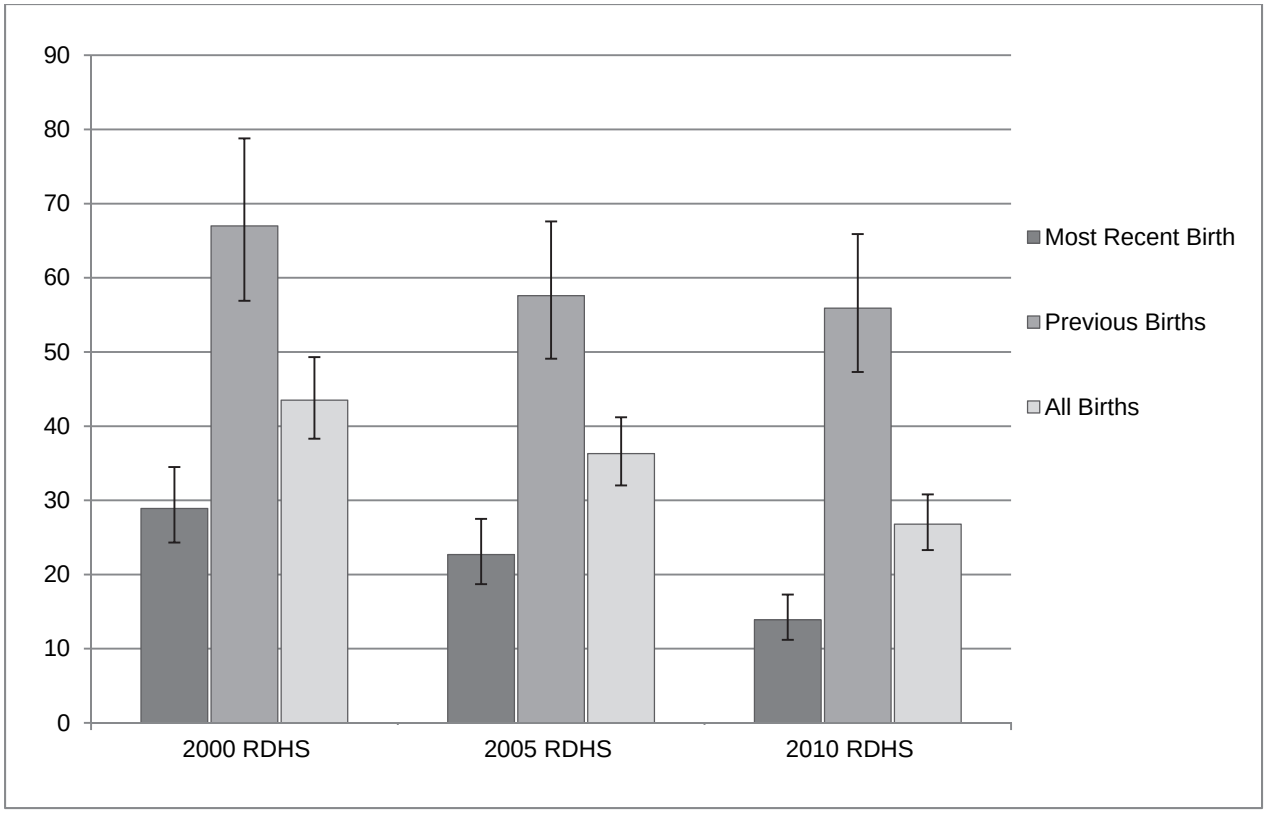
Several limitations to the study are worth noting. Most importantly, while we would like to know which interventions actually led to a reduction in neonatal mortality, the DHS is a cross-sectional survey and thus we can only report associations. We cannot infer causation.

In addition, the DHS collects information from respondents about past events, behaviors, and outcomes. Such information—for example, concerning women's receipt of maternal care services—is subject to recall bias. For several indicators of interest, there is an issue regarding the timing of measurement. While we are interested in assessing characteristics at the time of the mother's pregnancy and at the birth of the child, certain variables are only measured at the time of interview. For example, women's body mass index, educational attainment, and all household characteristics are measured at the time of the interview rather than during the pregnancy. Perhaps most problematically, to assess the mother's mosquito net use during pregnancy, we use her mosquito net use the night before the interview as a proxy, with the understanding that the findings must be interpreted cautiously.

Between 2000 and 2010 there were some revisions to the DHS survey questionnaires and definitions of some variables. For this reason it was not possible to include some indicators of interest, such as exposure to postnatal care for either the mother or the newborn.

Finally, it is critical to remember that, as noted above, several key maternal care indicators are only available for women's most recent birth, rather than all births in the last five years. Figure 2.1 shows that in all three surveys there is a significant difference in neonatal mortality rates between all births and most recent births in the last five years. This difference is likely due to a selection bias in the most recent birth sample. The selection tends to omit closely spaced births, and close spacing between births is associated with higher mortality risk. Readers are advised to interpret the results with caution, and not to compare rates for indicators that are available for all births with rates for indicators that are only available for the most recent birth.

Figure 2.1. Neonatal mortality rate among most recent births, previous births, and all births in the five years preceding the survey, Rwanda 2000, 2005, and 2010



3. RESULTS

3.1 Trends in Socio-Demographic and Health Indicators

As described previously, a range of factors, including characteristics of the household, the mother, the child, and the maternal and delivery care received, affect neonatal mortality. Tables 3.1 to 3.4 present trends in selected indicators at each of these levels, using data from the 2000, 2005, and 2010 RDHS.

Household-level characteristics. Table 3.1 presents the distributions of household-level characteristics for births occurring during the five years preceding the 2000, 2005, and 2010 surveys. The geographic distribution of births across Rwanda remained similar between 2000 and 2010. Of children born in the five years preceding the 2010 RDHS, 12% were in urban households and 88% in rural households. By province, 10% of births were in Kigali, roughly one-fourth were in each of the Southern, Western, and Eastern provinces, and 16% were in the Northern province.

In all three surveys births were fairly evenly distributed across the wealth terciles. The terciles are constructed to contain equal numbers of households, but because of variations in the number of women per household and the number of children per woman, there are some departures from an exactly uniform distribution of births.

In terms of household size, just under half of children were born into households with five to seven members (48%), over one-third were born into households with fewer than five members (37%), and the remaining 15% of children were born into households with eight or more members.

A household's access to improved water and sanitation sources is believed to be associated with child, infant, and neonatal survival. The percentage of children born into households with access to improved sources of drinking water increased substantially during the study period, from 40% in 2000 to 73% in 2010. There has also been a dramatic increase in the percentage of children born into households with improved, non-shared toilets, from 7% in 2000 to 57% in 2010 (see Figure 3.1).

Table 3.1. Trend in select characteristics of the household that could have influenced neonatal mortality, among children born in the five years preceding the survey, Rwanda 2000, 2005, and 2010

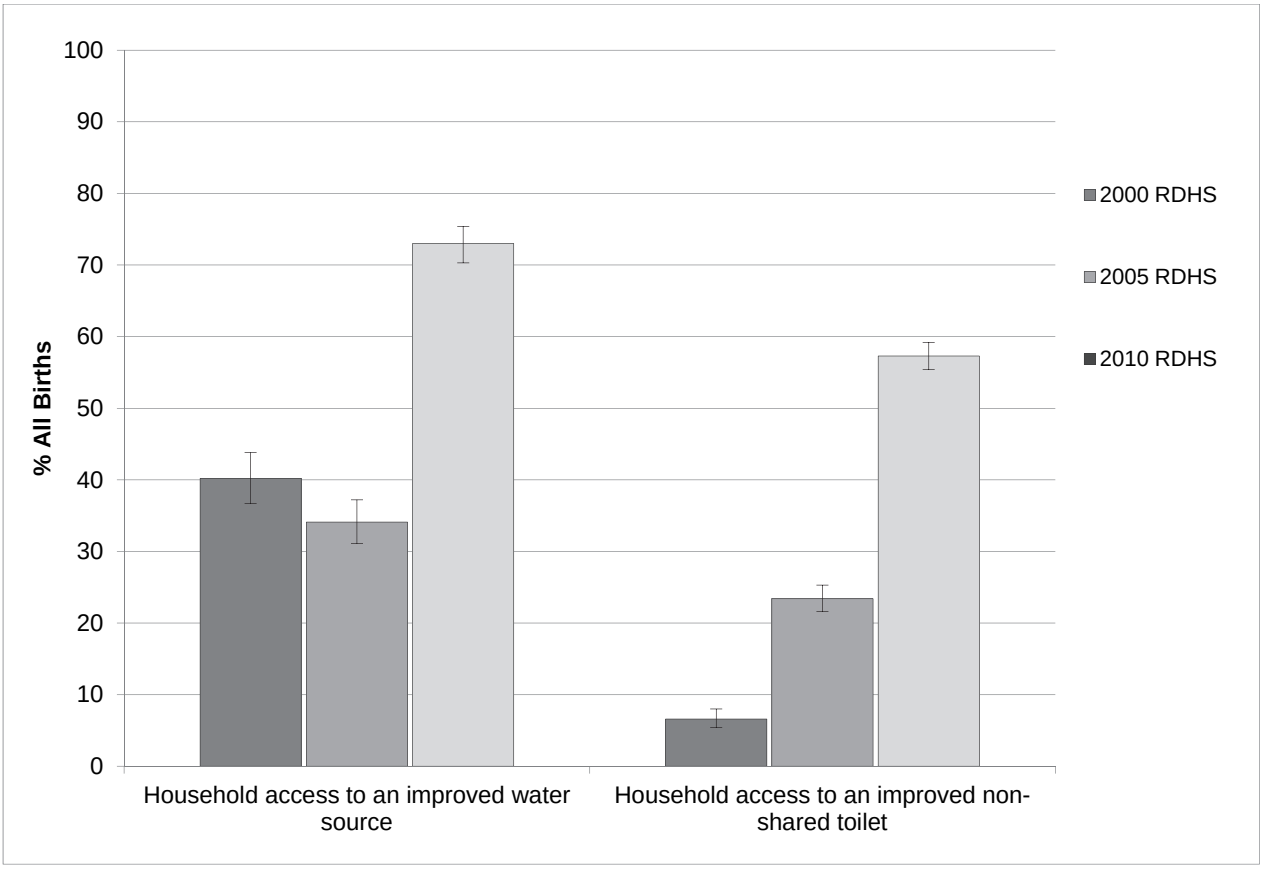
Characteristics of the household	2000 RDHS %	2005 RDHS %	2010 RDHS %
Place of residence			
Urban	14.9	14.1	12.0
Rural	85.1	85.9	88.0
Province			
Kigali	8.2	7.5	9.6
South	23.0	24.5	23.8
West	26.9	26.1	24.8
North	22.1	19.7	15.7
East	19.8	22.3	26.0
Wealth tercile			
Highest	36.3	34.9	34.3
Middle	34.3	31.5	31.6
Lowest	29.3	33.7	34.1
Household size			
<5 residents	35.2	32.1	37.0
5-7 residents	45.9	50.1	48.4
8+ residents	18.9	17.8	14.6
Household access to improved water source[1]			
Improved	40.2	34.1	73.0
Not improved	59.8	65.9	27.0
Household access to improved toilet[2]			
Improved	6.6	23.4	57.3
Not improved	93.4	76.6	42.7

Note: Percentages are restricted to all births in the 1-60 months preceding the interview. N=8,249 for the 2000 RDHS, N=8,768 for the 2005 RHDS, and N=9,229 for the 2010 RDHS.

[1] An improved water source refers to any of the following: piped water into the dwelling, yard, or plot; a public tap or standpipe, tubewell, or borehole; a protected dug well or protected spring; rainwater; or bottled water.

[2] An improved toilet source refers to any of the following types of facilities, as long as the facility is not shared with another household: a flush or pour flush to piped sewer system, septic tank, or pit latrine; a ventilated improved pit (VIP) latrine; a pit latrine with a slab; or a composting toilet.

Figure 3.1. Trend in household access to an improved water and toilet source among children born in the five years preceding the survey, Rwanda 2000, 2005, and 2010



Maternal characteristics. Several characteristics of the mother, including age at the child's birth, educational attainment, nutritional status, and marital status, have been found to be associated with neonatal survival. Table 3.2 presents trends in these characteristics among children born in the five years preceding the 2000, 2005, and 2010 surveys in Rwanda. The percentage of children born to mothers in the optimal age range, 18-34, increased slightly, from 73% in 2000 to 78% in 2010, with a corresponding decline in the percentage of children born to mothers age 35 or older, from 25% in 2000 to 21% in 2010. The percentage of children born to young mothers (under age 18) has remained low, at 1% in 2010. According to the 2010 RDHS, the great majority of children (86%) were born to mothers either married or in union, and this percentage was similar in the earlier two surveys. There have been noteworthy improvements in mothers' educational attainment. The percentage of mothers with primary education increased from 56% in 2000 to 72% in 2010, while the percentage with no education fell from 34% to 19% (see Figure 3.2).

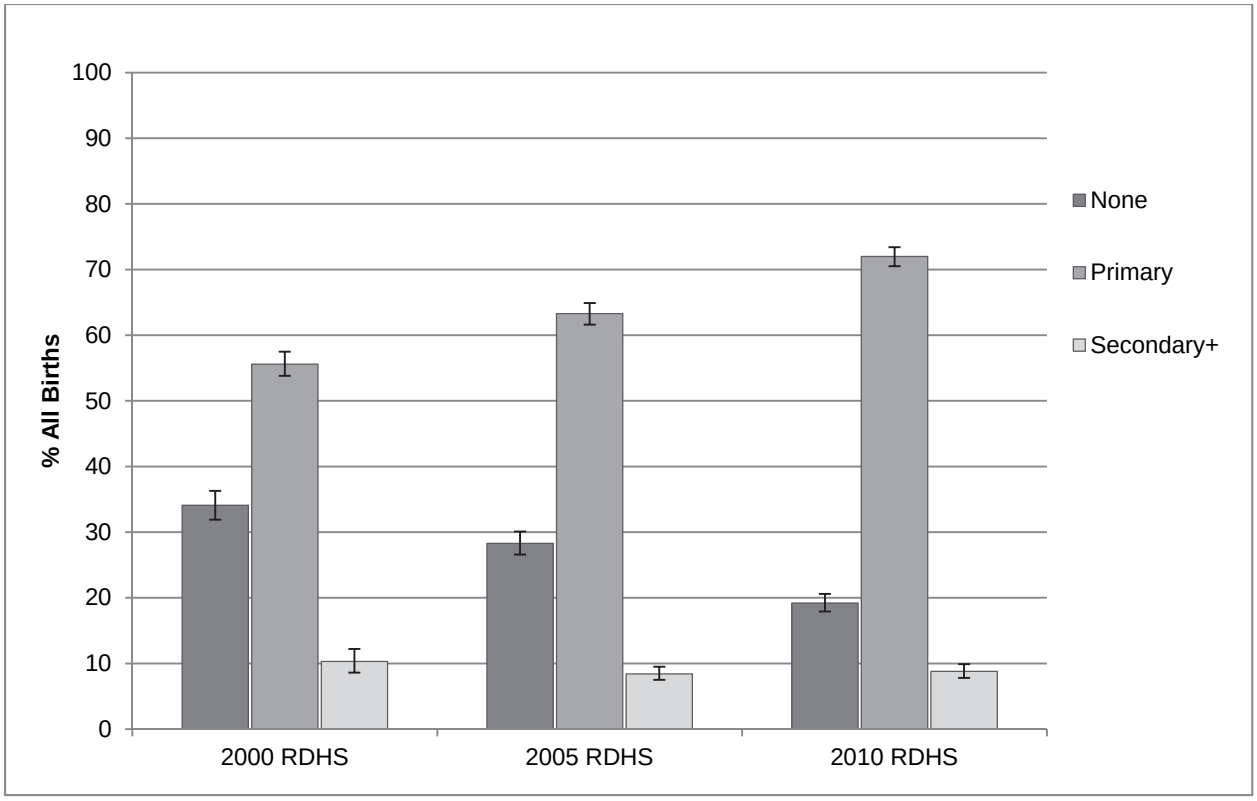
Table 3.2. Trend in select characteristics of the mother that could have influenced neonatal mortality, among children born in the five years preceding the survey, Rwanda 2000, 2005, and 2010

Characteristics of the mother	2000 RDHS %	2005 RDHS %	2010 RDHS %
Mother's age at child's birth			
18-34	72.8	74.6	77.8
<18	2.0	1.4	1.3
35+	25.2	24.0	20.9
Marital status			
Currently in union	83.0	86.7	85.5
Not currently in union	17.0	13.3	14.5
Educational attainment			
Secondary or higher	10.3	8.4	8.8
Primary	55.6	63.3	72.0
None	34.1	28.3	19.2
Body mass index[1]			
Normal (2nd-3rd quartile)	52.1	52.7	53.2
Low (1st quartile)	22.1	19.8	23.8
High (4th quartile)	25.8	27.6	23.0
Short stature[1]			
No (2nd-4th quartile)	74.2	70.5	71.8
Yes (1st quartile)	25.8	29.5	28.2

Note: Percentages are restricted to all births in the 1-60 months preceding the interview unless otherwise noted; N=8,249 for the 2000 RDHS, N=8,768 for the 2005 RHDS, and N=9,229 for the 2010 RDHS.

