Internal Migration in Kenya: Implications for Maternal and Child Healthcare Utilization

by

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Dedication

To my family, who always encourage me to chase my dreams.

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Abstract

Kenya has achieved impressive declines in maternal and under-five mortality over the last few decades; maternal mortality has dropped from 687 to 342 deaths per 100,000 live births and under-five mortality has decreased from 104 to 43 deaths per 1,000 live births. However, accelerated progress will be necessary if Kenya is to reach the Sustainable Development Goal targets of fewer than 70 maternal deaths per 100,000 live births and 25 under-five deaths per 1,000 live births by 2030. As many of these deaths could be prevented with access to healthcare during childbirth and early childhood, identifying factors leading to underutilization of care is a key strategy to reducing mortality. Research in low- and middle-income countries suggests internal migrants may be a particularly vulnerable group as the process of migration is disruptive and typically requires a period of adaptation before women can effectively engage with the healthcare system. This dissertation investigated the influence of maternal migration on the use of maternal and child healthcare services in Kenya.

The first aim analyzed the relationship between maternal migration and receipt of recommended childhood vaccinations using nationally representative data from the 2014 Kenya Demographic and Health Survey. Migration status and migration stream (e.g., rural-urban) were used as exposures and two measures of vaccination status, full and up-to-date vaccination, were explored as outcomes. After accounting for selection and confounding biases using multiple imputation and inverse probability of treatment weighting (IPTW), relationships between migration and vaccination were statistically insignificant. These findings are an important deviation from previous literature that did not rigorously address important biases common to this area of research.

The second aim examined how maternal migration into informal urban settlements (IUSs) in Nairobi, Kenya influenced childhood vaccination timeliness. This aim leveraged 2002-2018 data from the Nairobi Urban Health and Demographic Surveillance System (NUHDSS). The primary analysis explored the impact of migration status and secondary analyses of migrants examined whether migrant origin or previous experience living in the IUS differentially influenced timely vaccine receipt. There was no evidence that migration status or characteristics influenced vaccination timeliness in IPTW-weighted models. However, a considerable portion of both migrant and non-migrant children in the IUSs received their vaccinations late or not at all, indicating vaccination programs in the settlements should shift focus from simply increasing coverage to improving timeliness.

Using 2004-2018 NUHDSS data, the third aim analyzed the relationship between migrant women's adaptation to living in an IUS and use of recommended childbirth services. Heterogeneity in the relationship between adaptation and childbirth care was explored by characteristics of the migration experience. Use of recommended childbirth services was widespread in the IUSs but not associated with migrant adaptation. The relationship between adaptation and childbirth care did not differ significantly by a migration type, migration stream, migration companions, or reason for migrating.

Collectively, these dissertation aims provide an in-depth analysis of the relationship between migration and utilization of maternal and child healthcare services in Kenya. Findings suggest that, in Kenya, characteristics enabling migration such as wealth and education, rather than the process of migration itself, drive differential healthcare use between migrants and non-

migrants. As the public health community works towards further global reductions in maternal and under-five mortality the populations of women and children who don’t receive adequate healthcare must be clearly defined and targeted by outreach efforts.

Chapter 1 Introduction and Research Aims

Although the United Nations and the global public health community have identified maternal and child health as key priorities, substantial international health disparities in maternal and child mortality persist.[1–3] Nearly 94% of maternal deaths globally are among women living in low- and middle-income countries with approximately two-thirds of those deaths in women in sub-Saharan Africa.[2] Similar global disparities exist in child mortality; children living in sub-Saharan Africa are 15 times more likely to die before their fifth birthday than children living in high-income countries.[4] Many of these deaths could be prevented with access to proper medical care during childbirth and early childhood. In 2015, in an effort to improve the lives of individuals across the globe, the United Nations drafted the Sustainable Development Goals (SDGs).[5] The SDGs were developed as a follow-up to the Millennium Development Goals (MDGs) to build upon the MDGs' successes in improving global health.[5] Importantly, the SDGs were developed through a consensus process that included more involvement from low- and middle-income countries than was present in the drafting of the MDGs.[5] The SDGs provide a framework for global targets aimed at achieving important development goals ranging from alleviating (or eliminating) poverty to increases in clean energy to health and wellbeing.[5] SDG targets 3.1 and 3.2 are particularly relevant to maternal and child health, aiming to decrease the global maternal mortality ratio to 70 deaths per 100,000 live births (and no country above 140 deaths per 100,000 live births) and under-five mortality to 25 deaths per 1,000 live births by

2030.[1] Receipt of high quality health services throughout childbirth and childhood is critical to improving maternal and child health and eliminating preventable mortality.[2,4]

For women, many complications of childbirth, such as infection and severe bleeding, can be deadly without the assistance of skilled healthcare providers in a clinical setting with appropriate supplies. Yet, childbirth without a skilled attendant and outside a health facility is still common in many low- and middle-income countries (LMICs).[2] Among children, vaccine preventable diseases, such as pneumonia and diarrhea, are leading causes of death despite the provision of recommended vaccines for free in most LMICs under the Expanded Program on Immunization.[4] In an effort to decrease disparities in maternal and child mortality it is imperative to understand the factors contributing to the underutilization of these lifesaving maternal and child healthcare services. Historically the literature has explored the influence of family features, like wealth,[6–10] and maternal characteristics, like education and empowerment,[9–12] as drivers of maternal and child healthcare use. Another potential factor may be maternal migration, as research suggests migration influences a variety of indicators of health and healthcare utilization, including under-five mortality,[13] incomplete childhood immunization,[14] and antenatal care and health facility delivery.[15]

This dissertation explored the influence of maternal migration on the use of maternal and child healthcare services in Kenya. The first aim investigated the relationship between maternal migration and the receipt of recommended childhood vaccinations using nationally representative data from the 2014 Kenya Demographic and Health Survey. The second and third aims examined how maternal migration into two informal urban settlements in Nairobi, Kenya impacted vaccination timeliness (Aim 2) and the use of childbirth services (Aim 3) using 2002-2018 data from the Nairobi Urban Health and Demographic Surveillance System. This introductory chapter discusses the country of Kenya and outlines key concepts relevant to childhood vaccination, childbirth services, migration and health, and the informal urban settlements of Nairobi.

Kenya

With a population of approximately 54.6 million, people Kenya, located in Eastern Africa, is among the top ten most populated countries on the African continent.[16] It has demonstrated consistently strong economic growth (5%-6% real gross domestic product growth rate since 2010) and transitioned from a low- to a middle-income economy in 2014.[16,17] Though Kenya's economy is still primarily agrarian, its tourism and technology sectors are booming, making Kenya an important economic, technology, and travel hotspot in Africa.[16,18] This growing economy has led to substantial increases in the quality of life of Kenyan residents. Kenya's human development index (HDI, a measure that combines national-level life expectancy, education, and income levels into a number ranging from 0 to 1) increased from 0.46 to 0.60 between 2000 and 2019.[19] However, when the level of inequality is accounted for the IHDI (inequality-adjusted HDI) shrinks to 0.44, representing a loss in development of 26% due to intranational inequalities in life expectancy, education, and income.[19] Kenya's Gini index (a measure of income inequality in which higher values indicate more inequality) similarly demonstrates sizable income inequality in Kenya. At 40.8, Kenya's 2015 Gini index was not as high as countries like South Africa (63.0), but was higher than other countries in eastern Africa including Tanzania (37.8) and Ethiopia (35.0).[20] These inequalities are particularly stark when comparing Kenya's rural and urban populations. Urban dwellers enjoy substantially higher education (22% of men and 19% of women have received higher than a secondary education) and more wealth (49% of urban households fall into the richest wealth quintile) than rural populations, of whom only 7% and 6% of men and women, respectively have higher than a secondary education and a mere 5% of households belong to the richest wealth quintile.[21]

Kenya's government is a presidential republic.[16] Prior to 2010, political power in Kenya was highly centralized with an unicameral National Assembly and a president who wielded immense authority including the ability to, at will, dismiss judges and detain citizens without a trial.[16,22] In a 2010 national referendum Kenyans voted to approve a new Constitution, which moved power and resources away from the federal government, reinstated a bicameral parliament, created a Supreme Court, and dissolved the eight regions (Central, Coast, Eastern, Nairobi, North Eastern, Nyanza, Rift Valley, and Western) in favor of 47 counties (Figure 1.1).[16,22] This new governmental system was incrementally phased-in beginning with 2013 county Governor elections and aiming for the new decentralized government to obtain full authority by 2016.[22]

Following this decentralization of political power, in 2013 Kenya's health system was also restructured and much of the authority and responsibilities for health services moved from the central government to the local county governments.[21,23] The goal of this devolution of the health sector was to promote efficiency and equality in health services and reduce regional disparities in health outcomes.[23] As an example of the stark disparities in healthcare access before devolution, in 2008-2009 96.4% of women living in the Nairobi region received antenatal care from a skilled provider (doctor, nurse, midwife, etc.) and 89.4% gave birth in a health facility while in the North Eastern region only 69.5% of women received skilled antenatal care and only 17.3% of women delivered their child in a health facility.[24] Childhood vaccination coverage demonstrated similar regional inequities, with nearly 86% of children in the Central region receiving all basic immunizations compared to less than 50% of children in the North Eastern region.[24] After decentralization of the health sector, the central government now creates national health policy and provides technical and capacity building support to counties, while county governments are responsible for the provision of public health services and the promotion of health services utilization, including the organization of community health volunteers and community health extension workers.[21,23] The central government of Kenya has developed a variety of maternal and child health programs and policies designed to improve maternal and child health and increase health service use such as the Kenya Expanded Program on Immunization, free delivery services at public health facilities, the Integrated Management of Childhood Illness Initiative, the Community-Based Newborn Care Program, the Infant and Young Child Feeding Program, Malezi Bora (maternal and child health and nutrition weeks held twice a year), and campaigns to increase the receipt of vitamin A supplementation and deworming medications.[21,25]

Child vaccination in Kenya

Childhood mortality in Kenya has seen a striking decrease since the early 2000s, with under-five mortality dropping from 100 to 43 deaths per 1,000 live births between 1990 and 2019, though reaching the 2030 SDG target of 25 under-five deaths per 1,000 live births has remained elusive.[3,26] This decline in under-five mortality is largely the result of Kenya's impressive improvements in vaccination coverage since the introduction of the Kenya Expanded Program on Immunization (KEPI), as 35% of under-five deaths in Kenya are due to diarrheal diseases, pneumonia, and measles, all of which are vaccine preventable.[27,28] The KEPI was instituted in 1980 with the goal of providing vaccines that protect against tuberculosis, polio, diphtheria, pertussis, tetanus, and measles (the “basic” vaccination series) to the children of Kenya for free.[27] Since its initiation, new vaccines have been added to the KEPI schedule which now includes 15 doses: one dose of Bacille Calmette- Guérin vaccine given at birth (BCG, protects against tuberculosis); three doses each of the oral poliovirus vaccine (OPV), the pentavalent vaccine (penta, includes diphtheria, tetanus, pertussis [DTP], hepatitis B [HBV], and *Haemophilus influenza* type b [Hib] antigens), and the pneumococcal conjugate vaccine (PCV) given at 6, 10, and 14 weeks; one dose of the inactivated poliovirus vaccine (IPV) given at 10 weeks; two doses of the rotavirus vaccine (rota) given at 6 and 10 weeks, and two doses of the measles vaccine given at 9 and 18 months (Table 1).[21,29]

Implementation of the KEPI has resulted in significant increases in vaccination coverage in Kenya. Coverage of the third dose of the diphtheria-tetanus-pertussis-containing vaccine (DPT3, a precursor to the pentavalent vaccine and an indicator often used to estimate vaccination program performance) among children aged 12-23 months increased from 58% in 1984 to 92% in 2019.[27,30] Other doses followed a similar trend with coverage of BCG increasing from 76% to 95% and the 9-month dose of the measles vaccine increasing from 55% to 89% in the same period.[30] The proportion of children who are fully vaccinated with all recommended doses has followed a similar trend. Further, receipt of all vaccines (except PCV, rota, and IPV, which weren’t introduced until later) has continued to increase consistently over the past two decades from 57% in 2003 to 77% in 2008-2009 and 79% in 2014.[21] These advances are considerable and receipt of many individual doses reach the World Health Organization Africa Regional Strategic Plan for Immunization’s goal of 90% national coverage in by 2020.[31] However, DPT3 coverage at the county level demonstrates less success as almost half of Kenya’s 47 counties have DPT3 coverage below 80%, falling below the Plan’s goal of 80% coverage in all districts and representing important geographic disparities in vaccination coverage.[31,32] Clearly, much progress has been made in providing immunization services to children in Kenya, but much work remains to ensure this life-saving service is available to all Kenyan children.