[1] Anthropometry was collected in every second household in 2005 and 2010, so estimates are based on a subset of all women; N=4,422 for the 2005 RHDS and N=4,658 for the 2010 RDHS. For the 2000 RDHS, due to missing height and weight information, body mass index percentages are based on 8,100 women and short stature percentages are based on 8,171 women.

Figure 3.2. Trend in maternal education among children born in the five years preceding the survey, Rwanda 2000, 2005, and 2010



Child characteristics. Several characteristics of the child, including being male, being a multiple birth, being the mother's first birth or a high-order birth, and being born after a short interval or after a long interval are associated with an increased risk of neonatal mortality. Table 3.3 presents trends in these characteristics. The prevalence of these risk factors among children has remained little changed across the three surveys. About half of children are male, and 3% are multiple births. The percentage of children who were first births increased, from 20% in 2000 to 25% in 2010, while the percentage of children of fourth or higher order decreased, from 46% in 2000 to 41% in 2010. The percentage of children born after a short preceding birth interval (<24 months) increased, from 36% in 2000 to 39% in 2010, while the percentage of children born with the optimal 24-35 month spacing decreased, from 24% in 2000 to 20% in 2010.

Table 3.3. Trend in select characteristics of the child that could have influenced neonatal mortality, among children born in the five years preceding the survey, Rwanda 2000, 2005, and 2010

Characteristics of the child	2000 RDHS %	2005 RDHS %	2010 RDHS %
Sex of child			
Female	49.6	49.2	48.9
Male	50.4	50.8	51.1
Multiple birth			
Single birth	97.5	97.5	97.0
Multiple birth	2.5	2.5	3.0
Birth order			
First	20.3	18.7	24.9
Second	18.6	17.5	19.4
Third	14.9	15.9	14.8
Fourth or higher	46.2	48.0	40.9
Preceding birth interval[1]			
2 years	23.9	23.3	20.0
<2 years	36.4	40.7	39.3
3+ years	39.7	36.0	40.7

Note: Percentages are restricted to all births in the 1-60 months preceding the interview unless otherwise noted; N=8,249 for the 2000 RDHS, N=8,768 for the 2005 RHDS, and N=9,229 for the 2010 RDHS.

[1] First births are excluded from the percentages; N=6,558 for the 2000 RDHS, N=7,107 for the 2005 RDHS, and N=6,900 for the 2010 RDHS.

Maternal and delivery care. Between the 2000 and 2010 surveys there were noteworthy gains in coverage of essential birth-related care indicators. Figure 3.3 and Table 3.4 present these trends. Antenatal care is an essential gateway into maternal care services, and provides an opportunity to identify and treat pregnancy-related problems so that avoidable complications and deaths can be averted. The percentage of women in Rwanda who had at least one antenatal care check-up from a health professional for their most recent birth was already quite high in the 2000 survey, at 93%, and increased to 98% in the 2010 survey. The percentage of women who had at least four antenatal care visits (from any provider) for their most recent birth is much lower, at 36% in the 2010 survey, but it has increased more than threefold, from 11% in the 2000 survey.

Table 3.4. Trend in coverage of recommended maternal and delivery care, and other interventions that could have influenced neonatal mortality, among children born in the five years preceding the survey, Rwanda 2000, 2005, and 2010

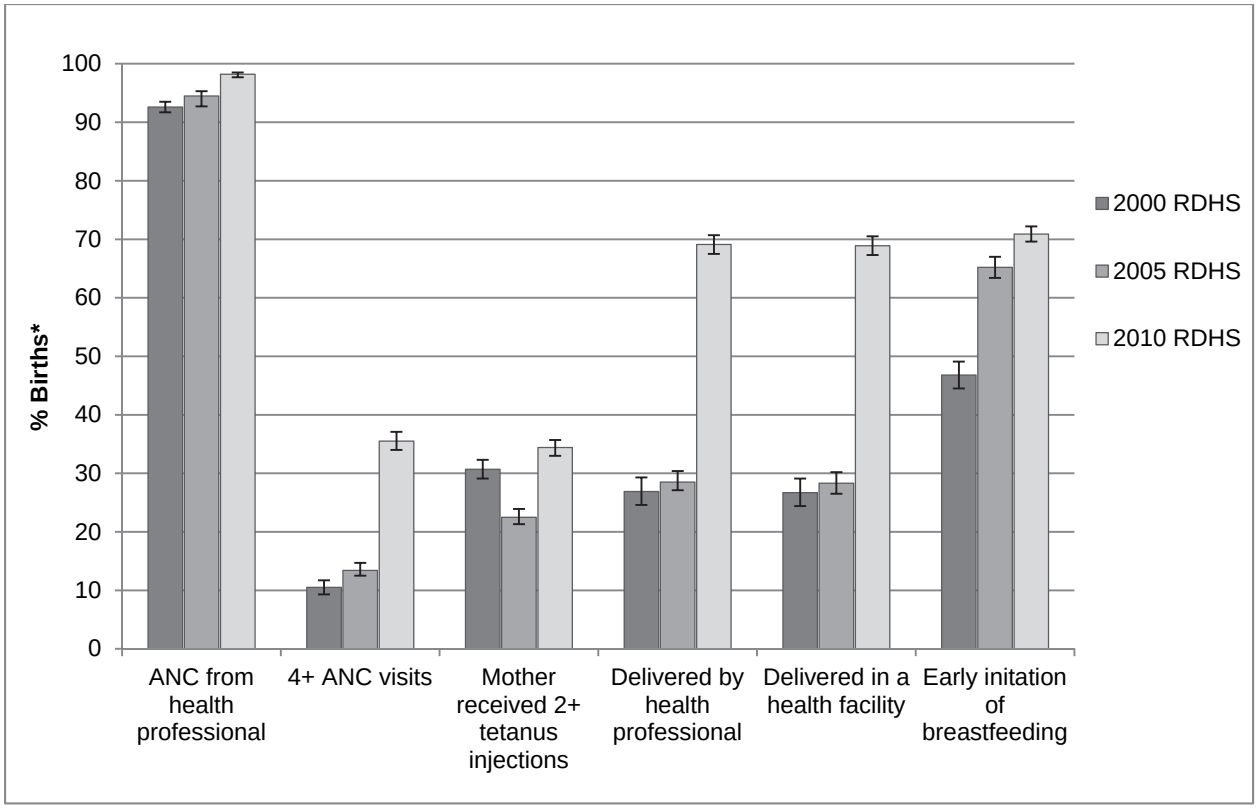
	2000 RDHS %	2005 RDHS %	2010 RDHS %
RECOMMENDED MATERNAL AND DELIVERY CARE			
ANC from a health professional[1]			
Yes	92.6	94.5	98.2
No	7.4	5.5	1.8
Number of ANC visits attended[1]			
4+	10.5	13.4	35.5
3	37.2	37.6	43.3
2	32.2	30.9	15.0
1	12.9	12.7	4.4
0	7.2	5.4	1.8
Mother received tetanus injections[1]			
2+	30.7	22.5	34.4
1	34.7	41.5	42.6
0	34.6	36.0	23.0
Delivered by a health professional[2]			
Yes	26.9	28.5	69.1
No	73.1	71.5	30.9
Delivered in health facility[2]			
Yes	26.7	28.3	68.9
No	73.3	71.7	31.1
ANC - place of delivery combination[1]			
Both	4.9	6.5	29.0
Just 4+ ANC	5.5	6.8	6.6
Facility birth only	20.9	22.7	42.8
Neither	68.7	63.9	21.7
Early initiation of breastfeeding (within one hour)[1]			
Yes	45.9	64.1	70.2
No	54.1	35.9	29.8
OTHER INTERVENTIONS RELEVANT TO NEONATAL SURVIVAL			
Mother has health insurance[3]			
Yes	n/a	45.0	73.1
No		55.0	26.9
Household owns a mosquito net[3]			
Net	8.2	23.8	93.5
No Net	91.8	76.2	6.5
Mother slept under a net previous night[3]			
Net	6.0	18.6	77.7
No net	94.0	81.4	22.3

[1] Percentages are restricted to women's most recent birth in the 1-59 months preceding the interview; N=5,062 for the 2000 RDHS, N=5,318 for the 2005 RHDS, and N=6,355 for the 2010 RDHS.

[2] Percentages are restricted to all births in the 1-59 months preceding the interview; N=8,108 for the 2000 RDHS, N=8,608 for the 2005 RHDS, and N=9,087 for the 2010 RDHS.

[3] Percentages are restricted to all births in the 1-60 months preceding the interview; N=8,249 for the 2000 RDHS, N=8,768 for the 2005 RHDS, and N=9,229 for the 2010 RDHS.

Figure 3.3. Trend in maternal and delivery care indicators in the five years preceding the survey, Rwanda 2000, 2005, and 2010



*Percentages are restricted to women's most recent birth for all indicators except two (delivered by a health professional and delivered in a health facility) which are calculated among all births.

The provision of neonatal tetanus toxoid (TT) injections is a particularly important component of antenatal care. Providing women with two doses of TT during pregnancy can prevent neonatal tetanus, which is nearly always fatal. If a woman has been previously vaccinated, one dose of TT is sufficient, and if she has already had five or more vaccinations, she will have acquired lifetime protection. According to the 2010 RDHS, 34% of mothers received at least two TT vaccinations for their most recent birth, up slightly from 31% in 2000.

Delivery in a health facility and delivery with assistance from a health professional are considered essential to promoting maternal and newborn survival. Both the percentage of children delivered in a health facility and the percentage delivered by a health professional remained little changed between 2000 and 2005, at under 30%, but then more than doubled between 2005 and 2010, reaching 69% coverage.

Consensus is growing regarding the importance of accessing services along the full continuum of maternal care—during pregnancy, through delivery and the immediate postpartum period, and into childhood. While this study does not cover the full continuum of care, we examine the combination of having at least four ANC visits and delivering in a health facility. There has been substantial improvement in the percentage of children whose mothers made at least four ANC visits *and* delivered in a facility, from 5% in the 2000 survey to 29% in the 2010 survey. However, among children born in the five years preceding the 2010 RDHS, more than one-fifth had neither of these services. In the 2010

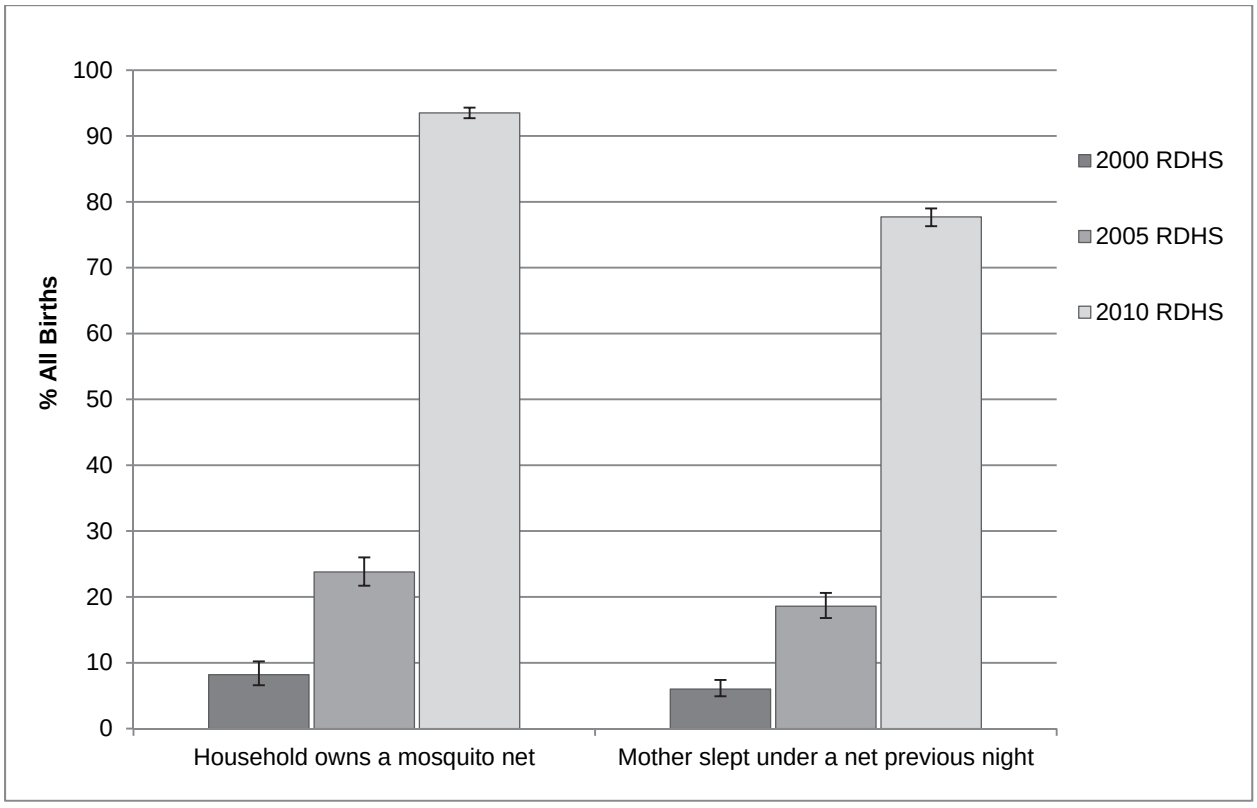
survey, an additional 43% of children were delivered in a facility, although their mothers had not had the recommended four ANC visits.

Early initiation of breastfeeding (within the first hour) is an important part of newborn care, for several reasons. It establishes the milk supply while reinforcing the bond between mother and newborn. At the same time, the newborn child receives colostrum, which provides vitamin A, antibodies, and other immune-boosting factors. Breastfeeding prevents hypoglycemia and hypothermia, which contribute to neonatal mortality (Huffman, Zehner, and Victora 2001). Between the 2000 and 2010 surveys the percentage of newborns breastfed within one hour of birth increased substantially, from 46% to 70%.

Community-based health insurance. Between the 2005 and 2010 surveys the percentage of children whose mothers had health insurance at the time of interview increased dramatically, from 45% to 73%. Health insurance coverage has been found to be significantly associated with skilled delivery care (Hong et al. 2011), and thus may indirectly reduce neonatal mortality.

Mosquito net coverage. Prevention of maternal malaria has been a priority in Rwanda, with massive mosquito net distribution campaigns and educational efforts. Between the 2000 and 2010 surveys the percentage of children born into households that own at least one mosquito net increased nearly twelvefold, from 8% to 94%. In 2010 the mothers of 78% of all children born in the past five years reported sleeping under a net the previous night, compared with only 6% in 2000 (see Figure 3.4).

Figure 3.4. Trend in household ownership of a mosquito net among children born in the five years preceding the survey, Rwanda 2000, 2005, and 2010



In sum, between 2000 and 2010 in Rwanda there were major improvements in maternal care—use of ANC, delivery in a facility, and delivery assisted by a health professional—alongside major improvements in household access to clean water and sanitation, and household mosquito net ownership and use by mothers. Subsequent sections in this report will examine the extent to which these factors are associated with lower levels of neonatal mortality, and will evaluate which improvements may have contributed to the overall decline in neonatal mortality during this period.

3.2 Trends and Differentials in Neonatal Mortality

Section 3.3 presents differentials in neonatal mortality by characteristics of the household, mother, and child, and by maternal and newborn exposure to maternal and delivery care and other interventions. Tables 3.5 to 3.9 display these differentials for children born in the five years preceding the 2000, 2005, and 2010 RDHS, so that trends in neonatal mortality can be examined over time for each indicator of interest. These tables also identify whether the decline in neonatal mortality was statistically significant for each indicator between 2000 and 2010, 2000 and 2005, and 2005 and 2010.

Household characteristics. Table 3.5 presents trends in the neonatal mortality rate (NMR), disaggregated by household-level characteristics. In all three surveys neonatal mortality was higher in rural households than in urban households (see Figure 3.5), but the urban-rural disparity narrowed considerably between 2000 and 2010 because the decline in the NMR was concentrated almost entirely among rural households. The decline in the NMR in rural households was statistically significant, comparing the 2010 survey with the 2000 survey and with the 2005 survey. The decline in neonatal mortality among rural households between 2000 and 2005 was not statistically significant, however, indicating that the decline in rural areas was concentrated in the more recent period (see Table 3.5).

Table 3.5. Neonatal mortality rate (NMR) (five-year rate) and the difference in NMR between surveys, by selected characteristics of the household, Rwanda 2000, 2005, and 2010

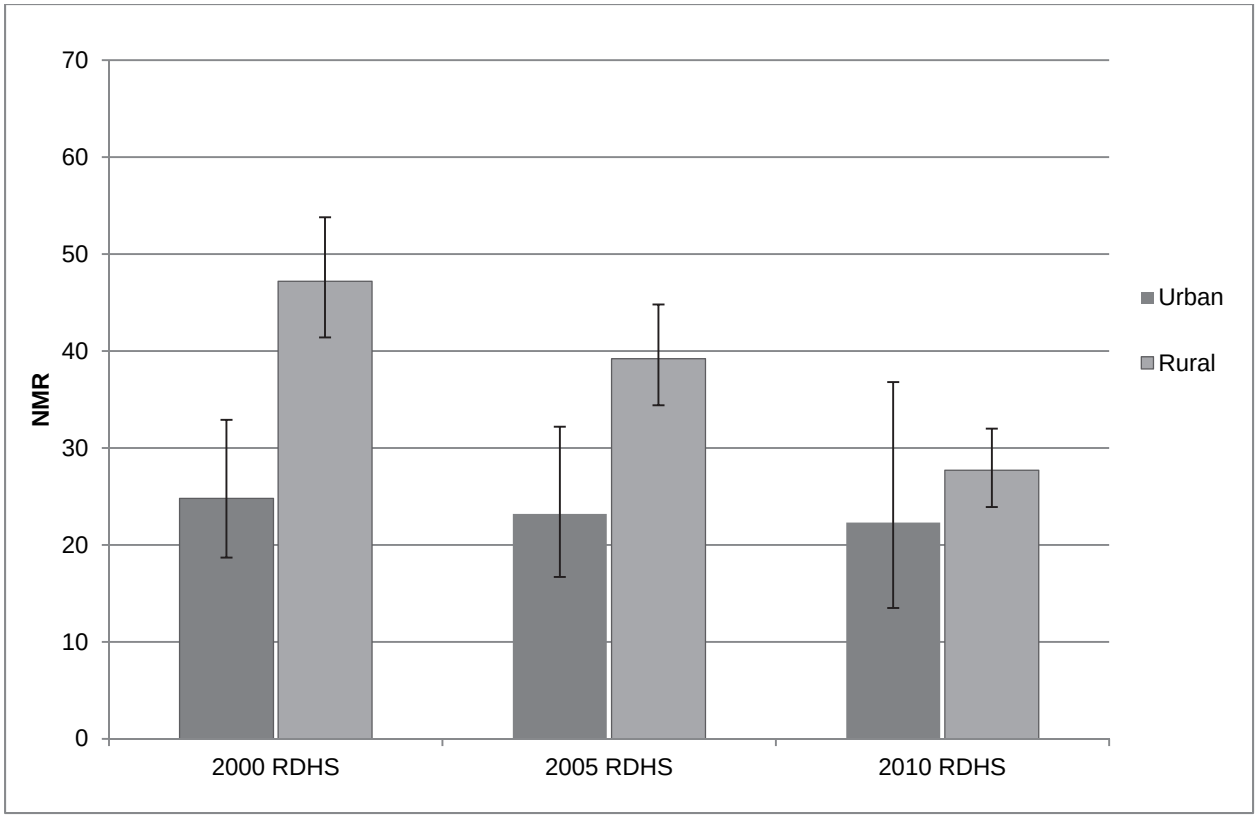
	2000 RDHS			2005 RDHS			2010 RDHS			Difference in NMR between surveys		
	Ref. period: 1996-2000			*Ref. period: 2001-2005*			*Ref. period: 2006-2010*					
Characteristics of the household	**NMR**	**95% LB**	**95% UB**	**NMR**	**95% LB**	**95% UB**	**NMR**	**95% LB**	**95% UB**	**2000-2005**	**2005-2010**	**2000-2010**
Place of residence												
Urban	24.8	18.7	32.9	23.2	16.7	32.2	22.3	13.5	36.8	-1.6	-0.9	-2.5
Rural	47.2	41.4	53.8	39.2	34.4	44.8	27.7	23.9	32.0	-8.0	-11.5 ***	-19.5 ***
Province												
Kigali	40.0	26.1	61.2	25.1	15.3	41.1	19.1	10.5	34.8	-14.9	-6.0	-20.9 *
South	47.1	38.1	58.4	36.1	28.2	46.3	25.0	18.7	33.4	-11.0	-11.1	-22.1 ***
West	46.0	36.0	58.7	35.5	28.2	44.8	26.4	20.0	34.8	-10.5	-9.1	-19.6 **
North	40.2	30.2	53.3	36.1	27.6	47.2	33.0	24.8	44.0	-4.0	-3.1	-7.2
East	43.1	31.1	59.7	44.3	33.9	57.9	28.8	22.0	37.9	1.2	-15.5 *	-14.2
Wealth tercile												
Highest	37.9	30.8	46.6	33.9	27.4	42.0	21.7	16.4	28.9	-3.9	-12.2 *	-16.1 **
Middle	40.8	32.3	51.5	35.8	28.9	44.3	27.9	22.3	34.8	-5.0	-7.9	-12.9 *
Lowest	52.0	42.9	63.2	40.9	33.6	49.7	31.1	24.6	39.3	-11.2	-9.8	-21.0 ***
Household size												
<5 residents	65.1	54.9	77.1	62.1	52.5	73.5	39.6	33.0	47.5	-3.0	-22.5 ***	-25.5 ***
5-7 residents	31.1	24.9	38.8	26.1	21.3	32.0	20.3	16.1	25.8	-4.9	-5.8	-10.7 *
8+ residents	35.7	24.7	51.6	22.2	15.2	32.3	17.6	11.5	27.0	-13.5	-4.6	-18.1 *
Household access to improved water source[1]												
Improved	39.1	31.9	47.9	32.4	25.8	40.6	25.7	21.7	30.3	-6.7	-6.7	-13.4 **
Not improved	47.1	40.3	55.1	39.3	33.9	45.6	30.7	23.6	40.0	-7.8	-8.6	-16.4 **
Household access to improved toilet[2]												
Improved	22.7	10.9	47.5	38.8	30.5	49.3	25.5	21.1	30.8	16.0	-13.3 **	2.8
Not improved	45.4	40.0	51.5	36.4	31.5	42.2	29.1	23.6	36.0	-9.0 *	-7.3	-16.2 ***
Total	43.9	38.7	49.7	37.0	32.6	41.9	27.0	23.6	31.0	-6.9	-9.9 ***	-16.8 ***

Note: * indicates p<.05; ** indicates p<.01;*** indicates p<.001. Neonatal mortality rates are based on all births in the 1-60 months preceding the interview; N=8,249 for the 2000 RDHS, N=8,768 for the 2005 RHDS, and N=9,229 for the 2010 RDHS.

[1] An improved water source refers to any of the following: piped water into the dwelling, yard, or plot; a public tap or standpipe, tubewell, or borehole; a protected dug well or protected spring; rainwater; or bottled water.

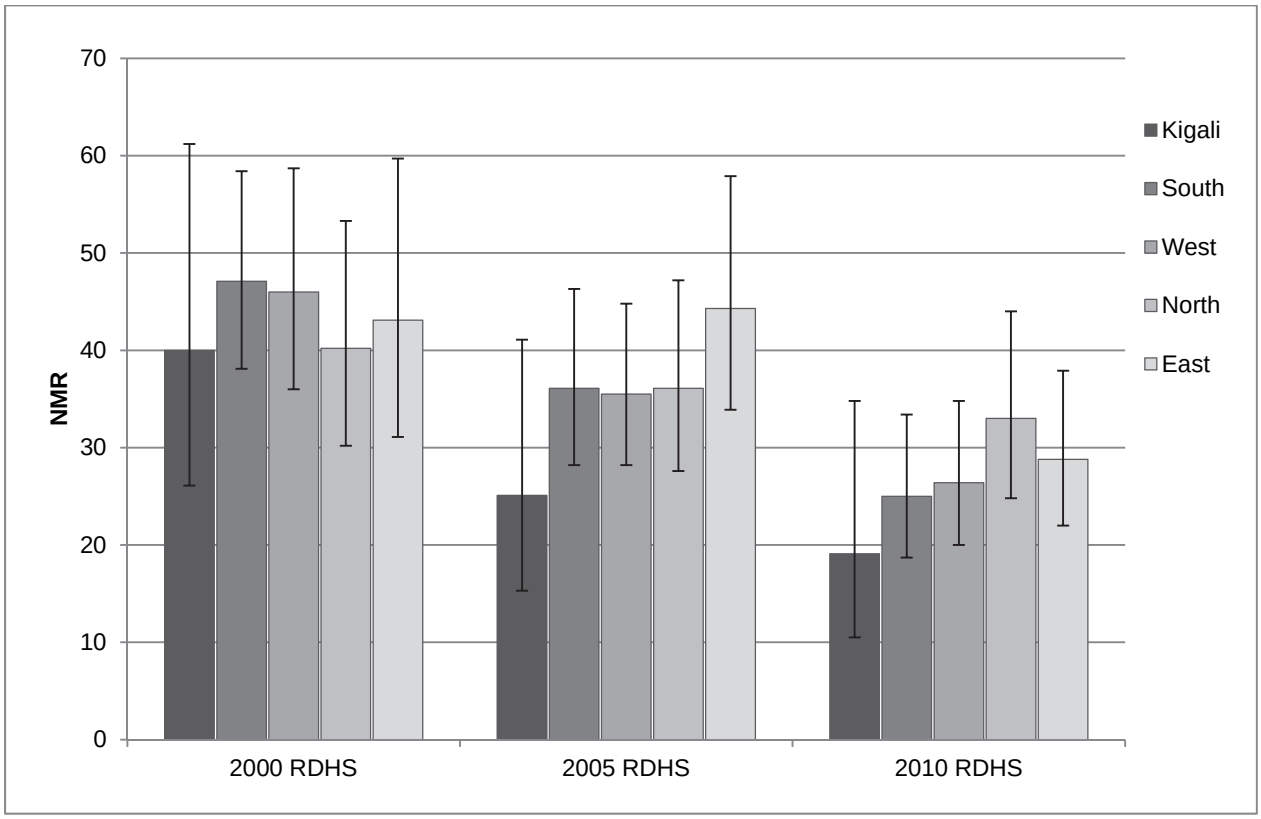
[2] An improved toilet source refers to any of the following types of facilities, as long as the facility is not shared with another household: a flush or pour flush to piped sewer system, septic tank, or pit latrine; a ventilated improved pit (VIP) latrine; a pit latrine with a slab; or a composting toilet.

Figure 3.5. Neonatal mortality rate (five-year rate), by place of residence, Rwanda 2000, 2005, and 2010



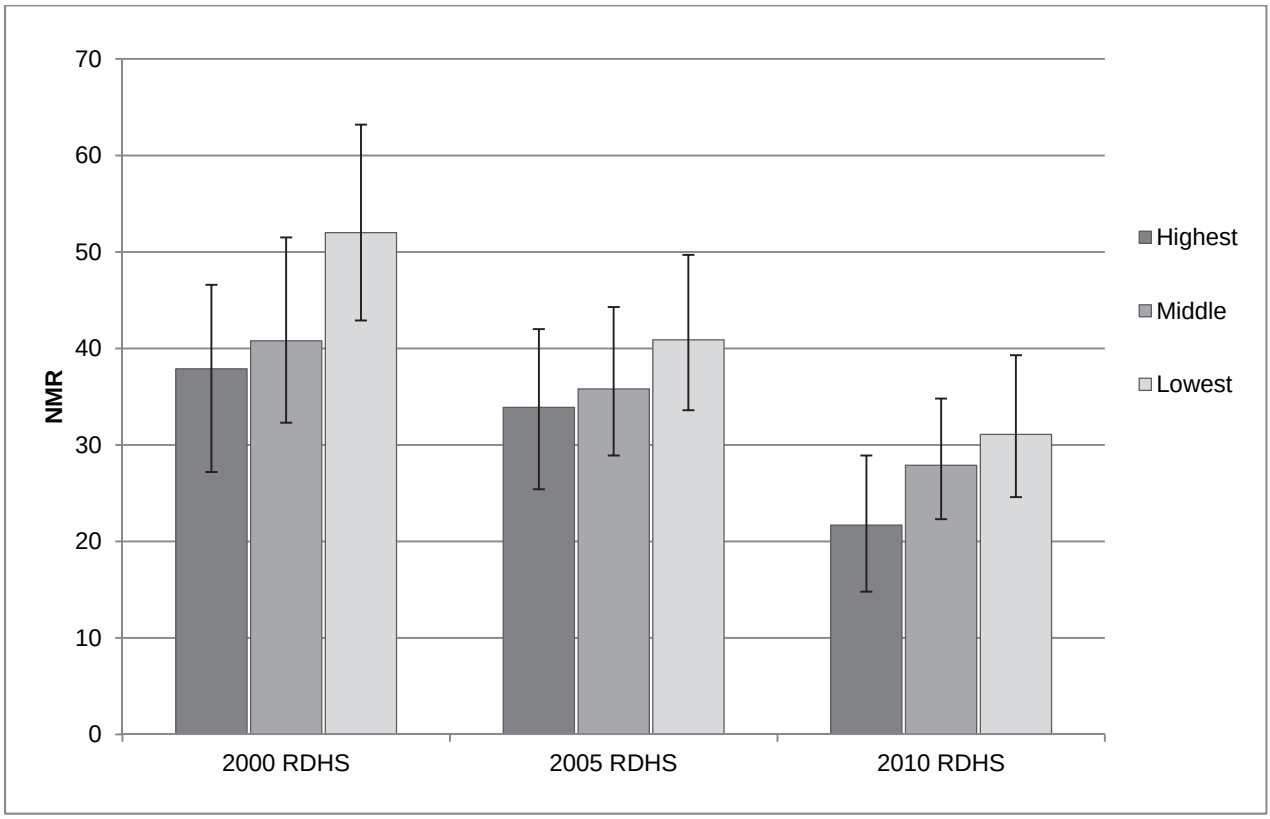
By province, in the 2010 survey neonatal mortality was lowest in Kigali and highest in the North (see Figure 3.6). However, this pattern was not consistent across the three surveys. In the 2000 survey the NMR was lowest in both the North and Kigali, but then declined rapidly in Kigali and only modestly in the North. While the decline in the NMR was statistically significant in Kigali, the South, and the West, comparing the 2000 and 2010 surveys, and was significant in the East, comparing the 2005 and 2010 surveys, there has been no significant decline in the NMR in the North.

Figure 3.6. Neonatal mortality rate (five-year rate), by province, Rwanda 2000, 2005, and 2010



By level of wealth, in all three surveys neonatal mortality was highest in the poorest tercile and declined with increasing wealth (see Figure 3.7). The decline in mortality since 2000 was comparable at all three levels of wealth, and the decline between the 2000 and 2010 surveys was significant for each wealth tercile, suggesting equity in progress in neonatal survival.