Estimating cumulative vaccination coverage at certain age intervals (e.g., proportion of children aged 12-23 months who have received DPT3) is the most straightforward and common manner in which researchers and public health officials estimate community protection against vaccine preventable diseases (VPDs). However, simple coverage estimates can mask important delays in vaccine receipt that may result in substantial disease transmission among children who are younger than the examined age interval and at ages when they are particularly prone to more serious disease, hospitalization, and death. These delays leave children susceptible to VPDs longer than necessary and place communities at risk of VPD outbreaks.[33,34] In an effort to better understand child and community protection against VPDs researchers have begun examining vaccination timeliness in addition to vaccination coverage. Vaccination timeliness, calculated as the continuous measure of a child's age at vaccine receipt, can provide a better characterization of whether a child is delayed in receiving individual vaccines and whether a community has sufficient vaccination levels to protect against outbreaks. Using this continuous measure of age at vaccination, a particular vaccine dose is considered timely if it is received within one month of the date recommended by a country's national vaccination schedule.[35] Interest in estimating vaccination timeliness has increased dramatically in the last ten years as vaccination programs transition from simply optimizing vaccination coverage to ensuring timely vaccine receipt. The need for an increased focus on vaccine timeliness is exemplified by Kenya, which has high levels of vaccine coverage but only 37% of children currently aged 12-36 months received all eight basic KEPI vaccines on time.[8] This proportion masks a significant inequity in timeliness by urbanicity, with 48% of urban children compared to only 31% of rural children receiving all basic vaccines on time.[8] Similar to vaccination coverage, there is much work to be done to decrease disparities in vaccination timeliness in Kenya and ensure all children not only receive each recommended dose but receive each dose on time.

Maternal childbirth services in Kenya

Kenya has also achieved impressive improvements in maternal mortality in the 2000s with the maternal mortality ratio declining from 678 to 342 deaths per 100,000 live births between 2003 and 2017.[36] Though still well above the 2030 SDG target of 70 deaths per 100,000 live births, it is clear that decreasing maternal mortality has been a priority for Kenyan public health officials.[26] Many of these deaths that occur during or soon after pregnancy and childbirth are preventable with prenatal care and simple interventions such as injections to reduce bleeding or the timely identification and treatment of infection.[2] Encouraging women to give birth accompanied by a skilled birth attendant in a health facility increases the likelihood they will have access to appropriate medical supplies and trained staff who can quickly recognize and treat complications as they arise.[2] In fact, these two services – facility delivery and assistance by a skilled birth attendant – have been pivotal components of global efforts to reduce and eventually eliminate preventable maternal mortality.

Delivery in a health facility is an important strategy to mitigate potential poor birth outcomes for a mother and her child.[2,37] Women who give birth in a health facility ideally have access to skilled birth attendants who have the medical supplies and equipment necessary to assess and treat complications or, in more serious situations, access to a referral and transportation to a higher-level hospital that is equipped to handle complications of childbirth.[37]

Despite these benefits, in the early 2000s only 43% of women in Kenya gave birth in a health facility.[21] As part of the national effort to reduce maternal mortality Kenya's president signed a directive in 2013 that changed the delivery fee structure in public health facilities.[25] This directive stated that public health facilities should provide childbirth care for free to all women and the Ministry of Health would cover the costs.[25] Evidence suggests this policy has had an impressive impact on the use of facilities for childbirth; the number of deliveries at select health facilities across Kenya demonstrated statistically significant increases after the policy was implemented and in 2014, just a year after implementation, the proportion of women nationally who gave birth in a health facility increased to 61%.[21,38,39] This increase in uptake is encouraging but remains far from the goal of universal facility delivery.

Having a skilled birth attendant (SBA) assist with childbirth is another service crucial to the elimination of preventable maternal mortality.[2,37] SBAs are defined by the World Health Organization as accredited health professionals (doctors, nurses, midwives, etc.) who have been appropriately trained to provide care during normal deliveries, who can identify and treat (or refer) complicated deliveries, and who have access to the necessary equipment and medical supplies to assist a woman during childbirth.[40] Traditional birth attendants, who often assist women during their pregnancies and deliveries are not considered SBAs as they typically lack the training, education, and equipment necessary to adequately care for women during obstetric complications or emergencies.[40] However, traditional birth attendants can still play an important role in supporting and advocating for women as one component of their pregnancy and delivery care team. As of 2014, 62% (82% urban, 50% rural) of births were assisted by an SBA, a dramatic increase from 44% in the 2008/2009 DHS.[21] As would be expected, delivery at a health facility and having a skilled attendant at birth are closely intertwined; 99.2% of women who gave birth at a health facility delivered with a skilled attendant present while only 2.8% of women who delivered in a setting other than health facility had a skilled attendant present during childbirth.[21]

Migration and health

Migration

Many factors influence an individual's decision to migrate. Typically, these are categorized as "push factors" and "pull factors." Push factors are characteristics of the home community that make leaving appealing, including economic (agricultural failure, surplus workforce), social (discrimination, lifestyle factors), and environmental (reduction of natural resources, natural disasters) factors.[41–43] These same economic (better jobs and housing), social (marriage and educational opportunities), and environmental (finding new natural resources) factors are often also pull factors, or characteristics of the destination community that entice individuals to migrate there.[41–43] This combination of push and pull factors, and how they affect the entire family, is taken into consideration when individuals and families decide if they will migrate.[41,44] Migration then occurs if a family determines that migration to the destination community can improve the combination of the financial, physical, and social factors in their life.[41,45] Often, a portion of a family will stay in the home community and one or more family members will migrate to a new location with better economic opportunities and send back remittances.[41] Circular migration in which migrants cyclically migrate back and forth between origin and destination communities is a common strategy employed particularly among those migrating in the search of economic opportunities.[46] Though historically less frequent, in the last fifty years migration among young women (independent of their families) in sub-Saharan Africa has increased dramatically as they move to urban centers in search of self-improvement opportunities including better educational or occupational prospects.[46–48]

Migration in Kenya

Home to over 488,000 refugees and asylum seekers from neighboring Eastern African nations, Kenya is perhaps most well-known as a host for international refugees, who are attracted to Kenya due to the country's relative political stability since it gained independence from the United Kingdom in 1963.[16,49] However, internal migration – migration within a country's borders – has become increasingly common over the past 50 years.[50] Before independence, internal migration was highly controlled by the British resulting in a predominance of male migrants leaving their families behind in rural home communities and moving to other rural areas to work on large for-profit farms (as opposed to smaller subsistence farms back home) or to developing city centers to work in the manufacturing, retail, and service industries.[50] As governmental regulation of migration ended with independence from the United Kingdom, the levels of internal migration in Kenya increased substantially starting in the 1960s.[50] In addition to internal migrants who moved in search of better opportunities, it was estimated that in just 2019 approximately 162,000 Kenyans were forcibly displaced from their homes and fled to other regions within Kenya.[16,49] Internal population movement and displacement in Kenya has largely been due to a lack of economic opportunities in rural areas, land degradation and climate change, ethnic conflict, and, more recently, al-Shabaab terrorism.[49,51] Kenyans have also faced internal migration and displacement due to post-election political violence since the 1990s, with substantial displacements occurring after the elections in 1992, 1997, 2002, and 2007 with over 650,000 individuals displaced after the 2007 election alone.[49]

Internal migration in Kenya (and elsewhere) follows four migration streams: rural-urban, urban-rural, rural-rural, and urban-urban.[49,51] Rural-urban migration has been the most publicized as it has contributed to the rapid urbanization occurring in Kenya and across the continent. Traditionally, rural-urban migrants have largely originated in the Nyanza, Central, Western, and Eastern regions and moved to the urban centers of Nairobi (the nation's capital and largest city) in southern-central Kenya, Mombasa in the southeast, and Kisumu, Eldoret, and Nakuru in the west.[52] Though less widely discussed, rural-rural migration has historically been the most common migration stream in Kenya but has been decreasing in frequency in favor of rural-urban migration since the 1980s.[50,51]

Originally, migration was a largely male undertaking; men would more frequently move to urban areas in search of jobs and women would remain behind in the origin community or move between rural areas to join her husband's family after marriage.[49–51] However, starting in the 1990s female migration became much more common in Kenya.[49–51] In fact, in the early 2010s six of the ten counties with the largest number of in-migrants saw more female in-migrants than male in-migrants.[49,51] While women moving between rural areas still largely do so due to marriage (58% of rural-rural migrant women), women moving from rural to urban areas more frequently cite job and income opportunities (37%) than marriage (31%) as their reason for migrating.[50] For both men and women migration typically occurs in adolescence and young adulthood, with the majority of migrants moving before age 25.[49,50]

Migration and health

Two principal theories, migrant disruption and migrant adaptation, have been used to understand the relationship between migration and healthcare use (Figure 1.3). The act of migrating is thought to disrupt the social, instrumental, and economic resources a woman needs in order to take advantage of healthcare services. Though migration has the potential to increase a woman's economic wellbeing in the long term, transportation to the destination community, ending employment to move, searching for a new home, and time without income during the search for employment can severely impact the money available to pay for indirect healthcare costs (e.g., transportation to the clinic).[14,53,54] Additionally, increased physical distance between a migrant and her family and friends may decrease financial and emotional support, logistical assistance with childcare, and advice regarding childbirth and child rearing, such as where to give birth or when to vaccinate her child.[55–57] Low social support, expendable time, and monetary resources may mean a migrant must delay or forgo healthcare services like facility delivery or child vaccinations until her life circumstances are more stable.[14,53,58,59] Although maternal migration is hypothesized to initially disrupt a woman's access to resources, as migrants spend more time in and adapt to their new community their healthcare use is thought to improve and reach the utilization levels of their non-migrant peers.[53] It takes time to acquire a new job and housing, save enough money to afford indirect healthcare costs, and learn how to effectively find and navigate the healthcare system in a new community, all necessary prerequisites to access healthcare.[53] Other obstacles such as language barriers and documentation requirements may necessitate the identification and procurement of additional resources, such as a translator or proper documentation before services can be used.[60]

Previous studies have shown mixed relationships between migration and health and healthcare use; migration has demonstrated mixed associations with under-five mortality,[13,58,61,62] incomplete childhood immunization,[14,53,59,63] antenatal care,[15,64,65] and having a skilled birth attendant present at childbirth.[15,65] Generally, lower use of maternal and child healthcare has been found among migrants compared to non-migrants,[14,15,53,59,63] but some studies report migrants enjoy better healthcare uptake compared to their non-migrant peers[53,64–66] and others find no significant differences.[15] Investigations of the impact of migrant adaptation on the use of maternal and child healthcare services are similarly inconclusive, reporting null,[15] positive,[53,64,65] and negative[15] associations between the amount of time spent in the destination community and healthcare use. These mixed results may be due to the substantially different social, cultural, and economic settings in which the studies took place. They may also be due to inadequate control of confounding variables. Migration is an inherently selective process in which factors that predispose individuals to migrate – such as more financial resources and education – also promote healthcare use. If not properly accounted for these characteristics can substantially confound and bias analyses of the relationship between migration and the use of health services.[67,68] Most previous studies of maternal migration and healthcare uptake adjust for these characteristics in their models while rarely confirming that distributions of confounding variables are adequately balanced between migrants and non-migrants. This may leave the findings open to questions regarding whether results are due to more than just migrant selection.