Figure 3.7. Neonatal mortality rate (five-year rate), by wealth tercile, Rwanda 2000, 2005, and 2010



In all three surveys the NMR was higher in households without access to an improved water source. Between the 2000 and 2010 surveys, the improvement in neonatal mortality was significant both in households with an improved water source and those without access. According to the 2000 survey, the NMR was nearly twice as high in households without access to an improved toilet, but this gap narrowed considerably by the time of the 2010 survey, with significant improvement for households lacking an improved toilet.

Contrary to our initial expectation, neonatal mortality was highest in households with the fewest members, and lowest in the largest households. This pattern was observed in all three surveys.

Characteristics of the mother. Table 3.6 presents trends in neonatal mortality, disaggregated by characteristics of the mother. According to all three surveys, the NMR was highest among mothers under age 18, lowest among mothers age 18-34, and somewhat elevated among mothers age 35+. In the 2010 survey the NMR among children born to women under age 18 was nearly twice that of children born to mothers age 18-34 (44 deaths per 1,000 live births compared with 25 deaths per 1,000 live births).

Table 3.6. Neonatal mortality rate (NMR) (five-year rate) and the difference in NMR between surveys, by selected characteristics of the mother, Rwanda 2000, 2005, and 2010

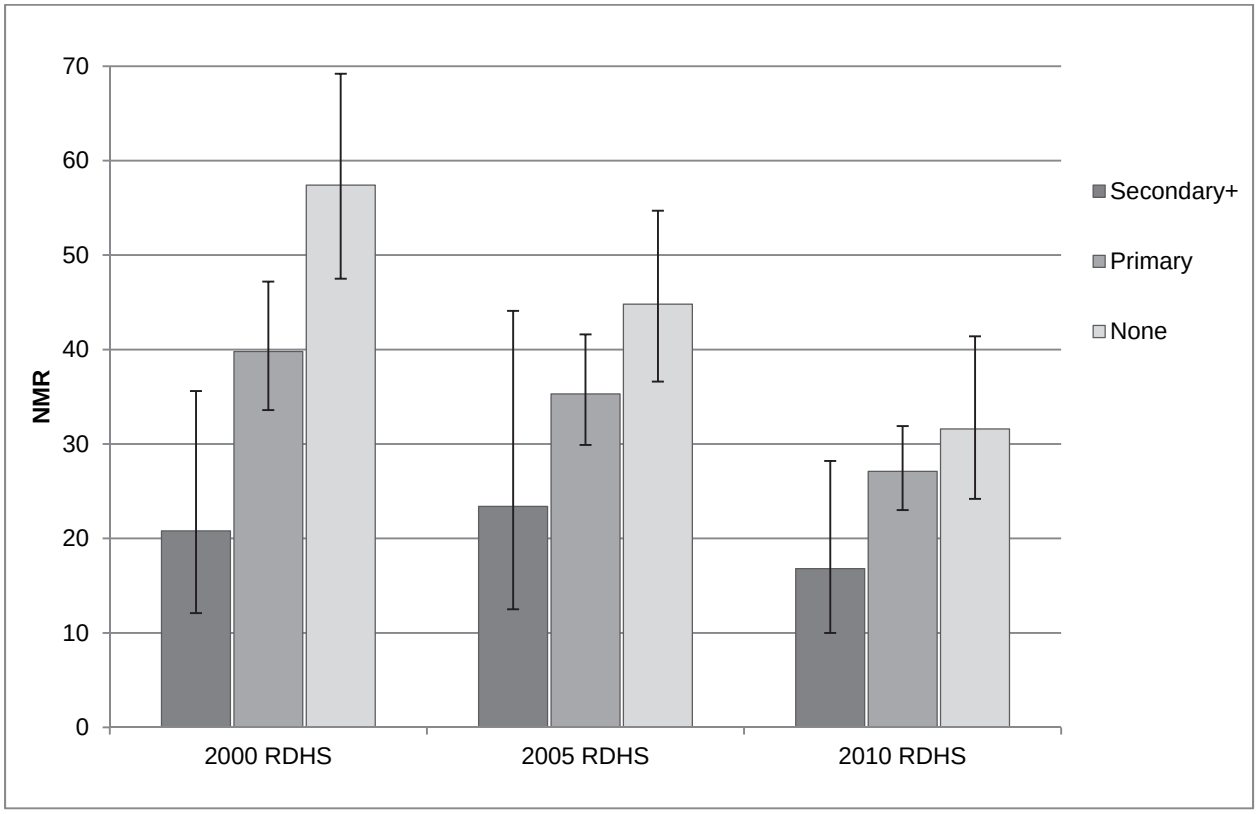
	2000 RDHS			2005 RDHS			2010 RDHS			Difference in NMR between surveys		
	Ref. period: 1996-2000			*Ref. period: 2001-2005*			*Ref. period: 2006-2010*					
Characteristics of the mother	**NMR**	**95% LB**	**95% UB**	**NMR**	**95% LB**	**95% UB**	**NMR**	**95% LB**	**95% UB**	**2000-2005**	**2005-2010**	**2000-2010**
Mother's age at child's birth												
18-34	41.3	35.8	47.8	35.7	31.0	41.1	24.6	21.0	28.9	-5.7	-11.0 ***	-16.7 ***
<18	78.5	44.5	138.4	69.2	29.5	162.2	44.1	16.6	116.9	-9.3	-25.1	-34.5
35+	48.4	38.4	61.1	39.1	30.9	49.6	35.0	26.6	46.0	-9.3	-4.1	-13.5
Marital status												
Currently in union	45.1	39.4	51.6	36.8	32.1	42.2	27.8	24.0	32.0	-8.3 *	-9.0 **	-17.4 ***
Not currently in union	37.9	28.2	51.0	38.2	27.9	52.2	22.8	15.3	34.0	0.3	-15.4 *	-15.1 *
Educational attainment												
Secondary or higher	20.8	12.1	35.6	23.4	12.5	44.1	16.8	10.0	28.2	2.7	-6.6	-4.0
Primary	39.8	33.6	47.2	35.3	29.9	41.6	27.1	23.0	31.9	-4.6	-8.2 *	-12.8 **
None	57.4	47.5	69.2	44.8	36.6	54.7	31.6	24.2	41.4	-12.6	-13.1 *	-25.7 ***
Body mass index (BMI)[1]												
Normal (2nd-3rd quartile)	45.6	38.1	54.5	31.0	24.0	40.0	30.3	23.9	38.4	-14.6 *	-0.7	-15.3 **
Low (1st quartile)	50.2	39.9	63.2	34.9	22.6	53.8	35.4	23.9	52.3	-15.3	0.5	-14.8
High (4th quartile)	36.7	28.9	46.6	39.1	28.5	53.6	35.1	24.4	50.4	2.4	-4.0	-1.6
Short stature[1]												
No (2nd-4th quartile)	39.3	33.8	45.7	32.0	25.6	40.0	28.6	22.8	36.0	-7.4	-3.3	-10.7 *
Yes (1st quartile)	57.7	46.6	71.6	38.8	28.5	52.7	42.8	32.1	57.0	-18.9 *	4.0	-15.0
Total	43.9	38.7	49.7	37.0	32.6	41.9	27.0	23.6	31.0	-6.9	-9.9 ***	-16.8 ***

Note: * indicates p<.05; ** indicates p<.01;*** indicates p<.001. Neonatal mortality rates are based on all births in the 1-60 months preceding the interview unless otherwise noted; N=8,249 for the 2000 RDHS, N=8,768 for the 2005 RHDS, and N=9,229 for the 2010 RDHS.

[1] Anthropometry was collected in every second household in 2005 and 2010, so estimates are based on a subset of all women; N=4,422 for the 2005 RHDS and N=4,658 for the 2010 RDHS. For the 2000 RDHS, due to missing height and weight information, body mass index percentages are based on 8,100 women and short stature percentages are based on 8,171 women.

In all three surveys, neonatal mortality was lowest among children born to women with at least a secondary education, and highest among children born to women with no education. Between 2000 and 2010, however, the education differential narrowed considerably, because neonatal mortality improved most among uneducated women (see Figure 3.8).

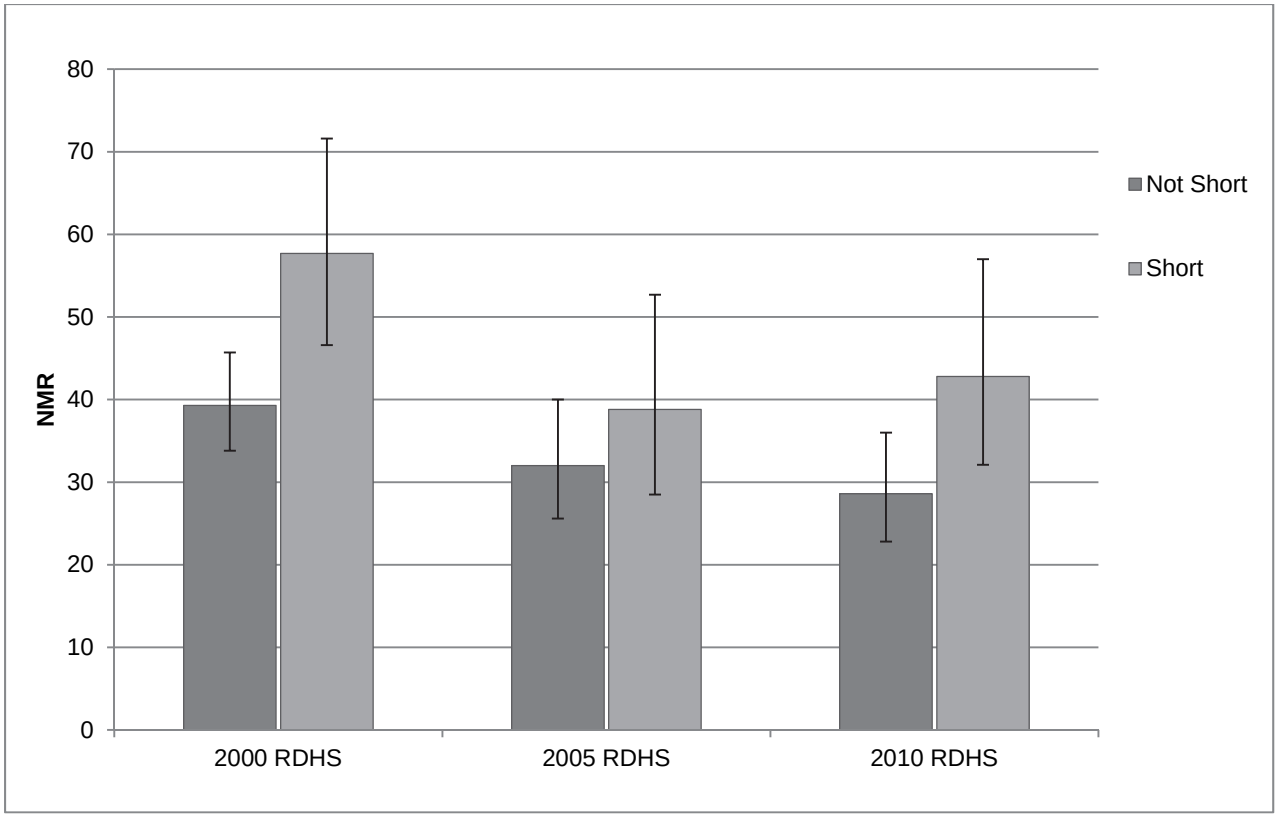
Figure 3.8. Neonatal mortality rate (five-year rate), by the mother's level of education, Rwanda 2000, 2005, and 2010



Neonatal mortality was expected to be higher among children born to mothers who were not married, but the opposite was found: In 2010, among women currently in union, the NMR was 28 deaths per 1,000 live births compared with 23 deaths per 1,000 live births among women not in union at the time of interview.

Short stature—an indicator of the mother's poor nutritional status early in life—was consistently associated with higher neonatal mortality risk (see Figure 3.9). In 2010 the NMR was 43 deaths per 1,000 live births to mothers of short stature, compared with 29 deaths per 1,000 live births to women of normal stature. The trend in neonatal mortality according to the mother's body mass index shifted somewhat during this period. For births during 1996-2000 the NMR was lowest among mothers in the highest BMI quartile, but for births during 2006-2010 the rate was lowest among mothers in the normal BMI range (the 2nd and 3rd quartiles).

Figure 3.9. Neonatal mortality rate (five-year rate), by the mother's height, Rwanda 2000, 2005, and 2010



Characteristics of the child. Table 3.7 presents neonatal mortality rates disaggregated by characteristics of the child. The NMR was consistently higher among male children, at 31 deaths per 1,000 live births compared with 23 deaths per 1,000 live births among female children, according to the 2010 RDHS. Also, the NMR was 133 among multiple births compared with 24 for singletons. Figure 3.10 highlights the trend in the NMR disaggregated by preceding birth interval. Among children born after a preceding birth interval less than 24 months, the NMR was 50 deaths per 1,000 live births compared with 18 deaths per 1,000 live births for an interval of 24 to 35 months, and 23 deaths per 1,000 live births for an interval of at least 36 months, according to the 2010 survey.

The improvement in neonatal mortality was significant between the 2000 RDHS and the 2010 RDHS among children born with optimal spacing and among children born after three or more years, but there was no significant change in neonatal mortality among children with a short preceding birth interval. Children of first and high-order births were at a disadvantage, according to the 2000 survey, but in the 2010 survey the neonatal mortality rates were similar across birth orders.

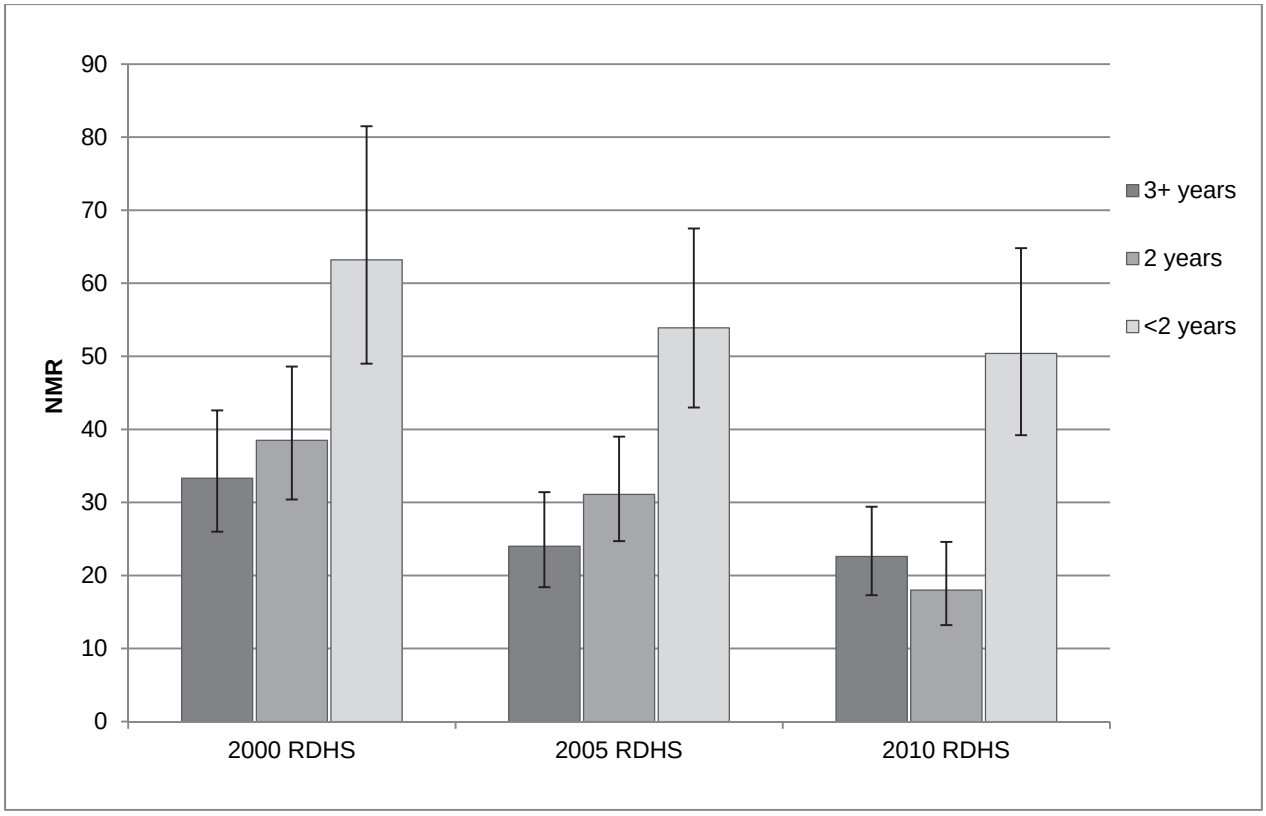
Table 3.7. Neonatal mortality rate (NMR) (five-year rate) and the difference in NMR between surveys, by selected characteristics of the child, Rwanda DHS 2000, 2005, and 2010