Informal urban settlements and health

Though the majority of Kenyans are rural dwellers, Kenya is a rapidly urbanizing nation, with 28% of its total population living in urban areas, a figure that is up from 17% in 1990 and projected to surpass 50% in 2025 (see Figure 1.2 for geographic distribution of population density).[16,69,70] The substantial increase in Kenya’s urban population is due to a combination of natural population growth among the urban population and migration to urban areas such as Nairobi, which has nearly 5 million residents.[16] As a result of the increasing urban population in

Kenya, informal urban settlements (IUSs, also known as slums) have developed in many major population centers and house large proportions of urban populations.[71] In fact, it is estimated that approximately 60-70% of Nairobi's inhabitants reside within the over 100 IUSs in the city.[72] Overcrowding large populations into small spaces with limited resources and infrastructure has resulted in poor living conditions in Nairobi's IUSs. Many residents live in chronic poverty and have little access to social services, safe housing, quality healthcare, employment, and educational opportunities.[72] IUSs are often densely populated and characterized by their pollution, poor access to safe food and clean water, and lack of hygiene and sanitation facilities.[72] As a result, IUSs are likely sites for outbreaks of infectious diseases including childhood vaccine preventable diseases.

Encouragingly, between 2000 and 2012, there were substantial decreases in both infant (88.2 to 39.2 deaths per 1,000 live births) and under-five (163.4 deaths per 1,000 live births to 79.8 deaths) mortality in Nairobi's IUSs.[72] However, child health remains sub-optimal in these communities; many homes still lack clean water and sanitation, have air pollution from kerosene and charcoal stoves, and are overcrowded.[72] Children living in these housing conditions are particularly susceptible to measles, pertussis, pneumonia, and diarrheal diseases, among the leading causes of child mortality in the IUSs.[72] Further, as of 2012 over half of children in Nairobi's IUSs were not fully immunized by 12 months and 15.4% of children hadn't received any vaccines by 12 months of age, leaving them particularly vulnerable to vaccine preventable diseases.[72] Utilization of maternal health services has been higher, with approximately 96% of mothers living in Nairobi's IUSs receiving any antenatal care, 83% giving birth in a health facility, and 82% having a skilled birth attendant present during childbirth.[72] While these statistics are promising, it should be noted that many IUS health centers do not have the personnel or equipment necessary to address high risk pregnancies and complicated deliveries, meaning some women who deliver at health facilities still do not receive the care they require.[72]

The healthcare use of women and children in two of Nairobi's IUSs, Korogocho and Viwandani, were examined in the second and third aim analyses of this dissertation. Data from individuals living in Korogocho and Viwandani are collected by the African Population and Health Research Center as part of the Nairobi Urban Health and Demographic Surveillance System (NUHDSS). NUHDSS consists of approximately 89,000 individuals from 33,500 households living in these settlements (Figure 1.4).[73] Viwandani and Korogocho were specifically chosen for inclusion in NUHDSS as they represent two very different IUS settings. Viwandani is situated near an industrial area southeast of the Nairobi city center and has historically attracted a younger, highly mobile, and more highly educated population in search of economic opportunities in the nearby industrial area.[73] Korogocho is located northeast of the city center and has a population that is more stable but had the worst health outcomes of all of Nairobi's examined IUSs in a 2000 survey.[52,73] Korogocho has a smaller geographic area than Viwandani (1-1.5 km^2 versus Viwandani's 4-5 km^2).[73] Although economic instability is common in both settlements, Korogocho has higher levels of unemployment (42% of women 18 years and older unemployed in Korogocho compared to 34% in Viwandani) and chronic poverty (76% of households in Korogocho compared to 54% in Viwandani remained below the poverty line between 2015 and 2018) than Viwandani.[73] Similar to the findings from IUSs throughout Nairobi, research from the NUHDSS suggests that important indicators of maternal and child health including maternal mortality,[74] child mortality,[62] and childhood immunization[75] are worse in Korogocho and Viwandani than averages in Nairobi and in Kenya as a whole.

Since the early 2000s the Government of Kenya has been developing efforts to improve the health and wellbeing of those living in Korogocho and Viwandani. In 2006 the government implemented a voucher system in Korogocho and Viwandani, among other sites, to increase access to facility deliveries, family planning services, and gender-based violence care by funding those services and making them free to women.[73] The Government of Italy, UN-HABITAT, and the Ministry of Local Government in Kenya collaborated and selected Korogocho for a slum upgrading program in 2008.[73] Additional projects in the 2000s and 2010s focused on improving educational opportunities, cardiovascular disease management, AIDS and sexually transmitted infection testing and counseling, and upgrading health facilities to be better able to handle obstetric emergencies.[73] As improvements to the health and living conditions of Kenya's residents and of those in Nairobi's IUSs progress it is imperative to continue examining health and healthcare utilization of the country's most vulnerable residents to ensure nobody is left behind. The work of this dissertation, as described below, explores the uptake of maternal and child healthcare services among internal migrants in Kenya in order to understand whether this potentially vulnerable group receives the healthcare needed to keep them healthy and free from disease.

Aims and hypotheses

This dissertation aimed to investigate the relationships between maternal migration and the uptake (Aim 1) and timing (Aim 2) of childhood vaccination and the use of recommended childbirth care (Aim 3). The migrant disruption and migrant adaptation theories were used as the framework to understand these relationships (see Figure 1.3 for a conceptual model of the dissertation).

Aim 1: The influence of maternal migration on child vaccination status in Kenya: An inverse probability of treatment-weighted analysis

The first aim investigated the relationship between maternal migration and childhood vaccination status in Kenya using 2014 Kenya Demographic and Health Survey data. Both whether a woman was a migrant (migrant status) and her migration stream (e.g., rural-urban) were considered as exposures in this analysis. Two measures of vaccination status were examined as outcomes: 1) whether a child received all recommended doses of the childhood vaccination series, among children aged 12-23 months, and 2) whether a child received all recommended doses by age 12 months. It was hypothesized that the children of migrant women would be less likely to be both fully vaccinated and have up-to-date vaccination compared to the children of non-migrant women. It was further hypothesized that the relationship between migration and vaccination would differ by a woman's migration stream. Specifically, it was hypothesized that the magnitude of the relationship between migration and childhood vaccination would be the largest for individuals moving from rural areas to urban areas and the smallest for individuals moving from one urban (or rural) area to another urban (rural) area.

Aim 2: Childhood vaccination timeliness following maternal migration to an informal urban settlement in Kenya

The second aim examined how maternal migration to an informal urban settlement of Nairobi influenced timely receipt of childhood vaccines. Data came from the Nairobi Urban Health and Demographic Surveillance System (NUHDSS) and were collected between 2002 and 2018. Childhood vaccination timeliness was compared by a mother's migrant status (migrant, non-migrant), migrant origin (rural, urban), and migrant type (first time, circular). The primary hypothesis was that the children of migrant mothers would have less timely receipt of each childhood vaccine examined compared to the children of non-migrant mothers. It was additionally hypothesized that the children of women who migrated from rural areas of Kenya would have less timely vaccination compared to children women who migrated from other urban areas Kenya. The final hypothesis was that the children of women who were first time migrants to the settlement would have lower vaccination timeliness compared to the children of women who had previously lived in the settlement (circular migrants).

Aim 3: Migration to an informal urban settlement and its impact on receipt of maternal childbirth care in Nairobi, Kenya: An exploration of migrant adaptation

The third aim explored the relationship between a migrant woman's adaptation to living in an informal urban settlement and her receipt of recommended childbirth care, which included delivery in a health facility and having a skilled birth attendant present at childbirth, using NUHDSS data. Adaptation was operationalized as the number of years between the date of migration into the settlement and childbirth and secondary analyses investigated heterogeneity in the relationship by a migrant woman's origin (urban, rural), with whom she migrated (alone, with others), migrant type (first time, circular), and motivation for migrating (to be with family/friends, living conditions, good job prospects, other). The primary hypothesis was that migrant adaptation would promote receipt of recommend childbirth care; the longer a woman lived in the settlement before childbirth would increase the likelihood that she would deliver in a health facility with a skilled birth attendant. Secondary hypotheses were that the impact of adaptation on the receipt of recommended childbirth care would be stronger for more theoretically disadvantaged women – those migrating from rural areas, migrating alone, entering the settlement for the first time, and for reasons other than reuniting with family.

Table 1.1 Vaccination schedule under the Kenya Expanded Program on Immunization (2018)

Vaccine	Birth	6 weeks	10 weeks	14 weeks	9 months	18 months
Bacille Calmette-Guérin vaccine (BCG)[1]	X					
Oral Poliovirus Vaccine (OPV)[1]		X	X	X		
Inactivated Poliovirus Vaccine (IPV)			X			
DPT-HepB-Hib Vaccine (Pentavalent)[1]		X	X	X		
Pneumococcal Conjugate Vaccine (PCV)[1]		X	X	X		
Rotavirus Vaccine (RV)		X	X			
Measles and Rubella (MR)[1,2]					X	X

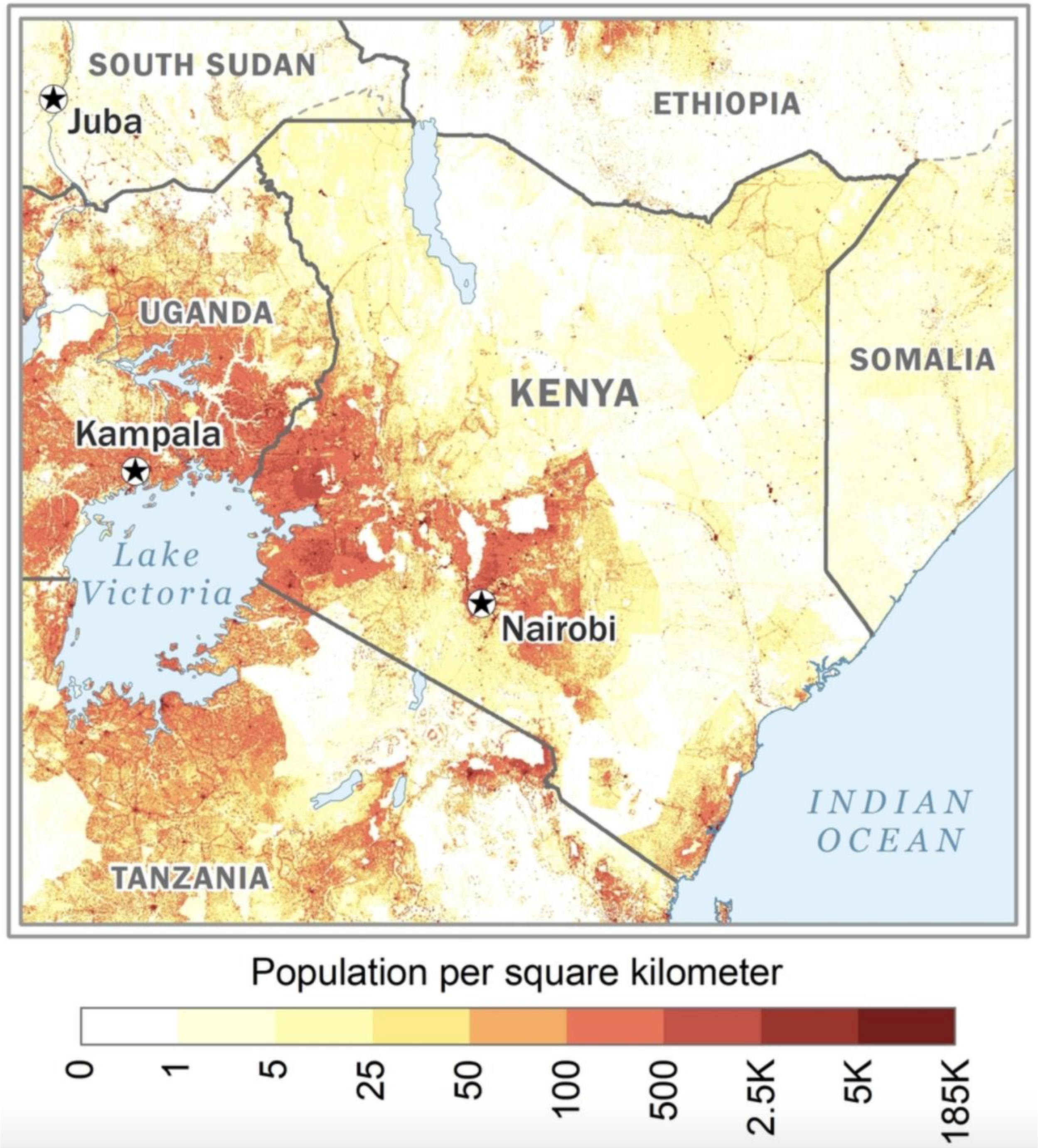
[1] Included in the KEPI in 2014

[2] In 2014, measles was given by itself in one dose at 9 months

Figure 1.1 Map of 47 Kenyan counties color-coded by previous regions

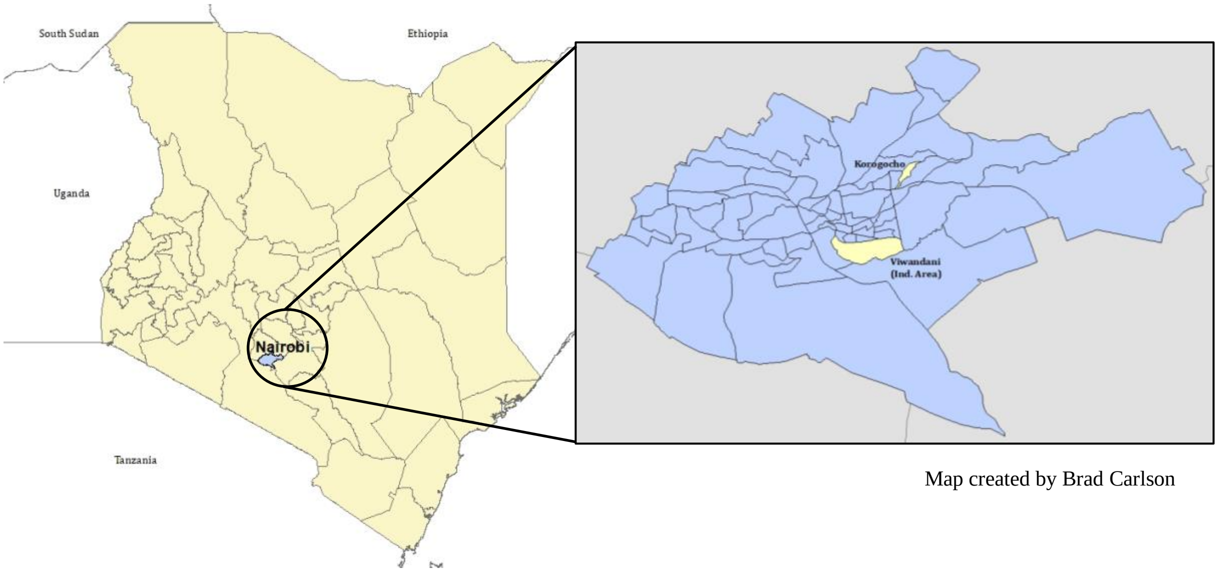
Image from 2014 Kenya Demographic and Health Survey Final Report[13]

Figure 1.2 Population distribution map of Kenya



Created by the CIA World Factbook.[9] Darker red indicates higher population density, with highest population densities around Lake Victoria in the west and Nairobi in central Kenya.

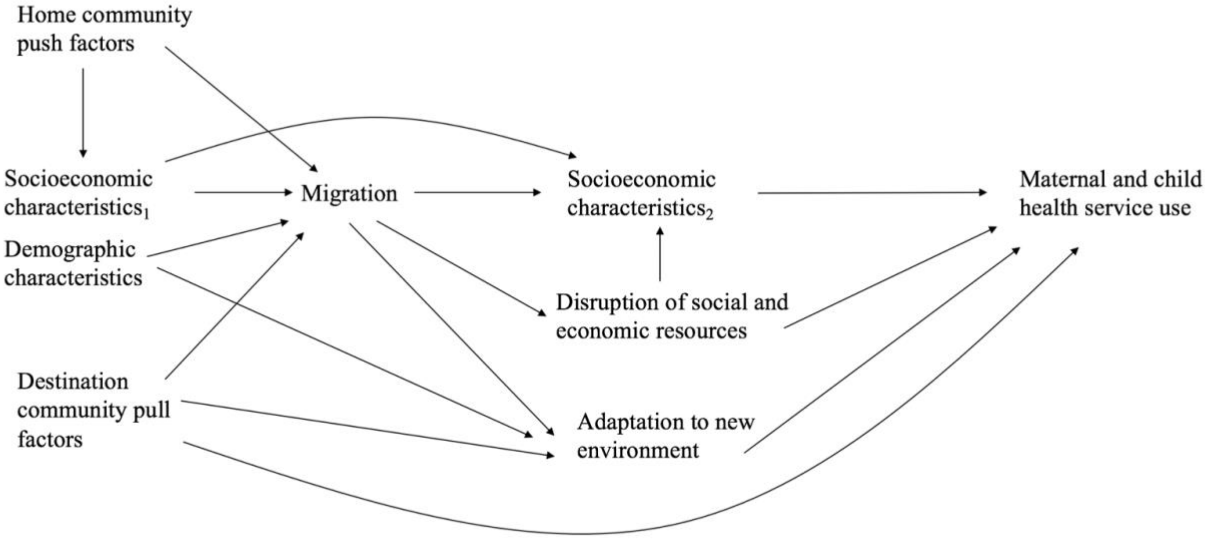
Figure 1.3 Administrative maps of Kenya and Nairobi



Map created by Brad Carlson

Left: Map of counties in Kenya, with Nairobi (location of Nairobi Urban Health and Demographic Surveillance System) highlighted in blue. Right: Map of Nairobi, with Korogocho and Viwandani informal urban settlements (Nairobi Urban Health and Demographic Surveillance System data collection sites) highlighted in yellow.

Figure 1.4 Conceptual model of dissertation



References

1. United Nations. Goal 3: Ensure healthy lives and promote well-being for all at all ages. Sustainable Development Goals. https://www.un.org/sustainabledevelopment/health/.
2. World Health Organization. Maternal Mortality. https://www.who.int/news-room/fact-sheets/detail/maternal-mortality. Published 2018. Accessed February 22, 2021.
3. UNICEF. Under-five mortality. https://data.unicef.org/topic/child-survival/under-five-mortality/. Published 2020. Accessed September 18, 2020.
4. World Health Organization. Children: reducing mortality. https://www.who.int/en/news-room/fact-sheets/detail/children-reducing-mortality. Published 2018.
5. United Nations. About the Sustainable Development Goals.
6. Restrepo-Méndez MC, Barros JD, Wong LM, et al. Inequalities in full immunization coverage : Trends in low- and middle-income countries. *Bull World Health Organ*. 2016;94(11):794-805. doi:10.2471/BLT.15.162172
7. Hajizadeh M. Socioeconomic inequalities in child vaccination in low/middle-income countries: What accounts for the differences? *J Epidemiol Community Health*. 2018;72(8):719-725. doi:10.1136/jech-2017-210296
8. Mutua MK, Mohamed SF, Porth JM, Faye CM. Inequities in On-Time Childhood Vaccination: Evidence From Sub-Saharan Africa. *Am J Prev Med*. 2020;60(1):S11-S23. doi:10.1016/j.amepre.2020.10.002
9. Achia TNO, Mageto LE. Individual and Contextual Determinants of Adequate Maternal Health Care Services in Kenya. *Women Heal*. 2015;55(2):203-226. doi:10.1080/03630242.2014.979971
10. Fotso JC, Ezeh A, Madise N, Ziraba A, Ogollah R. What does access to maternal care mean among the urban poor? Factors associated with use of appropriate maternal health services in the slum settlements of Nairobi, Kenya. *Matern Child Health J*. 2009;13(1):130-137. doi:10.1007/s10995-008-0326-4
11. Forshaw J, Gerver SM, Gill M, Cooper E, Manikam L, Ward H. The global effect of maternal education on complete childhood vaccination: A systematic review and meta-analysis. *BMC Infect Dis*. 2017;17(1):1-16. doi:10.1186/s12879-017-2890-y
12. Thorpe S, VanderEnde K, Peters C, Bardin L, Yount KM. The Influence of Women’s Empowerment on Child Immunization Coverage in Low, Lower-Middle, and Upper-Middle Income Countries: A Systematic Review of the Literature. *Matern Child Health J*. 2016;20(1):172-186. doi:10.1007/s10995-015-1817-8
13. Issaka AI, Agho KE, Renzaho AMN. The impact of internal migration on under-five mortality in 27 sub-Saharan African countries. *PLoS One*. 2016;11(10):1-16. doi:10.1371/journal.pone.0163179
14. Kiros GE, White MJ. Migration, community context, and child immunization in Ethiopia. *Soc Sci Med*. 2004;59(12):2603-2616. doi:10.1016/j.socscimed.2004.04.009
15. Cotton C. Migration and young women’s access to maternal healthcare in sub-Saharan Africa. *Heal Place*. 2019;55(January):136-144. doi:10.1016/j.healthplace.2018.12.006

16. Central Intelligence Agency. CIA World Factbook | Kenya. Central Intelligence Agency Library. https://www.cia.gov/the-world-factbook/countries/kenya. Published 2020. Accessed March 13, 2021.