	2000 RDHS			2005 RDHS			2010 RDHS			Difference in NMR between surveys		
	Ref. period: 1996-2000			*Ref. period: 2001-2005*			*Ref. period: 2006-2010*					
Characteristics of the child	**NMR**	**95% LB**	**95% UB**	**NMR**	**95% LB**	**95% UB**	**NMR**	**95% LB**	**95% UB**	**2000-2005**	**2005-2010**	**2000-2010**
Sex of child												
Female	36.3	29.8	44.2	32.9	27.6	39.4	22.5	18.2	27.8	-3.4	-10.4 **	-13.8 **
Male	51.3	44.2	59.6	40.9	34.9	47.8	31.4	26.5	37.2	-10.5 *	-9.5 *	-20.0 ***
Multiple birth												
Single birth	39.5	34.7	44.9	33.1	29.0	37.7	23.8	20.6	27.6	-6.4	-9.2 **	-15.7 ***
Multiple birth	213.8	154.7	295.6	183.1	126.9	264.1	133.0	89.8	197.0	-30.7	-50.1	-80.8
Birth order												
First	50.3	39.7	63.6	47.6	37.6	60.2	27.6	21.6	35.4	-2.7	-19.9 **	-22.6 ***
Second	39.8	30.4	52.3	33.7	25.8	44.0	28.9	21.6	38.9	-6.1	-4.8	-10.9
Third	26.9	18.7	38.8	34.3	25.7	45.9	23.8	17.0	33.4	7.4	-10.5	-3.1
Fourth or higher	48.1	40.4	57.3	34.9	29.0	42.0	26.9	21.8	33.2	-13.2 *	-8.0	-21.2 ***
Birth interval[1]												
2 years	38.5	30.4	48.6	31.1	24.7	39.0	18.0	13.2	24.6	-7.4	-13.0 **	-20.4 ***
<2 years	63.2	49.0	81.5	53.9	43.0	67.5	50.4	39.2	64.8	-9.3	-3.5	-12.8
3+ years	33.3	26.0	42.6	24.0	18.4	31.4	22.6	17.3	29.4	-9.3	-1.5	-10.7 *
Total	43.9	38.7	49.7	37.0	32.6	41.9	27.0	23.6	31.0	-6.9	-9.9 ***	-16.8 ***

Note: * indicates p<.05; ** indicates p<.01;*** indicates p<.001. Neonatal mortality rates are based on all births in the 1-60 months preceding the interview unless otherwise noted; N=8,249 for the 2000 RDHS, N=8,768 for the 2005 RHDS, and N=9,229 for the 2010 RDHS.

[1] First births are excluded from the neonatal mortality rates disaggregated by birth interval; N=6,558 for the 2000 RDHS, N=7,107 for the 2005 RDHS, and N=6,900 for the 2010 RDHS.

Figure 3.10. Neonatal mortality rate (five-year rate), by the previous birth interval, Rwanda 2000, 2005, and 2010



Recommended maternal and delivery care. Table 3.8 presents disaggregated neonatal mortality rates by maternal and delivery care interventions. According to the 2010 survey, neonatal mortality was twice as high among children whose mothers did not have at least one ANC visit with a health professional, compared with children whose mothers had at least one visit. This pattern was similar in the two earlier surveys. There is also evidence across all three surveys that the number of ANC visits has an impact on neonatal mortality: mortality was highest among children whose mothers made no ANC visits and decreased as the number of ANC visits increased (see Figure 3.11).

Table 3.8. Neonatal mortality rate (NMR) (five-year rate) and the difference in NMR between surveys, by use of select recommended maternal and delivery care services and other relevant interventions, Rwanda 2000, 2005, and 2010

	2000 RDHS *Ref. period: 1996-2000*			2005 RDHS *Ref. period: 2001-2005*			2010 RDHS *Ref. period: 2006-2010*			Difference in NMR between surveys		
	NMR	95% LB	95% UB	NMR	95% LB	95% UB	NMR	95% LB	95% UB	2000-2005	2005-2010	2000-2010
RECOMMENDED MATERNAL AND DELIVERY CARE												
ANC from a health professional[1]												
Yes	28.3	23.4	34.3	21.4	17.5	26.3	13.7	11.0	17.1	-6.9 *	-7.7 **	-14.6 ***
No	43.4	25.0	75.3	50.2	30.9	81.5	26.7	9.4	75.8	6.7	-23.4	-16.7
Number of ANC visits attended[1]												
4+	18.4	9.3	36.5	9.8	4.7	20.7	10.7	6.8	16.8	-8.6	0.9	-7.7
3	20.9	15.3	28.7	19.7	13.9	28.1	13.9	10.0	19.2	-1.2	-5.9	-7.0
2	30.1	21.6	41.8	26.9	19.2	37.6	16.2	9.8	26.8	-3.2	-10.7	-13.9 *
1	54.4	39.0	75.7	25.4	16.1	40.2	29.0	14.1	59.6	-28.9 **	3.5	-25.4
0	44.4	25.6	76.9	54.3	34.1	86.6	37.1	16.5	83.3	9.9	-17.2	-7.3
Mother received tetanus injections[1]												
2+	24.7	18.0	34.0	15.5	9.9	24.4	14.3	9.9	20.6	-9.2	-1.3	-10.5 *
1	28.1	21.2	37.2	21.6	16.1	29.1	10.8	7.3	16.0	-6.4	-10.8 **	-17.3 ***
0	35.9	26.8	48.0	28.8	21.4	38.6	19.8	13.6	28.7	-7.1	-9.0	-16.1 *
Delivered by a health professional[2]												
Yes	37.8	30.1	47.3	33.8	26.6	42.8	26.0	21.9	30.8	-4.0	-7.8	-11.8 **
No	45.1	39.0	52.2	36.4	31.4	42.1	27.7	21.7	35.4	-8.7 *	-8.6	-17.4 ***
Delivered in health facility[2]												
Yes	38.4	30.8	47.9	34.7	27.4	43.8	26.5	22.4	31.4	-3.8	-8.1	-11.9 **
No	45.0	38.9	52.0	36.3	31.3	42.0	27.2	21.3	34.8	-8.7 *	-9.1 *	-17.8 ***
ANC - place of delivery interaction[1]												
Both	13.4	4.7	38.4	12.1	4.2	34.5	12.0	7.4	19.3	-1.4	-0.1	-1.5
4+ ANC visits only	23.0	9.1	57.9	7.7	2.3	25.8	5.1	1.3	20.5	-15.2	-2.6	-17.8
Delivered in health facility only	32.7	22.7	46.9	28.6	19.6	41.6	15.5	11.5	21.0	-4.1	-13.0 *	-17.1 **
Neither	30.4	24.5	37.6	23.9	19.0	30.1	16.4	10.8	25.0	-6.5	-7.5	-13.9 *

(Continued...)

Table 3.8. – *Continued*

	2000 RDHS Ref. period: 1996-2000			2005 RDHS Ref. period: 2001-2005			2010 RDHS Ref. period: 2006-2010			Difference in NMR between surveys					
	NMR	95% LB	95% UB	NMR	95% LB	95% UB	NMR	95% LB	95% UB	2000-2005		2005-2010		2000-2010	
Early initiation of breastfeeding (within one hour)[1]															
Yes	13.9	9.9	19.6	8.6	5.8	12.8	6.7	4.5	9.9	-5.2		-1.9		-7.2	**
No	42.5	34.5	52.3	48.7	39.3	60.2	31.1	24.0	40.3	6.2		-17.5	**	-11.3	
OTHER INTERVENTIONS RELEVANT TO NEONATAL SURVIVAL															
Mother has health insurance[3]															
Yes	n/a			35.9	29.5	43.7	27.1	23.1	31.8			-8.8	*		
No				37.8	32.3	44.2	26.9	20.7	34.8			-10.9	*		
Household owns a mosquito net[3]															
Net	21.5	11.9	38.6	26.5	19.7	35.8	25.0	21.5	29.1	5.1		-1.5		3.6	
No net	45.9	40.4	52.1	40.2	35.1	46.0	56.2	36.9	85.4	-5.7		16.0		10.3	
Mother slept under a net previous night[3]															
Net	21.7	10.6	44.4	27.0	19.6	37.2	24.9	21.1	29.4	5.3		-2.1		3.2	
No net	45.3	39.9	51.5	39.2	34.4	44.7	34.4	26.3	45.1	-6.1		-4.8		-10.9	
Total	43.9	38.7	49.7	37.0	32.6	41.9	27.0	23.6	31.0	-6.9		-9.9	***	-16.8	***

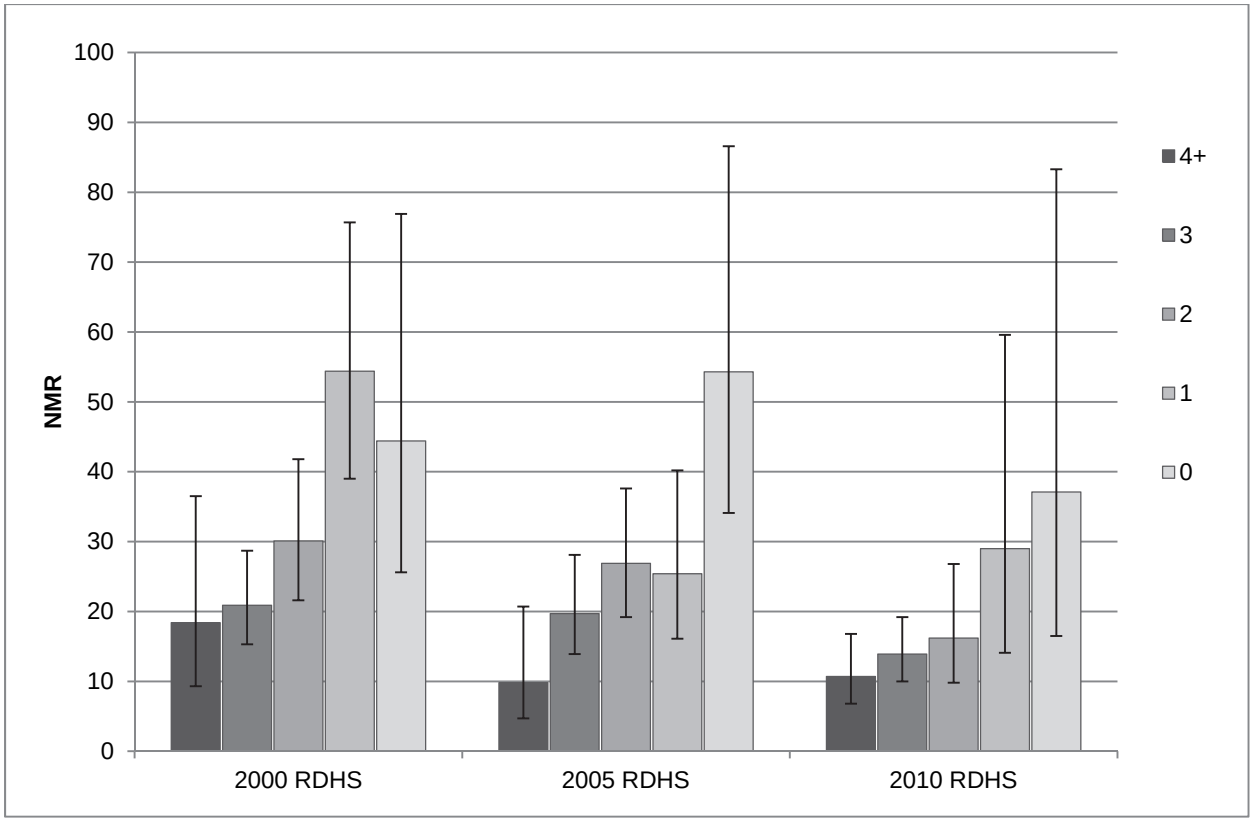
Note: * indicates p<.05; ** indicates p<.01;*** indicates p<.001.

[1] Neonatal mortality rates are based on women's most recent birth in the 1-59 months preceding the interview; N=5,062 for the 2000 RDHS, N=5,318 for the 2005 RHDS, and N=6,355 for the 2010 RDHS.

[2] Neonatal mortality rates are based on all births in the 1-59 months preceding the interview; N=8,108 for the 2000 RDHS, N=8,608 for the 2005 RHDS, and N=9,087 for the 2010 RDHS.

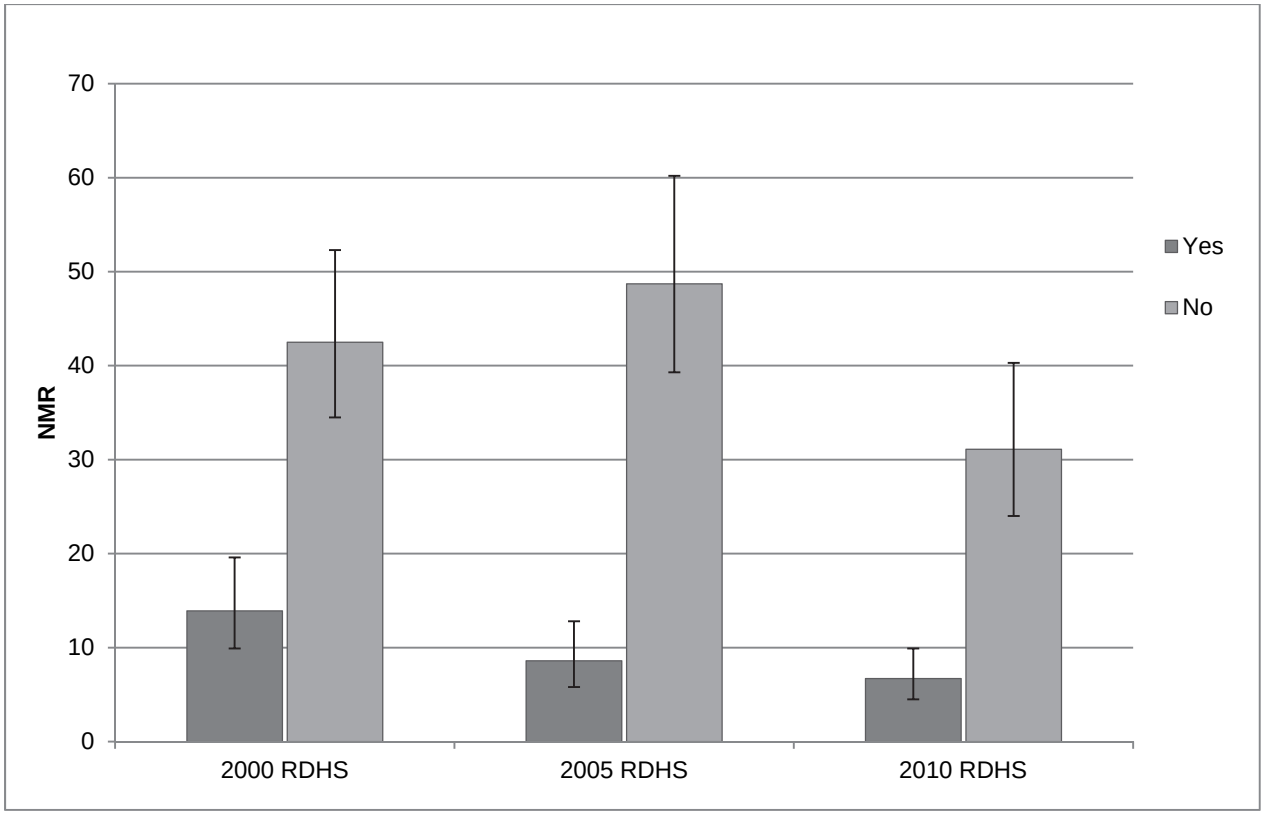
[3] Neonatal mortality rates are based on all births in the 1-60 months preceding the interview; N=8,249 for the 2000 RDHS, N=8,768 for the 2005 RHDS, and N=9,229 for the 2010 RDHS.

Figure 3.11. Neonatal mortality rate (five-year rate), by the number of ANC visits made, Rwanda 2000, 2005, and 2010



In all three surveys neonatal mortality was higher among children whose mothers had not received the recommended two tetanus toxoid (TT) injections during the pregnancy. Also, as Figure 3.12 illustrates, neonatal mortality was substantially higher (more than five times higher in the 2010 survey) among infants who were not breastfed within the first hour of life. For children born in the five years preceding the 2000 survey, neonatal mortality was higher among those not delivered in a facility and among those not delivered by a health professional, but this difference nearly disappeared in the two subsequent surveys. In the 2010 survey, for example, there was no difference in the NMR associated with place of delivery (facility versus non-facility); the NMR was 27 deaths per 1,000 live births in both groups.

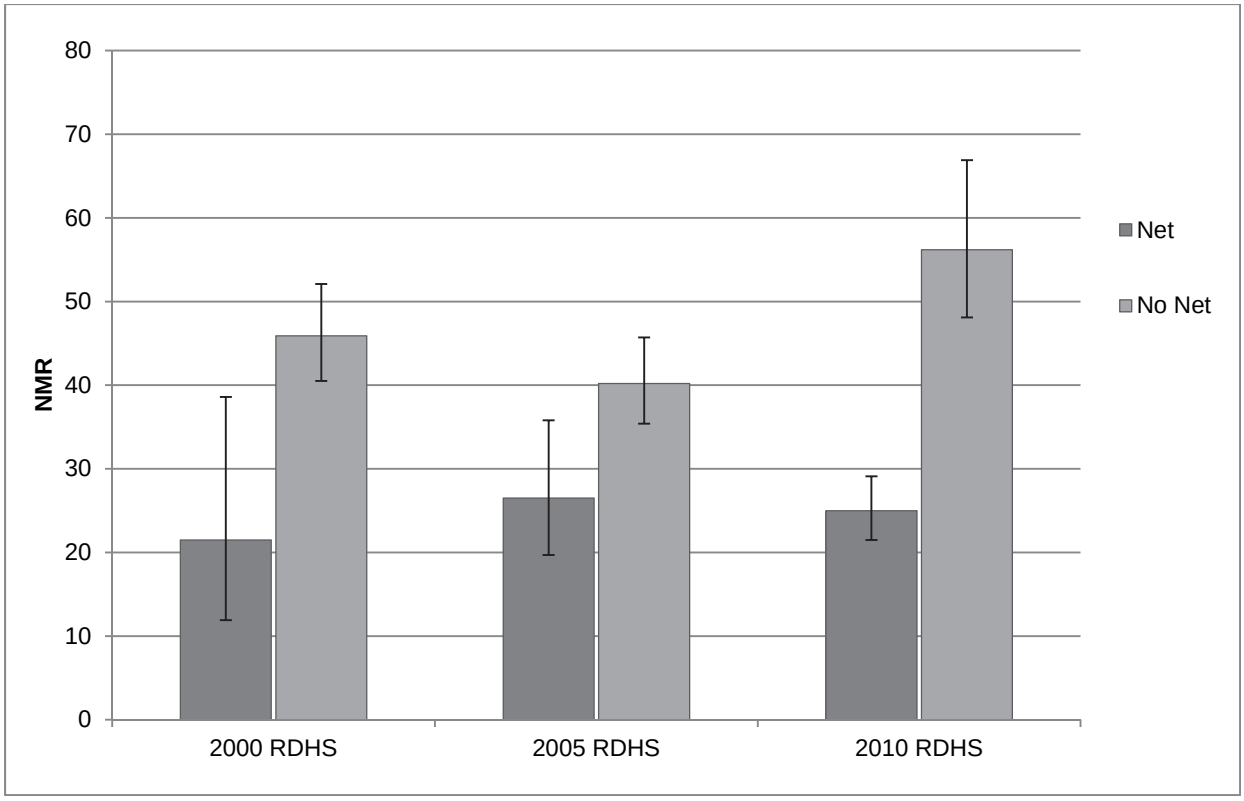
Figure 3.12. Neonatal mortality rate (five-year rate), by whether the child was breastfed in the first hour of life, Rwanda 2000, 2005, and 2010



Other intervention-related indicators. Table 3.8 also presents disaggregated neonatal mortality rates by indicators of coverage of two major health interventions in Rwanda: the promotion of universal health insurance coverage, which could improve neonatal survival by increasing access to and use of maternal and child care services, and mosquito net campaigns, which could improve neonatal survival by lowering transmission of malaria to women during pregnancy.

The NMR does not appear to differ according to mothers' health insurance status, although (as described earlier) having health insurance is associated with increased utilization of health services. However, in all three surveys the NMR was substantially higher for children born into households that did not own a mosquito net at the time of the interview than for children born into households that owned a net (see Figure 3.13). Also, neonatal mortality was higher among mothers who had not slept under a mosquito net the night before the interview.

Figure 3.13. Neonatal mortality rate (five-year rate), by whether the household owns a mosquito net, Rwanda 2000, 2005, and 2010



3.3 Results of Multivariate Analysis

A multivariate analysis was carried out to examine which characteristics of the household, mother, child, and maternal and delivery care are significantly associated with neonatal mortality in Rwanda, and to identify which associations remain significant after controlling for key factors that may confound these associations. Log probability models were used to examine the probability of dying during the first month of life. In such a model the exponentiated intercept is the fitted NMR for the reference group or category of the model. The exponentiated slopes are interpreted as relative risks or risk ratios (RR), which compare the probability of dying in one group relative to the probability of dying in the reference group or category. An RR greater than 1.0 indicates higher risk of mortality, and an RR smaller than 1.0 indicates lower risk of mortality relative to the reference category.

Table 3.9 presents unadjusted and adjusted relative risks for neonatal mortality by socio-demographic characteristics of the household, mother, and child, among children born in the five-year period preceding each survey. The adjusted model controls for key socio-demographic characteristics of the household (place of residence, province, wealth tercile, household size, access to an improved water source, and access to an improved non-shared toilet facility), the mother (mother's age at the child's birth, marital status, and educational attainment), and the child (sex, birth order, and birth interval).

Household-level characteristics. Among children born in the five years preceding the 2010 RDHS, few household-level characteristics were significantly associated with neonatal mortality. Only the number of household members remained significant in the adjusted model, such that children born

into large families (8+ members) were 70% less likely to die during the neonatal period compared with children born into the smallest families (<5 members). In the two earlier surveys children born into rural households were at a disadvantage, but this disadvantage had largely disappeared in the 2010 survey. It is possible that household characteristics are more important to survival at post-neonatal and early childhood ages than in the neonatal period.

Mother-level characteristics. Among children born in the five years preceding the 2010 survey, those whose mothers were age 35 or older had twice the risk of dying in the first month of life compared with children whose mothers were age 18-34, after adjusting for socio-demographic characteristics. This association was similar in the 2005 survey, but was not statistically significant in the 2000 survey. While children whose mothers had no education were at a disadvantage in all three surveys in the unadjusted model, after controlling for socio-demographic characteristics the association was only significant in the 2000 survey. In the unadjusted model, children whose mothers were of short stature—indicating a nutritional deficit early in life—were 1.5 times more likely to die in the first month of life compared with children whose mothers were of normal stature[5].

Child-level characteristics. In the 2010 survey being male and being born after a short interval (<2 years) were significantly associated with elevated risk of neonatal death in adjusted models. For example, children born after an interval of less than two years were three times more likely to die in the first month of life than children born after a two-year interval, after adjusting for socio-demographic factors. Multiplicity of birth was also a highly significant predictor of neonatal death. Children of a multiple birth were six times more likely to die in the first month of life than singleton births, in the unadjusted model.[6]

[5] Short stature was not included in the adjusted model, since height information was only collected in a subset of all households in 2005 and 2010, and the sample size would have been greatly reduced; thus only the unadjusted associations are presented.

[6] Multiplicity of birth was not included in the adjusted model due to the small number of multiple births.

Table 3.9. Unadjusted and adjusted effects of selected characteristics of the household, mother, and child on neonatal mortality among children born in the five years preceding the surveys, Rwanda 2000, 2005, and 2010

	2000 RDHS *Ref. period: 1996-2000*								2005 RDHS *Ref. period: 2001-2005*								2010 RDHS *Ref. period: 2006-2010*							
	uRR	95% LB	95% UB	Sig.	aRR	95% LB	95% UB	Sig.	uRR	95% LB	95% UB	Sig.	aRR	95% LB	95% UB	Sig.	uRR	95% LB	95% UB	Sig.	aRR	95% LB	95% UB	Sig.
CHARACTERISTICS OF THE HOUSEHOLD																								
Place of residence																								
Urban	1.0				1.0				1.0				1.0				1.0				1.0			
Rural	1.9	1.4	2.6	***	1.5	1.0	2.4		1.7	1.2	2.4	**	1.4	0.9	2.1		1.2	0.8	2.0		0.9	0.4	2.0	
Province																								
Kigali	1.0				1.0				1.0				1.0				1.0				1.0			
South	1.2	0.7	1.9		0.7	0.4	1.2		1.4	0.8	2.5		0.9	0.5	1.8		1.3	0.7	2.6		1.2	0.5	2.9	
West	1.2	0.7	1.9		0.7	0.5	1.2		1.4	0.8	2.4		1.0	0.5	1.9		1.4	0.7	2.7		1.3	0.5	3.2	
North	1.0	0.6	1.7		0.6	0.4	1.1		1.4	0.8	2.5		1.0	0.5	2.0		1.7	0.9	3.4		1.6	0.7	3.9	
East	1.1	0.6	1.8		0.6	0.4	1.1		1.8	1.0	3.1	*	1.1	0.6	2.1		1.5	0.8	2.9		1.4	0.6	3.4	
Wealth tercile																								
Highest	1.0				1.0				1.0				1.0				1.0				1.0			
Middle	1.1	0.8	1.4	ns	0.8	0.6	1.1		1.1	0.8	1.4		0.9	0.7	1.3		1.3	0.9	1.8		1.1	0.7	1.7	
Lowest	1.4	1.0	1.8	*	1.0	0.7	1.3		1.2	0.9	1.6		1.1	0.8	1.6		1.4	1.0	2.1		1.2	0.8	1.8	
Household size																								
<5 residents	1.0				1.0				1.0				1.0				1.0				1.0			
5-7 residents	0.5	0.4	0.6	***	0.4	0.3	0.5	***	0.4	0.3	0.5	***	0.4	0.3	0.5	***	0.5	0.4	0.7	***	0.4	0.3	0.6	***
8+ residents	0.5	0.4	0.8	**	0.4	0.2	0.6	***	0.4	0.2	0.5	***	0.2	0.1	0.4	***	0.4	0.3	0.7	***	0.3	0.1	0.5	***
Household access to improved water source[1]																								
Improved	1.0				1.0				1.0				1.0				1.0				1.0			
Not improved	1.2	0.9	1.6		1.0	0.8	1.4		1.2	0.9	1.6		1.1	0.8	1.5		1.2	0.9	1.6		1.1	0.8	1.5	
Household access to improved toilet[2]																								
Improved	1.0				1.0				1.0				1.0				1.0				1.0			
Not improved	2.0	0.9	4.2		1.4	0.7	3.1		0.9	0.7	1.2		0.8	0.6	1.1		1.1	0.9	1.5		1.1	0.8	1.5	

(Continued...)

Table 3.9. – *Continued*

	2000 RDHS *Ref. period: 1996-2000*								2005 RDHS *Ref. period: 2001-2005*								2010 RDHS *Ref. period: 2006-2010*							
	uRR	95% LB	95% UB	Sig.	aRR	95% LB	95% UB	Sig.	uRR	95% LB	95% UB	Sig.	aRR	95% LB	95% UB	Sig.	uRR	95% LB	95% UB	Sig.	aRR	95% LB	95% UB	Sig.
CHARACTERISTICS OF THE MOTHER																								
Mother's age at child's birth																								
18-34	1.0				1.0				1.0				1.0				1.0				1.0			
<18	1.9	1.1	3.4	*	1.6	0.9	2.9		1.9	0.9	4.4		2.0	0.9	4.4		1.8	0.7	4.3		2.1	0.8	5.3	
35+	1.2	0.9	1.5		1.2	0.8	1.8		1.1	0.8	1.4		1.6	1.2	2.3	**	1.4	1.0	1.9	*	2.0	1.4	3.0	***
Marital status																								
Currently in union	1.0				1.0				1.0				1.0				1.0				1.0			
Not currently in union	0.8	0.6	1.2		0.8	0.5	1.0		1.0	0.7	1.5		1.0	0.7	1.5		0.8	0.5	1.2		0.8	0.5	1.3	
Educational attainment																								
Secondary or higher	1.0				1.0				1.0				1.0				1.0				1.0			
Primary	1.9	1.1	3.4	*	1.6	0.9	2.9		1.5	0.8	2.8		1.2	0.7	2.2		1.6	0.9	2.8		1.4	0.7	2.5	
None	2.8	1.6	4.9	***	2.2	1.1	4.1	*	1.9	1.0	3.6	*	1.5	0.8	2.8		1.9	1.0	3.4	*	1.5	0.7	2.9	
Body mass index (BMI)[3]																								
Normal (2nd-3rd quartile)	1.0								1.0								1.0							
Low (1st quartile)	1.1	0.8	1.5						1.1	0.7	1.8						1.2	0.7	1.8					
High (4th quartile)	0.8	0.6	1.1						1.3	0.8	1.9						1.2	0.7	1.8					
Short stature[3]																								
No (2nd-4th quartile)	1.0								1.0								1.0							
Yes (1st quartile)	1.5	1.1	1.9	**					1.2	0.8	1.8						1.5	1.0	2.2	*				
CHARACTERISTICS OF THE CHILD																								
Sex of child																								
Female	1.0				1.0				1.0				1.0				1.0				1.0			
Male	1.4	1.1	1.8	**	1.4	1.1	1.8	**	1.2	1.0	1.6		1.2	1.0	1.5		1.4	1.1	1.8	*	1.4	1.1	1.8	*
Multiple birth																								
Single birth	1.0								1.0								1.0							
Multiple birth	5.4	3.8	7.7	***					5.5	3.8	8.0	***					5.6	3.7	8.4	***				

(Continued...)

Table 3.9. – *Continued*

	2000 RDHS *Ref. period: 1996-2000*								2005 RDHS *Ref. period: 2001-2005*								2010 RDHS *Ref. period: 2006-2010*							
	uRR	95% LB	95% UB	Sig.	aRR	95% LB	95% UB	Sig.	uRR	95% LB	95% UB	Sig.	aRR	95% LB	95% UB	Sig.	uRR	95% LB	95% UB	Sig.	aRR	95% LB	95% UB	Sig.
Birth order																								
First	1.0				1.0				1.0				1.0				1.0				1.0			
Second	0.8	0.6	1.1		0.8	0.5	1.2		0.7	0.5	1.0	*	0.7	0.5	1.0		1.0	0.7	1.5		0.7	0.4	1.1	
Third	0.5	0.3	0.8	**	0.7	0.4	1.1		0.7	0.5	1.1		1.0	0.7	1.6		0.9	0.6	1.3		0.8	0.4	1.5	
Fourth or higher	1.0	0.7	1.3		1.5	0.9	2.3		0.7	0.5	1.0	*	1.2	0.8	1.8		1.0	0.7	1.3		1.0	0.5	1.8	
Birth interval																								
2 years	1.0				1.0				1.0				1.0				1.0				1.0			
<2 years	1.6	1.2	2.3	**	1.6	1.1	2.3	**	1.7	1.3	2.3	***	1.7	1.2	2.3	***	2.8	1.9	4.1	***	2.9	1.9	4.3	***
3+ years	0.9	0.6	1.2		0.8	0.6	1.1		0.8	0.5	1.1		0.6	0.4	0.9	*	1.3	0.8	1.9		1.1	0.7	1.7	
First birth	1.3	0.9	1.8		0.7	0.4	1.1		1.5	1.1	2.1	*	0.8	0.5	1.3		1.5	1.0	2.3	*	1.0	0.6	1.8	

Note: * indicates p<.05; ** indicates p<.01;*** indicates p<.001. Relative risk estimates are based on all births in the 1-60 months preceding the interview unless otherwise noted; N=8,249 for the 2000 RDHS, N=8,768 for the 2005 RHDS, and N=9,229 for the 2010 RDHS. Adjusted relative risk estimates control for characteristics of the household (urban residence, wealth tercile, province, household size, access to an improved water source, and access to an improved non-shared toilet), characteristics of the mother (age at child's birth, marital status, and level of education) and characteristics of the child (sex, birth order, and birth interval). Multiple birth was not included in the adjusted model because the few number of cases of multiple births resulted in empty cells. BMI and short stature were excluded from the adjusted model because these were only collected from half of all households in 2005 and 2010, and would have substantially reduced the sample size.