17. Copley A. Africa in the News: Kenya Becomes a Middle-Income Country; Mo Ibrahim Index Released; South Sudan Peace Talks Yield Promise. The Brookings Institution. https://www.brookings.edu/blog/africa-in-focus/2014/10/03/africa-in-the-news-kenya-becomes-a-middle-income-country-mo-ibrahim-index-released-south-sudan-peace-talks-yield-promise/. Published 2014. Accessed October 26, 2020.

18. Shapshak T. Africa's Booming Tech Hubs Are "Backbone of Tech Ecosystem" Having Grown 40% This Year. Forbes. https://www.forbes.com/sites/tobyshapshak/2019/07/11/africas-booming-tech-hubs-are-backbone-of-tech-ecosystem-having-grown-40-this-year/#2bb1d8dd24c2. Published 2019. Accessed October 26, 2020.

19. United Nations Development Programme (UNDP). *Human Development Report 2020, Briefing Note - Kenya*.; 2020. http://hdr.undp.org/sites/all/themes/hdr_theme/country-notes/KEN.pdf.

20. The World Bank. Gini index (World Bank estimate). https://data.worldbank.org/indicator/SI.POV.GINI?contextual=default&end=2015&locations=KE-XO-ET-TZ&most_recent_value_desc=false&start=1992. Published 2019. Accessed April 15, 2020.

21. Kenya Bureau of Statistics, ICF International. *Kenya Demographic and Health Survey 2014*.; 2015. doi:10.5261/2013.GEN1.04

22. Ominde SH, Ingham K, Ntarangwi M. Kenya. Britannica. https://www.britannica.com/place/Kenya. Published 2020. Accessed October 27, 2020.

23. McCollum R, Theobald S, Otiso L, et al. Priority setting for health in the context of devolution in Kenya: Implications for health equity and community-based primary care. *Health Policy Plan*. 2018;33(6):729-742. doi:10.1093/heapol/czy043

24. Kenya National Bureau of Statistics (KNBS); ORC Macro. Kenya Demographic and Health Survey 2008-09. 2010:1-314.

25. Ministry of Health Kenya. *Implementing Free Maternal Health Care in Kenya- Challenges, Strategies and Recommendations*.; 2013.

26. United Nations. Goal 3 Targets and Indicators. https://sdgs.un.org/goals/goal3. Published 2020. Accessed December 27, 2020.

27. Kenya Ministry of Health Division of Vaccines and Immunization. *National Policy Guidelines on Immunization 2013*.; 2013. http://e-cavi.com/wp-content/uploads/2014/11/KENYA-NATIONAL-POLICY-ON-IMMUNIZATION-2013.pdf.

28. The Partnership for Maternal Newborn & Child Health, Government of Kenya, Inter-Parliamentary Union. *Maternal and Child Health: Kenya*.; 2012.

29. Wandera EA, Mohammad S, Ouko JO, Yatitch J, Taniguchi K, Ichinose Y. Variation in rotavirus vaccine coverage by sub-counties in Kenya. *Trop Med Health*. 2017;45(1):1-5. doi:10.1186/s41182-017-0051-z

30. WHO/UNICEF. Immunization. https://data.unicef.org/topic/child-health/immunization/. Published 2019. Accessed December 12, 2020.

31. World Health Organization Regional Office for Africa. *Regional Strategic Plan for Immunization AFRO 2014-2020*. Brazzeville; 2015. http://www.afro.who.int/sites/default/files/2017-06/oms-ivb-rvap-afro-en-20150408_final_sent140317_0.pdf.

32. World Health Orgranization. WHO Vaccine-Preventable Diseases: Monitoring System. 2019 Kenya. http://apps.who.int/immunization_monitoring/globalsummary/countries?countrycriteria%5Bcountry%5D%5B%5D=KEN&commit=OK. Published 2019. Accessed March 13, 2020.

33. Grant CC, Roberts M, Scragg R, et al. Delayed immunisation and risk of pertussis in infants: unmatched case-control study. *BMJ*. 2003;326(7394):852-853. doi:10.1136/bmj.326.7394.852

34. Glanz JM, Newcomer SR, Narwaney KJ, et al. A population-based cohort study of undervaccination in 8 managed care organizations across the United States. *JAMA Pediatr*. 2013;167(3):274-281. doi:10.1001/jamapediatrics.2013.502

35. Masters NB, Wagner AL, Boulton ML. Vaccination timeliness and delay in low- and middle-income countries: a systematic review of the literature, 2007-2017. *Hum Vaccin Immunother*. 2019. doi:10.1080/21645515.2019.1616503

36. Williams R. Marginal effects for continuous variables. https://www3.nd.edu/~rwilliam/xsoc73994/Margins02.pdf. Published 2021. Accessed March 31, 2021.

37. The United Nations Children's Fund (UNICEF). Delivery care. https://data.unicef.org/topic/maternal-health/delivery-care/. Published 2020. Accessed February 22, 2021.

38. Gitobu CM, Gichangi PB, Mwanda WO. The effect of Kenya's free maternal health care policy on the utilization of health facility delivery services and maternal and neonatal mortality in public health facilities. *BMC Pregnancy Childbirth*. 2018;18(1):1-11. doi:10.1186/s12884-018-1708-2

39. Lang'At E, Mwanri L, Temmerman M. Effects of implementing free maternity service policy in Kenya: An interrupted time series analysis. *BMC Health Serv Res*. 2019;19(1):1-10. doi:10.1186/s12913-019-4462-x

40. WHO, UNFPA, UNICEF, et al. Definition of skilled health personnel providing care during birth: 2018 joint statement by WHO, UNFPA, UNICEF, ICM, ICN, FIGO, and IPA.

41. Kuhn R. Internal Migration: Developing Countries. *Int Encycl Soc Behav Sci Second Ed*. 2015;11:433-442. doi:10.1016/B978-0-08-097086-8.31120-5

42. Gong P, Liang S, Carlton EJ, et al. Urbanisation and health in China. *Lancet*. 2012;379(9818):843-852. doi:10.1016/S0140-6736(11)61878-3

43. Zhiliang Z, Tao Z, Qian Z. The push-pull theory of migration and its application. *Chin J Popul Sci*. 1997;9.

44. Becker CM, Stark O. The Migration of Labor. *Contemp Sociol*. 1993;22(2):223. doi:10.2307/2075765

45. Ellis F. Household strategies and rural livelihood diversification. *J Dev Stud*. 1998;35(1):1-38. doi:10.1080/00220389808422553

46. Beguy D, Bocquier P, Zulu EM. Circular migration patterns and determinants in Nairobi slum settlements. *Demogr Res*. 2010;23(December 2010):549-586. doi:10.4054/DemRes.2010.23.20

47. Hertrich V, Lesclingand M. Adolescent Migration in Rural Africa as a Challenge to Gender and Intergenerational Relationships: Evidence from Mali. *Ann Am Acad Pol Soc Sci*. 2013;648(1):175-188. doi:10.1177/0002716213485356

48. Gugler J. Women Stay on the Farm No More: Changing Patterns of Rural-Urban Migration in Sub-Saharan Africa. *J Mod Afr Stud*. 1989;27(2):347-352.

49. International Organization for Migration. *Migration in Kenya: A Country Profile 2018*. Nairobi; 2018.

50. Oyvat C, wa Gĩthĩnji M. Migration in Kenya: beyond Harris-Todaro. *Int Rev Appl Econ*. 2020;34(1):4-35. doi:10.1080/02692171.2019.1620702

51. Oucho JO. Migration and regional development in Kenya. *Development*. 2007;50(4):88-93. doi:10.1057/palgrave.development.1100425

52. Beguy D, Elung'ata P, Mberu B, et al. Health & Demographic Surveillance System Profile: The Nairobi Urban Health and Demographic Surveillance System (NUHDSS). *Int J Epidemiol*. 2015;44(2):462-471. doi:10.1093/ije/dyu251

53. Smith-Greenaway E, Madhavan S. Maternal migration and child health: An analysis of disruption and adaptation processes in Benin. *Soc Sci Res*. 2015;54:146-158. doi:10.1016/j.ssresearch.2015.06.005

54. Kusuma YS, Kumari R, Pandav CS, Gupta SK. Migration and immunization: Determinants of childhood immunization uptake among socioeconomically disadvantaged migrants in Delhi, India. *Trop Med Int Heal*. 2010. doi:10.1111/j.1365-3156.2010.02628.x

55. Clark S, Madhavan S, Kabiru C. Kin support and child health: Investigating two approaches in an African slum. *Soc Sci Res*. 2018;76(August):105-119. doi:10.1016/j.ssresearch.2018.08.001

56. Madhavan S, Clark S, Araos M, Beguy D. Distance or location? How the geographic distribution of kin networks shapes support given to single mothers in urban Kenya. *Geogr J*. 2018;184(1):75-88. doi:10.1111/geoj.12230

57. Clark S, Madhavan S, Cotton C, Beguy D, Kabiru C. Who Helps Single Mothers in Nairobi? The Role of Kin Support. *J Marriage Fam*. 2017;79(4):1186-1204. doi:10.1111/jomf.12404

58. Antai D, Wedrén S, Bellocco R, Moradi T. Migration and child health inequities in Nigeria: a multilevel analysis of contextual- and individual-level factors. *Trop Med Int Heal*. 2010;15(12):1464-1474. doi:10.1111/j.1365-3156.2010.02643.x

59. Antai D. Migration and child immunization in Nigeria: Individual- and community-level contexts. *BMC Public Health*. 2010;10:116. doi:10.1186/1471-2458-10-116

60. Arnold C, Theede J, Gagnon A. A qualitative exploration of access to urban migrant healthcare in Nairobi, Kenya. *Soc Sci Med*. 2014;110:1-9. doi:10.1016/j.socscimed.2014.03.019

61. Ginsburg C, Bocquier P, Béguy D, et al. Healthy or unhealthy migrants? Identifying internal migration effects on mortality in Africa using health and demographic surveillance systems of the INDEPTH network. *Soc Sci Med*. 2016;164:59-73. doi:10.1016/j.socscimed.2016.06.035

62. Bocquier P, Beguy D, Zulu EM, Muindi K, Konseiga A, Yé Y. Do migrant children face greater health hazards in slum settlements? evidence from Nairobi, Kenya. *J Urban Heal*. 2011;88(SUPPL. 2). doi:10.1007/s11524-010-9497-6

63. Awoh AB, Plugge E. Immunisation coverage in rural-urban migrant children in low and middle-

income countries (LMICs): A systematic review and meta-analysis. *J Epidemiol Community Health*. 2016;70(3):305-311. doi:10.1136/jech-2015-205652

64. Kusuma YS, Kumari R, Kaushal S. Migration and access to maternal healthcare: Determinants of adequate antenatal care and institutional delivery among socio-economically disadvantaged migrants in Delhi, India. *Trop Med Int Heal*. 2013;18(10):1202-1210. doi:10.1111/tmi.12166

65. Razzaque A, Clair K, Chin B, et al. Association of Time since Migration from Rural to Urban Slums and Maternal and Child Outcomes: Dhaka (North and South) and Gazipur City Corporations. *J Urban Heal*. 2020;97(1):158-170. doi:10.1007/s11524-019-00395-9

66. Atake EH. The impacts of migration on maternal and child health services utilisation in Sub-Saharan Africa: evidence from Togo. *Public Health*. 2018;162:16-24. doi:10.1016/j.puhe.2018.05.010

67. Riosmena F, Kuhn R, Jochem WC. Explaining the Immigrant Health Advantage: Self-selection and Protection in Health-Related Factors Among Five Major National-Origin Immigrant Groups in the United Statews. *Demography*. 2017;54(1):175-200. doi:10.1007/s13524-016-0542-2

68. Acevedo-Garcia D, Sanchez-Vaznaugh E V., Viruell-Fuentes EA, Almeida J. Integrating social epidemiology into immigrant health research: A cross-national framework. *Soc Sci Med*. 2012;75(12):2060-2068. doi:10.1016/j.socscimed.2012.04.040

69. United Nations Population Division. Urban population (% of total population) - Kenya. The World Bank. https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=KE. Published 2019. Accessed December 27, 2020.