[1] An improved water source refers to any of the following: piped water into the dwelling, yard, or plot; a public tap or standpipe, tubewell, or borehole; a protected dug well or protected spring; rainwater; or bottled water.

[2] An improved toilet source refers to any of the following types of facilities, as long as the facility is not shared with another household: a flush or pour flush to piped sewer system, septic tank, or pit latrine; a ventilated improved pit (VIP) latrine; a pit latrine with a slab; or a composting toilet.

[3] Anthropometry was collected in every second household in 2005 and 2010, so risk ratio estimates are based on a subset of all women; N=4,422 for the 2005 RHDS and N=4,658 for the 2010 RDHS. For the 2000 RDHS, due to missing height and weight information, body mass index percentages are based on 8,100 women and short stature percentages are based on 8,171 women.

Table 3.10 presents unadjusted and adjusted relative risks for neonatal mortality by the mother's use of selected maternal and child health services, and by coverage of other relevant interventions, among births in the five-year period preceding each survey. In Table 3.10 the adjusted model controls for the same socio-demographic characteristics included in the adjusted model in Table 3.9. The adjusted results in Table 3.10 indicate whether each recommended maternal and neonatal intervention is significantly associated with a lower probability of neonatal mortality after controlling for likely confounders.

Recommended maternal and delivery care. The number of antenatal care visits that a mother had made was significantly associated with neonatal survival. According to the 2010 RDHS, after adjusting for socio-demographic factors, children whose mothers had made no ANC visits were three times more likely to die in the first month of life compared with children whose mothers had made at least four visits. While not having received the recommended two tetanus injections during the pregnancy was significantly associated with neonatal mortality in the 2005 survey, the association was not significant in the 2010 survey. Consistent with our findings in the disaggregated rates of neonatal mortality, the regression analysis showed no evidence that delivery by a health professional or in a health facility was associated with neonatal mortality.

The data indicate a strong and significant positive association between early initiation of breastfeeding and neonatal survival. However, it is possible that this observed association is due partially to reverse causality, because newborns with life threatening conditions may not be put to the breast or may be unable to breastfeed. To investigate the likelihood of reverse causation, the analysis was repeated omitting all deaths that occurred on either the day of birth or on the next day (days 0 and 1), in an attempt to exclude newborns with severe illness from birth. With these infants omitted, the association was reduced, remaining statistically significant in the 2000 and 2005 surveys but not in the 2010 survey (aRR 2000: 1.93, p=.01; aRR 2005: 1.83, p=0.04, aRR 2010: 1.82, p=0.10). The reduction in the magnitude of this association (for example, after omitting deaths in days 0 and 1, the adjusted risk ratio in 2010 was reduced from 5.1 to 1.8) suggests that reverse causation explains a large portion of the observed association. However, the continued significance of the adjusted association in the 2000 and 2005 surveys suggests a protective effect of breastfeeding on neonatal survival.

Table 3.10. Unadjusted and adjusted effects of the mother's use of recommended maternal and delivery care services and coverage of other relevant interventions on neonatal mortality, among children born in the five years preceding the surveys, Rwanda 2000, 2005, and 2010

	2000 RDHS *Ref. period: 1996-2000*								2005 RDHS *Ref. period: 2001-2005*								2010 RDHS *Ref. period: 2006-2010*							
	uRR	95% LB	95% UB	Sig.	aRR	95% LB	95% UB	Sig.	uRR	95% LB	95% UB	Sig.	aRR	95% LB	95% UB	Sig.	uRR	95% LB	95% UB	Sig.	aRR	95% LB	95% UB	Sig.
RECOMMENDED MATERNAL AND DELIVERY CARE																								
ANC from a health professional[1]																								
Yes	1.0				1.0				1.0				1.0				1.0				1.0			
No	1.5	0.9	2.7		1.3	0.7	2.4		2.3	1.4	3.9	**	2.0	1.2	3.4	**	1.9	0.6	6.0		1.9	0.6	5.9	
Number of ANC visits attended[1]																								
4+	1.0				1.0				1.0				1.0				1.0				1.0			
3	1.1	0.5	2.4		1.0	0.5	2.1		2.0	0.9	4.7		1.9	0.8	4.5		1.3	0.7	2.3		1.3	0.7	2.2	
2	1.6	0.8	3.4		1.3	0.6	2.7		2.7	1.2	6.2	*	2.5	1.1	5.7	*	1.5	0.8	3.0		1.4	0.7	2.8	
1	3.0	1.4	6.3	**	2.4	1.1	5.1	*	2.6	1.1	6.2	*	2.4	1.0	5.8	*	2.7	1.2	6.1	*	1.9	0.8	4.4	
0	2.4	1.0	5.8		1.8	0.7	4.3		5.5	2.3	13.4	***	4.5	1.9	10.8	***	3.5	1.3	9.5	*	3.2	1.2	8.7	*
Mother received tetanus injections[1]																								
2+	1.0				1.0				1.0				1.0				1.0				1.0			
1	1.1	0.7	1.7		1.2	0.8	1.8		1.4	0.8	2.4		1.5	0.9	2.7		0.8	0.4	1.3		0.9	0.5	1.6	
0	1.5	0.9	2.2		1.5	0.9	2.3		1.9	1.1	3.2	*	2.2	1.2	4.1	*	1.4	0.8	2.3		1.4	0.7	2.6	
Delivered by a health professional[2]																								
Yes	1.0				1.0				1.0				1.0				1.0				1.0			
No	1.2	0.9	1.6		1.0	0.7	1.3		1.1	0.8	1.4		1.0	0.8	1.4		1.1	0.8	1.4		1.1	0.8	1.5	
Delivered in health facility[2]																								
Yes	1.0				1.0				1.0				1.0				1.0				1.0			
No	1.2	0.9	1.5		1.0	0.7	1.3		1.0	0.8	1.4		1.0	0.7	1.4		1.0	0.8	1.4		1.0	0.7	1.4	
4+ ANC visits - place of delivery combination[1]																								
Both	1.0				1.0				1.0				1.0				1.0				1.0			
4+ ANC visits only	1.7	0.4	6.8		1.1	0.3	4.5		0.6	0.1	2.9		0.5	0.1	2.2		0.4	0.1	1.9		0.4	0.1	1.6	
Delivered in health facility only	2.4	0.8	7.4		1.9	0.6	5.8		2.4	0.8	6.9		2.2	0.7	6.4		1.3	0.7	2.3		1.2	0.7	2.2	
Neither	2.3	0.8	6.6		1.3	0.4	4.0		2.0	0.7	5.5		1.5	0.5	4.2		1.4	0.7	2.6		1.1	0.6	2.2	
Early initiation of breastfeeding (within one hour)[1]																								
Yes	1.0				1.0				1.0				1.0				1.0				1.0			
No	3.1	2.0	4.6	***	3.2	2.1	4.8	***	5.6	3.6	8.7	***	5.3	3.4	8.5	***	4.6	2.9	7.4	***	5.1	3.0	8.6	***

(Continued...)

Table 3.10. – *Continued*

	2000 RDHS *Ref. period: 1996-2000*								2005 RDHS *Ref. period: 2001-2005*								2010 RDHS *Ref. period: 2006-2010*							
	uRR	95% LB	95% UB	Sig.	aRR	95% LB	95% UB	Sig.	uRR	95% LB	95% UB	Sig.	aRR	95% LB	95% UB	Sig.	uRR	95% LB	95% UB	Sig.	aRR	95% LB	95% UB	Sig.
OTHER INTERVENTIONS RELEVANT TO NEONATAL SURVIVAL																								
Mother has health insurance[3]																								
Yes	n/a				n/a				1.0				1.0				1.0				1.0			
No									1.1	0.8	1.4		1.0	0.8	1.3		1.0	0.7	1.3		0.9	0.7	1.3	
Household owns a mosquito net[3]																								
Net	1.0				1.0				1.0				1.0				1.0				1.0			
No net	2.1	1.2	3.8	**	1.5	0.8	2.8		1.5	1.1	2.1	**	1.4	1.0	1.8	*	2.2	1.4	3.5	***	2.1	1.4	3.3	***
Mother slept under a net previous night[3]																								
Net	1.0				1.0				1.0				1.0				1.0				1.0			
No net	2.1	1.0	4.3	*	1.6	0.8	3.3		1.5	1.0	2.0	*	1.4	1.0	1.9	*	1.4	1.0	1.9		1.5	1.1	2.0	*

Note: * indicates p<.05; ** indicates p<.01;*** indicates p<.001. Adjusted relative risk estimates control for characteristics of the household (urban residence, wealth tercile, province, household size, access to an improved water source, and access to an improved non-shared toilet), characteristics of the mother (age at child's birth, marital status, and level of education) and characteristics of the child (sex, birth order, and birth interval). Multiple birth was not included in the adjusted model because the few number of cases of multiple births resulted in empty cells. BMI and short stature were excluded from the adjusted model because these were only collected from one half of households in 2005 and 2010, and would have substantially reduced the sample size.

[1] Relative risk estimates are based on women's most recent birth in the 1-59 months preceding the interview; N=5,062 for the 2000 RDHS, N=5,318 for the 2005 RHDS, and N=6,355 for the 2010 RDHS.

[2] Relative risk estimates are based on all births in the 1-59 months preceding the interview; N=8,108 for the 2000 RDHS, N=8,608 for the 2005 RHDS, and N=9,087 for the 2010 RDHS.

[3] Relative risk estimates are based on all births in the 1-60 months preceding the interview; N=8,249 for the 2000 RDHS, N=8,768 for the 2005 RHDS, and N=9,229 for the 2010 RDHS.

Other interventions relevant to neonatal survival. Household ownership of a mosquito net and the mother having slept under a mosquito net the night before the interview were significantly associated with neonatal survival in adjusted models in the 2005 and 2010 surveys. Recall that these two indicators are based on the household situation at the time of interview but are used here as proxies for mosquito net ownership and use during the mother's pregnancy, the period during which protection against malaria would most likely contribute to neonatal survival. In the 2010 RDHS children born into households that did not own a mosquito net were twice as likely to die in the first month compared with children born into households that owned a mosquito net, after adjusting for socio-demographic factors. Similarly, children whose mothers had not slept under a mosquito net the night before interview were twice as likely to die during the neonatal period, in the adjusted model.

3.4 Multivariate Decomposition Results

While the previous section describes associations between indicators and the neonatal mortality rate within individual surveys, this section attempts to identify which factors are associated with the reduction in the NMR between surveys in Rwanda. To address this question, the change in neonatal mortality across the surveys will be divided into two parts, one representing changes in the distribution of household, mother, or child characteristics, or the coverage of interventions ("endowments"), and the other representing the size of the effect of those characteristics or interventions ("coefficients").

When limited to the most recent birth, the decline in the NMR was 16 points between the 2000 and 2010 surveys, and 9 points between the 2005 and 2010 surveys (see Technical Note 3.1 for a warning about bias). As with the correctly constructed NMR (using all births in the past five years), most of the mortality decline was between the second and third surveys.

In both decompositions we test whether the selected household-level variables (urban residence, household size, improved water source, and improved toilet source), maternal-level variables (mother's age at the child's birth, marital status, and education), child-level variables (sex, preceding birth interval), and care and intervention-related indicators[7] (number of ANC visits, number of tetanus injections during the pregnancy, whether delivery was assisted by a health professional, whether delivery was in a health facility, and whether the household owned a mosquito net) are significantly associated with the observed reductions in neonatal mortality.

Technical Note 3.1:

Biases due to the restriction to the most recent birth

The decomposition analysis is limited to women's most recent birth in each five-year interval, simply because the interventions of primary interest are only assessed for the most recent birth.

The limitation to the most recent birth tends to bias the sample toward women who had only one birth in the five-year interval, and such women tend to be better educated, have longer birth intervals, etc. As a result, the NMR is somewhat lower for the most recent birth than it is for all births. Therefore, under a restriction to the most recent birth, interest should focus exclusively on changes and differences and not on the level of the NMR, because the estimates of the NMR are biased. The estimates of changes and differences may also be somewhat biased under this restriction, relative to what would be possible if data on the interventions were available for all births, but to a smaller degree.

[7] Early initiation of breastfeeding was not included in the decomposition models, due to issues with reverse causality.

In Table 3.11, the "endowments" column essentially quantifies the amount of decline in neonatal mortality explained by the change in *coverage* in each selected indicator between the two points in time, assuming that the effect of the indicator was constant across the entire period. The "coefficients" column quantifies the amount of decline in neonatal mortality explained by the change in *effects* between the two time points, if coverage (the distribution of each variable) had been constant across the entire period.

In the final row of table 3.11, "-15.9" indicates that the (biased) NMR declined by 16 points between the 2000 and 2010 surveys. Above that number, the endowment for "Household ownership of a mosquito net" is "-23.6," the largest single number in the endowments column. The interpretation of that number is that if nothing in the model had changed between the 2000 and 2010 reference periods *except the level* of mosquito net ownership, as indicated by the percentage of households that own a mosquito net, the NMR would have declined by 23.6 points—considerably more than the decline actually observed, and an amount that is significantly different from zero. In the same row the number for "coefficients" is -0.6, indicating that if nothing had changed between the 2000 and 2010 reference periods *except the benefits* of mosquito net use, as indicated by the coefficient in the estimation model, then the NMR would have declined by 0.6 points—which is negligible and not statistically significant.

The combined effect of all the changes in characteristics or coverage ("endowments") would have been to reduce the NMR by 28.3 points, virtually twice (a 177% decrease) the observed decline of 15.9 points. By contrast, the combined effect of all coefficients (improved impacts of characteristics on reducing the NMR) would actually have led to an *increase* of 12.3 points in the NMR (a 77% increase), rather than a reduction. Together, the two components sum to 100% (-177% + 77% = -100%) of the total observed NMR decline.

In both decompositions the total change in "endowments" (i.e., coverage) in the covariates explained a significant portion of the observed reduction in NMR, while the change in "coefficients" (i.e. effect) of these covariates was not significant (see Table 3.11), but the effect of the change in "coefficients" was in the opposite direction and served to reduce or dampen the effect of change in "endowments".

Since only the "endowments" portion of the results was significantly associated with the reduction in NMR, we focus the remaining discussion on these results.

Household, maternal, and child-level characteristics. The change in composition of household size during this period—and specifically, the increase in the percentage of households with fewer than five residents, which most often identifies newly formed, young families—was associated with a slight increase in neonatal mortality (an estimated 1 death per 1,000 live births, between the 2000 and 2010 surveys). In contrast, the change in composition of women's age at the child's birth—and specifically, the increasing percentage of mothers in the optimal 18-34 age range—was associated with an estimated reduction in neonatal mortality of 2 deaths per 1,000 live births between the 2000 and 2010 surveys.

We found no evidence that changes in the composition of births by urban-rural residence, the mother's marital status, or sex of the child contributed to the decline in neonatal mortality. We also found no evidence that the increasing trend in access to improved water and sanitation, or the increase in women's level of education, contributed to the decline in neonatal mortality, although the latter may have influenced the trend toward delayed pregnancy.