70. UN Habitat. Overview - Kenya. https://unhabitat.org/kenya. Published 2020. Accessed December 27, 2020.

71. United Nations Human Settlements Programme (UN-Habitat). *World Cities Report 2020: Unpacking the Value of Sustainable Urbanization*. Nairoib, Kenya; 2020. doi:10.18356/c41ab67e-en

72. African Population and Health Research Center (APHRC). *Population and Health Dynamics in Nairobi's Informal Settlements: Report of the Nairobi Cross-Sectional Slums Survey (NCSS) 2012.*; 2014.

73. Wamukoya M, Kadengye DT, Iddi S, Chikozho C. The Nairobi Urban Health and Demographic Surveillance of slum dwellers, 2002–2019: Value, processes, and challenges. *Glob Epidemiol*. 2020;2:100024. doi:10.1016/j.gloepi.2020.100024

74. Ziraba AK, Madise N, Mills S, Kyobutungi C, Ezeh A. Maternal mortality in the informal settlements of Nairobi city: What do we know? *Reprod Health*. 2009;6(1):1-8. doi:10.1186/1742-4755-6-6

75. Mutua MK, Kimani-Murage E, Ngomi N, Ravn H, Mwaniki P, Echoka E. Fully immunized child: Coverage, timing and sequencing of routine immunization in an urban poor settlement in Nairobi, Kenya. *Trop Med Health*. 2016;44(1):1-12. doi:10.1186/s41182-016-0013-x

Chapter 2 The Influence of Maternal Migration in Kenya: An Inverse Probability of Treatment-Weighted Analysis[1]

Background: Kenya has substantially improved child mortality between 1990 and 2019, with under-five mortality decreasing from 104 to 43 deaths per 1,000 live births. However, only two-thirds of Kenyan children receive all recommended vaccines by one year, making it essential to identify under-vaccinated sub-populations. A potentially vulnerable group is internal migrants, who are at risk of decreased access to healthcare. This analysis explored how maternal migration within Kenya influences childhood vaccination.

Methods: Data were from the 2014 Kenya Demographic and Health Survey, a nationally representative cross-sectional survey. Logistic regressions assessed relationships between maternal migration and full and up-to-date child vaccination using inverse probability of treatment weighting. Two exposure variables were examined: migration status and stream (e.g., rural-urban). Multiple imputation was used to impute up-to-date status for children without vaccination cards to reduce selection bias.

Results: After accounting for selection and confounding biases all relationships between migration status and migration stream and both full and up-to-date vaccination became statistically insignificant.

Conclusions: Null findings indicate that, in Kenya, characteristics enabling migration, rather than the process of migration itself, drive differential vaccination behavior between migrants and non-migrants. This is an important deviation from previous literature that did not rigorously address important biases.

Introduction[1]

In 2019 approximately 5.2 million under-five children died worldwide, over half of whom resided in sub-Saharan Africa.[2] Vaccine-preventable diseases (VPDs), including pneumonia and diarrhea, are among leading causes of death in this age group, yet in 2019 nearly 20 million children globally did not receive all vaccines recommended by the World Health Organization (WHO).[3] This is particularly concerning for countries in sub-Saharan Africa where one in 13 children die before age five.[2]

With a large population, strong economic growth, and a booming tourism sector, Kenya is an important African economic and travel hotspot.[4] Kenya has experienced considerable internal population movement since the 1990s due to post-election political violence, climate change, and decreasing economic opportunities in rural areas.[5] During that same period, Kenya achieved substantial improvements in child mortality. Under-five mortality (U5M) decreased from 101 to 43 deaths per 1,000 live births between 1990 and 2019, although this remains short of the 2030 Sustainable Development Goal target of 25 deaths per 1,000 live births.[2,6] Declines in U5M are due, in part, to improvements in vaccination; coverage with all eight basic WHO-recommended vaccines have increased from 63% in 1989 to 79% in 2014.[7] Though this demonstrates impressive improvement in vaccination coverage, one-quarter of children remain unvaccinated or undervaccinated, despite free childhood vaccines through the Kenya Expanded Program on Immunization (KEPI). While vaccination coverage among children aged 12-23 months is commonly used to assess population protection from VPDs, it is important to examine whether children have received all vaccines by 12 months, a WHO-recommended checkpoint. Failure to receive all vaccinations by one year of age places children at increased risk of disease and death. In 2014, only 67% of Kenyan children received all recommended vaccines by 12 months.[8] This coverage gap is critical given the higher risk of death in infancy and early childhood.

Maternal migration may contribute to vaccination disparities. The interaction of social determinants of health and the destination community's attitude towards immigrants shape immigrant women's experiences utilizing healthcare.[9] Women may experience discrimination from healthcare workers due to ethnic or linguistic differences, which could create a barrier to use of services. Migration can also disrupt a migrant's social and economic networks. Extended family members may provide emotional, financial, and logistical support crucial to child health that may be compromised by distance and isolation from family.[10,11] This disruption may directly influence vaccination by impeding maternal knowledge of vaccination programming or ability to finance indirect costs (e.g., transportation), resulting in decreased vaccination of migrant children compared to non-migrant peers.[12,13] Moreover, migrants require time to adapt to their new environment (e.g., integrate into the community, find employment) before they can effectively find and use local healthcare.[14] As mothers become accustomed to their new community, migrant children become more likely to receive vaccinations.[14] A migrant's experience adapting may be influenced by her migration stream (origin/destination); the ease of adapting may be different, for example, for a migrant moving between rural areas compared to moving from a rural community to an urban one.[12]

Studies of migration and childhood vaccination are largely based in India and China, with more limited work in African nations.[12,14–17] Prior studies suggest migrant children are generally less likely to be fully vaccinated than non-migrants or the general population[12,13,16] and recent migrants are less likely to be fully vaccinated than settled migrants.[13] Additionally, evidence from Ethiopia suggests differential vaccination coverage by migrant stream, with rural-rural migrants demonstrating lower coverage than rural-urban migrants.[12]

From a methodological perspective, most studies examining migration and childhood vaccination do not adequately address selection bias and confounding. As migration is an inherently selective process and the availability of written vaccination records is not random, studies of migration and vaccination must appropriately account for these biases.[18,19] This analysis examines the relationship between maternal migration and childhood vaccination status in Kenya, accounting for confounding and selection biases by utilizing inverse probability of treatment weighting and multiple imputation. Analyses examine whether migration status influences receipt of all recommended childhood vaccines and up-to-date vaccination. Secondary analyses explore relationships between migration stream and childhood vaccination.

Methods

Study sample

Data are from the 2014 Kenya Demographic and Health Survey (KDHS). The KDHS was a repeated cross-sectional study using a stratified two-stage sampling design to ensure it was nationally and regionally representative.[8] The KDHS collected information about key indicators among all participants and asked additional questions about special topics in a subsample of participants (i.e., the "long questionnaire"). Within clusters, half of households selected for inclusion were asked the additional special topics questions. Details of the KDHS sampling strategy are published elsewhere.[8]

Only women who received the long questionnaire were eligible to be included in this analysis as migration-related variables were only collected in the long questionnaire. International migrants and visitors to surveyed homes were excluded. The study analyzed living children aged 12-23 months; thus, women with children outside the 12-23-month age range or with deceased children were excluded. Women were included regardless of ability to produce their child's vaccination card at the time of interview.

Measures

Two exposures were examined: migrant status and migration stream. Migrant status was defined as mothers who moved within five years prior to the interview, dichotomized into migrant or non-migrant. Those who moved more than five years before the interview were considered non-migrants. Migration stream was determined via a combination of past and current location of residence and length of stay. Among migrants, women were coded in four binary variables: rural-urban migrants, urban-rural migrants, rural-rural migrants, and urban-urban migrants. The four migrant stream groups were compared to non-migrants. For previous place of residence, "Nairobi/Mombasa/Kisumu" and "town" were considered urban and "countryside" was rural. Current place of residence was coded as urban or rural using the DHS-provided variable.[8]

The 2014 KEPI included: one dose of Bacillus Calmette-Guérine vaccine (BCG) given at birth, three doses each of oral poliovirus vaccine (OPV), pentavalent vaccine (containing diphtheria, tetanus, pertussis, hepatitis B, and *Haemophilus influenzae* type b antigens), and pneumococcal conjugate vaccine (PCV), all of which are administered at 6, 10, and 14 weeks, and one dose of measles-containing vaccine given at 9 months (Table 2.1). Vaccines not universally introduced at onset of data collection, notably the rotavirus vaccine, were excluded.[8] Vaccination details were collected among children aged 12-23 months. Immunization status was obtained via vaccination card review or through maternal recall if the card was unavailable. Mothers who could not produce a vaccination card were asked whether their child received each dose but were not asked to estimate vaccination dates. Children without vaccination cards were included in all analyses.

Outcomes were fully immunized children (FIC) and children with up-to-date vaccination (UTD). Children who received all 11 of the recommended doses according to card or recall, regardless of age at receipt, were FIC. Those who received all 11 doses by one year, an imprecise indicator of timely vaccination, were UTD.[8,20] UTD status was initially computed among children with vaccination dates and then imputed among children missing vaccination dates (i.e., receipt confirmed via recall or card without a date).

Complete birthdate was known for 96% of children. For the remaining children, month and year of birth were known. Date of birth was randomly selected from a uniform distribution for children missing it. For children who received BCG in the same month/year as birth, a birthdate was randomly chosen between the first of the month and date of BCG receipt. Among children who received BCG in a different month/year than birth or who did not have a BCG date documented, a date of birth was randomly selected between the first and last day of their birth month.

A directed acyclic graph (DAG, Figure 2.1) was developed to represent theorized relationships between maternal migration (exposure), childhood vaccination (outcome), and confounders. Variables included in the propensity scores and accounted for in final adjusted, weighted models are enclosed in boxes. Covariates were identified via a review of the literature on migration, childhood vaccination, and studies of the relationship between migration and child vaccination in African countries.[12,14,25–28,16–19,21–24] Identified confounders included maternal age, ethnicity (Kikuyu, Luhya, Kalenjin, Luo, other), religion (Catholic, Protestant/other Christian, Muslim, other religion/ none), maternal employment (didn't work/worked for no pay in last year, worked for cash/cash-in-kind in last year), marital status (never, currently, previously), number of children in the family (two or fewer, three or more), wealth (quintiles), child age, child's birth order (1st, 2nd, 3rd, 4th or higher), maternal education (none, some primary, some secondary or higher), household size (one to four members, five or more), current urbanicity (rural, urban), and region (Central, Coast, Eastern, Nairobi, North Eastern, Nyanza, Rift Valley, Western). Child sex (male, female) and mother's age at first birth were considered predictors of child vaccination and included in the model to improve precision and propensity score fit. Place of delivery, use of antenatal care (ANC), maternal receipt of tetanus toxoid vaccine, and possession of a vaccination card were theorized to be mediators and therefore not controlled for.

Statistical analysis

Inverse probability of treatment weighting

Propensity score weighting is a quasi-experimental analytical technique developed to reduce data dimensionality and ensure confounders are balanced between exposed and unexposed individuals.[29] When distributions of confounders are balanced, differences in the outcome are assumed to be due to exposure. Propensity scores (PSs) are calculated by estimating the conditional probability of exposure (here, migrant status), which can be used in inverse probability of treatment weighting (IPTW).[30,31] In IPTW, the PS is used to weight the sample such that the distribution of confounders is independent of exposure status, creating a "pseudo-randomized" sample that (theoretically) eliminates confounding and allows direct comparison of exposed and unexposed participants. IPTW weights are constructed so an individual's weight is the inverse of the probability of receiving the treatment the individual received (i.e., the inverse of the probability of being a migrant for migrants and the inverse of the probability of being a non-migrant among non-migrants).[31]

Unweighted logistic regressions were used to create the PSs used in generating the IPTW weights. The migration status PS predicted an individual's propensity to be a migrant by including the following variables as covariates in the model: child age, sex, birth order, maternal age, religion, ethnicity, education, working status, marital status, age at first birth, household size, number of children under-five in the household, wealth, urbanicity, and region. Survey weights were included as a covariate in the PS model but not as a design feature.[32] To improve precision, stabilized IPTW weights were used, $w = \frac{\Pr[migrant=1]}{propensity\ score}$ for migrants and $w = \frac{1-\Pr[migrant=1]}{1-propensity\ score}$ for non-migrants.[31,33–35] To accommodate the DHS complex survey design, the IPTW weight was then multiplied by the survey weight (IPTW-S weight).[32]

Separate PS models were run for each of the four migration streams (rural-urban migrant vs non-migrant, urban-rural, rural-rural, urban-urban) and new IPTW weights created for each stream. PS models used to predict each of the four migration streams all included the same set of categorical covariates. The use of categorical covariates in estimating the migration stream PSs was to optimize IPTW diagnostics. PS models used to predict each of the four migration streams all included the same set of categorical covariates: child age (12-17 months, 18-23 months), sex (male, female), birth order (1st or 2nd birth, 3rd or higher birth), maternal age (15-25 years, 26-30, 31 and older), religion (Christian, other), ethnicity (Kikuyu, other), education (never attended school, ever attended school), working status (didn't work/worked for no pay in last 12 months, worked for cash/cash-in-kind in last 12 months), marital status (currently married or living with a partner, not), age at first birth (17 or younger, 18 or older), household size (1-4 members, 5 or more members), number of under-five children in household (2 or fewer, 3 or more), wealth quintile, and survey weight. Variables included in PS estimation were identified a priori via literature review as discussed above; all available variables thought to be confounders or only associated with vaccination status were included.[31]

Diagnostics were run on the final IPTW-S weighted sample to assess the functionality of IPTW.[36] The distributions of the stabilized IPTW weights were examined (mean, standard deviation, minimum, maximum) as substantial deviations from a mean weight of one or extreme weight values indicate a positivity assumption violation or a poorly fit PS.[29,36] The standardized difference between migrants and non-migrants for each covariate was computed using *covbal* in Stata to evaluate whether IPTW-S weights adequately balanced the confounders between the two groups, and therefore reduced potential confounding bias[31,36,37] The same IPTW-S weights were used for FIC and UTD analyses.

Multiple imputation

In calculations of UTD status, typically only children with cards with dates of birth and vaccine receipt are included.[38] However, excluding children without vaccination cards could introduce selection bias; migrants may be less likely to retain their child’s vaccination card while moving and children without a card may be less likely to be UTD. Multiple imputation (MI) was used to address this selection issue by imputing UTD status for children without vaccination dates.

MI is a simulation-based statistical procedure for analyzing data sets with missing values by which missing data is replaced with multiple sets of possible values.[39–41] Under the MI framework, analyses are conducted separately within data sets with each imputed value and then estimates are combined into a single result.[39–41] MI is the standard for addressing missing data since it appropriately estimates standard errors by accounting for the variability associated with missing data imputation, in contrast to complete case analysis and single imputation methods which often result in standard errors that are too large or small.[41,42]

MI assumes that missing values are missing at random (MAR), meaning that missing up-to-date vaccination (UTD) values may depend on observed values of variables included in the imputation model but not on the unobserved values of UTD.[41,43] In the context of this analysis, the MAR assumption would mean the probability of a missing UTD value could be related to the values of variables included in the imputation model (such as maternal migrant status, maternal education, household wealth, etc.) but could not be dependent on the unobserved value of UTD status. The authors believe the MAR assumption is reasonable, as it is believed that UTD missingness is dependent on factors such as migration status and household wealth, rather than the UTD value itself (i.e., the authors do not believe information is missing because a child is/is not up-to-date). In fact, when an indicator of UTD missingness was regressed onto variables included in the imputation model, missingness was statistically significantly associated with maternal migration status, family wealth, region, maternal age at first childbirth, and household size. While this finding provides evidence to support the MAR assumption it does not prove the assumption holds. Given we do not have the values of the missing data we cannot fully assess the relationship between UTD missingness and UTD missing values, which is necessary to prove whether the MAR assumption holds.

The following variables were included in UTD imputation model: child age, sex, and birth order, maternal migrant status, age, education, working status, marital status, religion, ethnicity, frequency of reading the newspaper/magazine, listening to radio, and watching television, age at first birth, type of place of delivery of index child, whether mother received assistance at index child's birth from doctor, nurse/midwife, traditional birth attendant, community health worker, relative/friend, or no one, and household size, wealth, urbanicity, region, number of under-five children, sex of household head, and survey weight.[43] These variables were selected as they were either used in the migration-vaccination analyses, associated with analysis variables, or thought to predict missingness.[43] The *mi impute monotone* command in Stata was used to generate 100 analytic data sets in which UTD vaccination was conditionally imputed using logistic regression among individuals who received the long questionnaire. Distributions of the observed, imputed, and combined (observed and imputed) UTD variable were calculated in 15 randomly selected imputations to examine how well the imputation model performed. *Mi estimate* and *mi svy* commands were used in conjunction on the imputed data sets to calculate descriptive statistics and final effect estimates.[43] The multiply imputed data was only used in the UTD vaccination analyses.

Effect estimation

Descriptive statistics were calculated with survey weights and with IPTW-S weights. Crude binary logistic regression models and final multivariate logistic regression models assessed relationships between migration exposures and vaccination outcomes in both survey-weighted and IPTW-S-weighted data. Covariates included in the PS model (except survey weight) were included in the final estimation models to account for residual confounding not addressed via IPTW. Analyses were conducted in Stata version 15.1 (College Station, TX, USA).

Sensitivity analyses

Three regression models were run with the raw data to explore validity of imputed UTD results. First, a model excluding children without vaccination dates examined the influence of selection bias. Then, two models were run in which individuals missing dates were set as all not UTD and then all UTD. As some children without vaccination dates were likely UTD and some not, the MI estimate would be expected to fall between these two extreme estimates.[42]

Additional sensitivity analyses examining the relationships between migration streams and FIC used destination non-migrants as the referent group rather than all non-migrants. For example, for rural-urban migrants the sensitivity analysis compared rural-urban migrants to urban non-migrants. Prior to running the regression models, new IPTW-S weights were created for each migration stream using the same covariates included in the initial analysis.

Results

Full vaccination

The full unweighted KDHS sample included 20,956 children. Exclusions were: did not receive long questionnaire (10,872 children), child not 12-23 months (8,034), child deceased (77), mother an international migrant or visitor (42), and missing information on maternal working status (2) or location of previous residence (4). This left a raw unweighted sample of 1,925 observations for the FIC analysis. Incorporating the DHS-created survey weights decreased the sample size to 1,792.

Within the IPTW-S-weighted sample, both migrant and non-migrant children had a mean age of about 17 months and most frequently were fourth or higher birth order (Table 2.2). Approximately 74.8% of migrant children and 76.3% of non-migrant children were FIC. Only 72.1% of migrants had a vaccination card compared to 79.1% of non-migrants. Mothers averaged 27 years old, most had at least some primary education and half worked in the last year. Over one-third of mothers were migrants (36.4%), of whom the rural-rural stream was most common (46.2%) (Table 2.3).

The IPTW weight diagnostics suggested good fit (IPTW mean: 1.0, maximum: 10.0) (Table 2.4). Standardized differences assess covariate balance before and after incorporating IPTW and no covariates had standardized differences >0.1 after IPTW, indicating adequate balance of confounders. For all migration stream analyses the number of covariates with a standardized difference value >0.1 decreased upon inclusion of IPTW weights. IPTW-S weights had slightly lower mean values and larger maximum values, but differences were not substantial (Table 2.4).

The crude association between migrant status and FIC was positive and statistically significant (cOR: 1.46; 95% CI: 1.06, 2.01), but not statistically significant after addressing confounding (aOR: 0.87; 95% CI: 0.61, 1.24) (Table 2.5). In the adjusted models, none of the migration streams were statistically significantly associated with FIC.

Up-to-date vaccination

The UTD and FIC analyses included the same exclusions. UTD status was imputed for 476 children (24.7%). Distributions of the observed and imputed UTD variable demonstrate that proportions of up-to-date children were slightly lower in the imputed compared to observed data, but combined proportions were similar to observed data. It should be noted that the imputed data would not be expected to exactly mirror observed data as data were not assumed to be missing completely at random (Table 2.6). Substantially more children with vaccination dates were FIC compared to children without dates (80.1% vs 62.5%, respectively; Table 2.7). No covariate values were altered during MI. Only the proportion of UTD children changed: 64.9% of migrants and 65.1% of non-migrants (65.0% overall) in the imputed, IPTW-S-weighted data were UTD compared to 72.8% and 71.6% of migrants and non-migrants, respectively (72.0% overall) in the original IPTW-S-weighted data.

The crude model indicated a statistically significant positive association between migration status and UTD vaccination (cOR: 1.41; 95% CI: 1.02, 1.95), but this relationship lost statistical significance after accounting for confounding (aOR: 0.97; 95% CI: 0.66, 1.43) (Table 2.8). Similar to FIC results, migration stream regressions were statistically insignificant in the final adjusted models.