Recommended maternal and delivery care, and other relevant interventions. Of all the indicators included in our decomposition model, the dramatic increase in household ownership of a mosquito net was responsible for the greatest portion of the decline in neonatal mortality. On its own, as

noted above, the increase in mosquito net coverage was responsible for an estimated reduction in the NMR of 24 deaths per 1,000 live births between the 2000 and 2010 surveys, and a reduction of 20 deaths per 1,000 live births between the 2005 and 2010 surveys.

We found no evidence to suggest that the increasing coverage of other maternal and delivery care services—namely, antenatal care, tetanus injections, delivery by a health professional, or delivery in a health facility—contributed to the reduction in the NMR.

Table 3.11. Multivariate decomposition of household-level, mother-level, child-level, and maternal/delivery care and other intervention-related differences in the NMR, showing contributions to the NMR gap attributed to differences in endowments and to differences in coefficients, Rwanda DHS 2000, 2005, and 2010

	2000 RDHS - 2010 RDHS		2005 RDHS - 2010 RDHS	
Characteristics	**Endowments**	**Coefficient**	**Endowments**	**Coefficient**
Household-level				
Place of residence	-0.1	4.4	-0.1	4.1
Household size	0.9 *	4.2	1.4 **	0.3
Access to improved water source	0.8	1.0	1.0	1.6
Access to improved toilet source	-2.6	18.5	-1.8	24.2
Mother-level				
Mother's age at child's birth	-1.7 **	1.3	-1.5 **	8.6
Mother's marital status	0.2	-5.0	0.0	-4.4
Mother's education	0.3	0.4	0.1	1.7
Child-level				
Sex of child	0.1	3.2	0.0	-3.4
Preceding birth interval	-0.4	-3.1	-0.4	-1.9
Maternal/delivery care and other interventions				
Number of ANC visits	-3.5	2.4	-3.1	-0.8
Tetanus vaccination	-1.5	0.0	-1.4	-1.6
Delivery by a health professional	-6.8	2.2	-6.4	6.2
Delivery in a health facility	9.5	-3.8	9.0	-7.7
Household ownership of a mosquito net	-23.6 **	-0.6	-19.8 **	-2.7
Constant		-12.9		-9.8
Total	-28.3 **	12.3	-22.9 *	14.2
Percent	177.4 **	-77.4	263.2	-163.2
NMR difference (per 1,000)	-15.9 ***		-8.7 ***	

Note: * indicates p<.05; ** indicates p<.01;*** indicates p<.001. Decomposition models were restricted to women's most recent birth in the 1-59 months preceding each survey. Births with incomplete information on variables included in the model were excluded.

In sum, the results show that within the set of indicators included in our decomposition model, the reductions in the NMR were driven by improvements in coverage of maternal and delivery care interventions, as well as certain changes in the composition of socio-demographic characteristics, rather than by changes in the effect on individual children who received the interventions. Of the changes in coverage, the rapid increase in household ownership of mosquito nets stands out. Mosquito net ownership was significantly associated with the reduction in the NMR, both between the 2000 and 2010 surveys and between the 2005 and 2010 surveys.

4. DISCUSSION, CONCLUSIONS, AND POLICY IMPLICATIONS

Between 2000 and 2010 Rwanda's dramatic decline in under-five mortality was accompanied by a substantial but more modest reduction in neonatal mortality. During this period there was impressive improvement in coverage of key maternal care and intervention-related indicators associated with neonatal mortality—delivery by a health professional, delivery in a facility, use of ANC services, early initiation of breastfeeding, and ownership of mosquito nets.

Our analysis found that for three of these indicators—use of ANC services, early initiation of breastfeeding, and ownership of mosquito nets—increased coverage was associated with a lower probability of neonatal death after adjusting for socio-demographic factors. Decomposition results provided further evidence that the increase in household mosquito net ownership, in particular, was significantly associated with the reduction in neonatal mortality between the 2000 and 2010 surveys, and primarily between the 2005 and 2010 surveys.[8] Mosquito net ownership remained independently associated with the reduction in neonatal mortality even after controlling for socio-demographic characteristics[9] and the mother's use of maternal care services (including the number of ANC visits, number of tetanus injections received during the pregnancy, whether delivery was assisted by a health professional, and whether delivery was in a health facility).

Ownership of a mosquito net at the time of interview and net use by the mother the night before the interview are only proxies for the mother's behavior during pregnancy, but these indicators identify an important protective effect against neonatal mortality. This observed association seems plausible, given the well-documented association between malaria during pregnancy and elevated risk of neonatal death (Eisele et al. 2012, Guyatt and Snow 2001), and given that mosquito net use is the primary recommended protection for pregnant women against malaria (intermittent presumptive treatment (IPTp) was discontinued in Rwanda in 2008). These findings reinforce the importance of consistent and universal mosquito net use in areas with high prevalence of malaria. Future studies should look more closely at the effect of mosquito net usage and IPTp use alone versus use in combination on maternal and neonatal health in different epidemiological contexts.

While it is likely that, to some extent, the positive association found between early initiation of breastfeeding and neonatal survival is due to reverse causality, there is also a strong biological basis for the protective nature of early initiation of breastfeeding, and the study findings are in line with previous reported associations. A study in Ghana, for example, found that early initiation of breastfeeding could prevent 22% of all neonatal deaths (Edmond et al. 2006). The Lancet Neonatal Survival series suggested that early initiation and continued breastfeeding might reduce neonatal deaths by as much as 55% to 87% (Darmstadt et al. 2005). Our findings support continued efforts to promote early initiation of breastfeeding.

While we did not find evidence that delivery in a health facility or delivery with assistance from a health professional is protective against neonatal death, this does not mean that they are not important for neonatal survival. The null findings could be driven by the fact that women with higher-risk pregnancies

[8] Recall that the reduction in the NMR between the 2000 and 2005 surveys was not decomposed, since the reduction itself was non-significant.

[9] Decomposition models controlled for urban residence, household size, household access to an improved water source and to an improved toilet source, mother's age at the child's birth, mother's marital status, maternal education, the child's sex, and length of the preceding birth interval.

and birth complications are more likely to give birth in a facility and with skilled attendance. It was not possible in our analysis to control for this source of bias.

Our findings raise some concerns regarding the quality of delivery care and skilled birth attendance. First, the null finding about delivery care mentioned above, while potentially driven by selection biases, could also point to an issue in quality of care. Second, the fact that the improvement in the NMR has largely been concentrated in rural areas (where coverage of maternal and delivery care services has increased most dramatically), with little improvement in urban settings (where coverage was already higher), suggests that the improvement was driven primarily by an increase in coverage rather than an improvement in the quality of services for those receiving maternal and delivery care. Third, our decomposition findings point to this same conclusion—that the reduction in neonatal mortality was driven by changes in the coverage of interventions and by the distribution of certain socio-demographic characteristics, rather than by changes in the effect of interventions on those receiving them.

Previous studies suggest that there is room for improvement in the quality of maternal care services in Rwanda, going beyond the expansion of services. The 2007 Rwanda Service Provision Assessment found considerable deficits in the basic supplies necessary for ANC, normal and complicated deliveries, and postpartum care (NISR et al. 2008). Using data from the 2007 Rwanda Service Provision Assessment, Sipsma and colleagues (2012) found that monetary incentives were not associated with better quality of care. While Rwanda MOH norms state that all health centers should be able to provide basic emergency obstetric care and all district hospitals should be able to provide comprehensive emergency obstetric care, findings from a recent quality of care assessment show that actual availability is much lower (Ngabo et al. 2012). Poor-quality services could in part explain the absence of any association between place of delivery and neonatal survival, highlighting the need to build on the success in expanding coverage with increased attention to providing good quality of care, to ensure that the full benefit of the interventions is realized.

We did not find evidence of an association between the mother's health insurance status and neonatal mortality, but did find strong evidence that women with health insurance are more likely to deliver in a health care facility with a skilled provider. This on its own is an important outcome.

Several findings regarding the association between socio-demographic characteristics and neonatal mortality are worth noting. As expected, short preceding birth intervals are consistently associated with elevated risk of neonatal death. Initiatives should continue to emphasize optimal birth spacing (two to three years) to improve neonatal health outcomes. Multiple births are also associated with a substantially higher risk of dying during the first month after birth. Early identification of multiple pregnancies, referral for appropriate delivery care, and close monitoring during the neonatal period can prevent most of these deaths. *S*pecial initiatives should focus on identifying high-risk births with an emphasis on equity of care so that, regardless of household resources, precautions are available to all mothers with high-risk births. Also in line with previous studies (Christian 2010), we found that maternal nutrition, particularly the mother's nutrition early in life, is important to the survival of her children during the neonatal period. This finding points to the value of addressing nutrition for today's youth, recognizing the benefits of adequate nutrition for child survival in the next generation.

This study found no evidence of an association between household access to clean water and sanitation and neonatal survival. These results are consistent with previous findings (Chant 2008). It is likely that these household-level factors have a greater impact on survival after the neonatal period, when infection-related illnesses comprise a larger portion of children's cause of death.

In conclusion, Rwanda has made dramatic improvements in under-five survival in recent years, while the gains in neonatal survival have been notable but more modest. Our analysis of the 2000, 2005,

and 2010 Rwanda Demographic and Health Surveys highlights the importance of consistent and universal mosquito net use to making further improvements in neonatal survival in areas where malaria is prevalent. In addition, the findings suggest that further improvements in neonatal survival will require more attention not only to extending the coverage of maternal and delivery care but also to improving the quality of these services.

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APPENDIX

Table A.1. Distribution of reported neonatal deaths by age at death in days, and percentage of early neonatal deaths (deaths occurring at age 0-6 days), among births in the five years preceding the survey, Rwanda 2000-2010.

	Age of death (in days)		
	RDHS 2000	RDHS 2005	RDHS 2010
<1	127	133	79
1	47	27	33
2	28	23	18
3	22	20	22
4	13	10	8
5	6	9	1
6	12	6	6
7	37	33	34
8	5	4	0
9	7	3	0
10	6	1	2
11	4	1	2
12	0	1	0
13	0	1	2
14	17	20	18
15	1	11	7
16	0	0	0
17	2	0	1
18	1	1	0
19	0	0	0
20	2	5	0
21	12	2	10
22	0	0	0
23	0	1	2
24	4	0	0
25	0	0	1
26	0	2	0
27	1	1	1
28	1	1	0
29	1	1	0
30	1	6	2
Total neonatal deaths	357	324	249
Early neonatal deaths (n)	254	229	167
Early neonatal deaths (%)	71.2%	70.6%	67.1%
Deaths on Day 1 (%)	35.6%	41.1%	31.7%

Note: Table includes deaths occurring 1-60 months preceding the date of interview.

Table A.2. Adjusted association between health insurance status of the mother and three maternal care outcomes: delivery at home, delivery assisted by an unskilled birth attendant, and making at least four ANC visits for the most recent birth, among births in the five years preceding the 2005 and 2010 RDHS

	RDHS 2005						RDHS 2010					
	Delivery at home		Delivery assisted by unskilled birth attendant/unassisted		Made <4 ANC visits, most recent birth		Delivery at home		Delivery assisted by unskilled birth attendant/unassisted		Made <4 ANC visits, most recent birth	
	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI
Health insurance status of the mother												
Insured	0.71***	0.61,0.84	0.75***	0.65,0.87	0.80*	0.66,0.97	0.57***	0.49,0.65	0.59***	0.52,0.68	0.85*	0.74,0.97
Uninsured	1.00		1.00		1.00		1.00		1.00		1.00	
Birth order												
1	1.00		1.00		1.00		1.00		1.00		1.00	
2-3	3.38***	2.89,3.94	3.04***	2.61,3.54	1.68***	1.30,2.17	3.15***	2.66,3.73	3.19***	2.73,3.74	1.53***	1.32,1.77
4-5	4.34***	3.65,5.15	3.81***	3.25,4.47	1.65***	1.25,2.17	4.94***	4.08,5.98	4.91***	4.10,5.88	1.77***	1.50,2.10
6+	5.42***	4.21,6.98	4.80***	3.83,6.02	1.92***	1.34,2.77	6.62***	5.37,8.17	6.54***	5.33,8.02	1.86***	1.53,2.26
Age of mother at childbirth												
<20												
20-34	0.85	0.66,1.08	0.80	0.63,1.02	0.63	0.39,1.02	0.86	0.66,1.13	0.85	0.65,1.10	0.73*	0.57,0.94
35-49	0.68*	0.49,0.94	0.64**	0.49,0.86	0.50*	0.29,0.86	0.75	0.55,1.04	0.75	0.56,1.01	0.64**	0.47,0.85
Mother's education												
None	1.00		1.00		1.00		1.00		1.00		1.00	
Some primary	0.77**	0.65,0.90	0.73***	0.62,0.85	1.15	0.93,1.42	0.72***	0.63,0.82	0.74***	0.65,0.85	0.99	0.85,1.15
Some secondary or higher	0.30***	0.23,0.40	0.34***	0.26,0.45	0.66*	0.48,0.91	0.43***	0.32,0.58	0.45***	0.34,0.60	0.85	0.67,1.07
Occupation												
Not working	1.00		1.00.		1.00		1.00		1.00		1.00	
Manual	1.52*	1.03,2.24	1.36	0.92,2.00	1.23	0.74,2.04	1.19	0.83,1.70	1.16	0.82,1.65	1.32	0.94,1.86
Agriculture	1.41**	1.14,1.73	1.33**	1.11,1.60	1.31*	1.02,1.68	1.48***	1.18,1.86	1.43**	1.14,1.80	1.10	0.89,1.36
Professional/sales/services	0.64*	0.46,0.90	0.60**	0.42,0.84	0.88	0.62,1.26	0.89	0.64,1.25	0.87	0.62,1.23	1.10	0.84,1.44
Wealth quintile												
Poorest	1.00		1.00		1.00		1.00		1.00		1.00	
Poorer	0.85	0.68,1.04	0.90	0.74,1.09	0.87	0.65,1.18	0.96	0.82,1.13	0.94	0.80,1.10	0.97	0.82,1.14
Middle	0.74*	0.58,0.94	0.81	0.65,1.00	0.92	0.66,1.27	0.89	0.75,1.06	0.86	0.72,1.03	1.05	0.88,1.25
Richer	0.63***	0.51,0.79	0.70***	0.57,0.85	0.80	0.58,1.10	0.65***	0.54,0.77	0.63***	0.53,0.76	0.92	0.76,1.11
Richest	0.29***	0.23,0.38	0.35***	0.28,0.46	0.63*	0.45,0.90	0.39***	0.30,0.51	0.40***	0.31,0.51	0.66***	0.52,0.84

(Continued...)

Table A.2. – *Continued*

	RDHS 2005						RDHS 2010					
	Delivery at home		Delivery assisted by unskilled birth attendant/unassisted		Made 4+ ANC visits, most recent birth		Delivery at home		Delivery assisted by unskilled birth attendant/unassisted		Made <4 ANC visits, most recent birth	
	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI
Province												
Kigali												
South	1.06	0.74,1.52	0.74	0.51,1.06	0.98	0.69,1.41	0.88	0.60,1.30	0.97	0.66,1.43	0.57**	0.41,0.80
West	1.14	0.79,1.63	0.89	0.61,1.29	1.22	0.83,1.78	0.76	0.50,1.17	0.80	0.52,1.22	0.68*	0.47,0.97
North	0.90	0.62,1.32	0.92	0.62,1.36	0.90	0.61,1.34	1.06	0.71,1.59	1.14	0.76,1.71	0.59**	0.40,0.85
East	1.35	0.91,2.01	0.66*	0.44,0.98	1.17	0.78,1.77	0.89	0.60,1.33	0.93	0.62,1.38	0.89	0.63,1.26
Residence												
Urban	1.00		1.00		1.00		1.00		1.00		1.00	
Rural	1.74***	1.30,2.34	1.87***	1.44,2.43	0.93	0.71,1.22	1.06	0.72,1.57	1.06	0.72,1.54	1.12	0.81,1.54

Note: This table replicates results presented in Hong et al. 2011 (with the addition of ANC as a third outcome variable). Variables are cut to match the categories presented in that article.