Sensitivity analyses

When children without vaccination dates were excluded instead of imputed, the estimate and confidence interval remained similar to original results, demonstrating limited concern of bias but improved precision imputed analyses (Table 2.9). The estimate from the imputed model fell between estimates from analyses in which no or all children with missing dates were set as UTD.

Sensitivity analyses in which the referent group changed to destination non-migrants provided improved IPTW and IPTW-S weight diagnostics (Table 2.10), but effect estimates did not substantially deviate from original results (Table 2.11).

Discussion

This analysis explored the impact of maternal migration on childhood vaccination. Migration is hypothesized to influence healthcare utilization by disrupting a migrant's access to resources and requiring an adjustment period before commencing use of healthcare. Analyses of migration and childhood vaccination from low- and middle-income countries mostly demonstrate inverse associations, though many studies fail to appropriately address selection bias and confounding.[15] This analysis found null associations between migration status and stream and both FIC and UTD vaccination after accounting for these biases.

In contrast to literature from sub-Saharan Africa, this analysis found maternal migration did not influence child vaccination. An Ethiopian study[12] found children of rural-rural migrants were less likely to be vaccinated compared to rural non-migrant children and a Nigerian analysis reported rural-urban migrant children were less likely to be fully vaccinated compared to both rural and urban non-migrant children.[16] Inconsistent results may be due to the substantially disparate social, cultural and economic environments between Kenya, Ethiopia, and Nigeria. Though both are ethnically diverse, Ethiopia differs from Kenya in that its numerous tribal groups were never united under colonial rule and still experience substantial inter-ethnic group violence.[44] Nigeria similarly faces ongoing religious and ethnic clashes.[45] Inter-group conflicts in Ethiopia and Nigeria may make integration into a new community more difficult for migrants than in countries that share a larger common identity. Null results may mask sub-group results with opposing directionality. Research from Benin reported opposite relationships between migration and child vaccination for children who were born before versus after migration; children born before migration were less likely to be vaccinated but children born after migration were more likely to be vaccinated compared to non-migrants.[14] Had the authors ignored the temporality of migration and vaccination their results would appear null, though an interesting relationship was present.

In the survey-weighted sample, every sociodemographic characteristic, except child age and religion, revealed imbalance between migrant and non-migrant households. Migrants were younger, more highly educated, and wealthier than non-migrants. That is, migrants were positively selected on traits that facilitate healthcare use.[9,18] After including IPTW-S weights, all covariates demonstrated acceptable balance. Appropriately adjusting for confounding allowed the examination of whether the migration process itself, rather than differences in predisposing characteristics, accounted for differential healthcare utilization. Only one other study from Togo similarly examined the balance of covariates before and after accounting for confounding.[17] Confirming appropriate balance of confounders is an important analytic step in analyses of migration and health in which migrant selection is an important source of bias.

Studies of UTD vaccination often exclude children without vaccination cards because vaccination dates are used to determine age at vaccination. This likely results in biased estimates as vaccination use among children with and without cards is not comparable; children without cards more likely belong to vulnerable groups (i.e. less educated parents).[19] Card retention is also likely associated with vaccination timeliness as caregivers of children without documented vaccination dates may not remember when to return for vaccination. In fact, evidence from Kenya demonstrated children with cards had significantly higher vaccination coverage than children without cards.[26] The disparity in FIC between children with and without cards in this analysis shows that exclusion of children without vaccination dates results in the loss of children with substantially worse vaccination outcomes. As expected, UTD vaccination dropped from 72% to 65% when incorporating children without dates. This estimate is slightly lower than that from the DHS Final Report (67%), which was calculated assuming the proportion of children with UTD vaccination is the same regardless of card retention.[8] Theoretically, by imputing UTD vaccination for children who do not have cards this analysis avoided potential selection bias and allowed characteristics of women and their children to determine UTD status, an advance in the literature. In practice, the influence of selection bias in this analysis appears minimal, as demonstrated by the similarity of the MI results to the results when all children without cards were excluded (complete case analysis). The influence of selection bias would likely be more substantial in settings with larger proportions of children missing vaccination cards. With a larger proportion of children missing vaccination cards, multiply imputed results would be preferable as MI only assumes data are missing at random, whereas complete case analyses assume missing data are missing completely at random, which is unlikely.[41]

Limitations and strengths

This study has limitations. The use of IPTW is a strength but it is sensitive to unmeasured confounding and whether the PS has been correctly estimated.[36] Though effort was made to include confounders, unmeasured confounding may remain. Calculation of e-values suggests that the observed migrant status odds ratio could be shifted from 0.87 to 1.00 by an unmeasured confounder that was associated with both migration status and FIC vaccination status by an odds ratio of 1.35-fold each (see Table 2.12 and Figure 2.2 for e-values for all regressions included in this analysis).[46,47] Similarly, MI is an advantage of this analysis, but there is risk of imputation model misspecification, which could impact the values of imputed observations, and MI's assumption that missing values are missing at random cannot be tested.[42] The KDHS is cross-sectional and therefore results represent association, not causation. DHS surveys provide minimal migration-related questions; they do not ask about reasons for migration or provide detailed migration histories that would allow a more precise measure of migration (timing, duration, specific locations of residence). Data do not distinguish between those who migrated from one urban (rural) area to another urban (rural) area and those who moved between neighborhoods within the same city. Inclusion of those who moved within the same city likely attenuate results as they may retain close ties with their origin community. Finally, a preferred approach would have been to compare migrants to destination non-migrants (i.e., compare rural-urban migrants to urban non-migrants). However, in an effort to have a common non-migrant comparison group for all analyses, all migrant groups were compared to non-migrants generally. Sensitivity analyses did not demonstrate markedly different results when destination non-migrants were the referent group.

This analysis also has important strengths. Examining both FIC and UTD vaccination provides a more nuanced understanding of the relationship between migration childhood vaccination. Moreover, investigation of migration streams as exposures acknowledged that characteristics of the migration process may differentially impact healthcare use. The use of IPTW to assess and correct confounding and MI to address selection bias are advances over previous literature. Conventional regression modeling does not include inspection of whether covariate adjustment adequately balanced confounders. In this analysis, covariate balance was evaluated before and after inclusion of IPTW weights to ensure confounding was accounted for in a manner separate from effect estimate estimation.[31] MI was used to address the potential selection bias common among studies of UTD vaccination. By including children whose vaccination information was obtained via maternal recall, an accurate source of vaccine receipt in the region[48], this analysis included those least likely to have received UTD vaccination resulting in more accurate results.

Conclusions

Conflict, changes in climate, and new economic and education opportunities in urban areas have prompted considerable increases in migration.[49] Therefore, it is critical to understand the ways in which this phenomenon influences healthcare utilization. Results suggest that, after accounting for selection bias and confounding, there is no association between maternal migration and childhood vaccination in Kenya, though unexplored heterogeneity in the migrant experience may drive this result. This research demonstrates an advancement in examining the migration-childhood vaccination relationship as it utilizes advanced methods to address biases common to this area of research.

Future research should explore the temporal relationship between migration and health. Though studied in limited contexts,[14] further investigation regarding precise timing between migration and childbirth could determine whether migration within ‘high impact intervals’ before or after childbirth differently influences vaccination. Studies should also examine how reasons for migrating (e.g., marriage vs forced migration) differentially influence child health and vaccination. By better understanding the ways in which migration influences child healthcare utilization, strides can be made to further decrease U5M and promote health equity.

Table 2.1 Kenya 2014 childhood vaccination schedule[1,2]

Vaccine	Birth	6 weeks	10 weeks	14 weeks	9 months
BCG	X				
OPV		X	X	X	
Pentavalent		X	X	X	
PCV		X	X	X	
Measles					X

[1] The rotavirus vaccine (given at 6 and 10 weeks) was introduced in Kenya in 2014. As implementation had not been fully rolled out by the time data was collected, estimates of rotavirus vaccine coverage in the 2014 KDHS do not represent overall uptake and therefore it was not included in this analysis

[2] BCG: Bacillus Calmette-Guérine vaccine; OPV: oral poliovirus vaccine; PCV: pneumococcal conjugate vaccine

Table 2.2 Descriptive statistics of children and their mothers included in the 2014 Kenya DHS, separately weighted by survey weights and IPTW-S weights

	Survey Weighted[1] (n=1,792)			IPTW x Survey Weighted[2] (n=1,792)		
	Migrants (n=767)	**Non-migrants (n=1,025)**	**Standardized difference**	**Migrants (n=653)**	**Non-migrants (n=1,139)**	**Standardized difference**
	Reported as mean (sd) or n(%)					
Child characteristics						
Age (in months)	17.39 (0.16)	17.30 (0.13)	0.03	17.19 (0.18)	17.31 (0.18)	0.04
Gender			**0.10**			0.08
Male	412 (53.70%)	502 (48.95%)		326 (49.90%)	611 (53.63%)	
Female	355 (46.30%)	523 (51.05%)		327 (50.10%)	528 (46.37%)	
Birth order			**0.99**			0.08
First birth	308 (40.13%)	156 (15.18%)		178 (27.28%)	283 (24.79%)	
Second birth	256 (33.33%)	158 (15.38%)		159 (24.39%)	259 (22.78%)	
Third birth	108 (14.14%)	194 (18.92%)		112 (17.05%)	209 (18.39%	
Fourth or higher birth	95 (12.40%)	518 (50.52%)		204 (31.28%)	388 (34.04%)	
Fully vaccinated (FIC)	609 (79.41%)	743 (72.49%)	---	488 (74.82%)	869 (76.30%)	---
Up-to-date with vaccinations (UTD)	414 (76.70%)	533 (66.34%)	---	337 (72.75%)	633 (71.58%)	---
Imputed up-to-date with vaccinations (UTD)[3]	68.47%	60.70%	---	64.85%	65.07%	---
Has a vaccination card	551 (71.89%)	819 (79.85%)	---	470 (72.05%)	901 (79.14%)	---
Maternal characteristics						
Age (in years)	25.12 (0.24)	29.14 (0.25)	**0.71**	27.29 (0.55)	27.49 (0.30)	0.03
Religion			0.08			0.03
Protestant/other Christian	569 (74.18%)	718 (70.08%)		443 (67.92%)	842 (73.95%)	
Roman Catholic	129 (16.79%)	176 (17.21%)		119 (18.25%)	175 (15.36%)	
Muslim	51 (6.70%)	88 (8.55%)		60 (9.13%)	85 (7.44%)	
No religion/other religion	18 (2.33%)	43 (4.16%)		31 (4.70%)	37 (3.25%)	
Ethnicity			**0.27**			0.05
Kikuyu	165 (21.46%)	145 (14.18%)		118 (18.06%)	225 (19.79%)	
Luhya	163 (21.30%)	131 (12.79%)		104 (15.88%)	161 (14.17%)	
Kalenjin	89 (11.52%)	175 (17.02%)		76 (11.62%)	160 (14.00%)	
Luo	82 (10.72%)	126 (12.30%)		72 (11.02%)	141 (12.35%)	
Other ethnic groups	268 (35.00%)	448 (43.71%)		283 (43.42%)	452 (39.69%)	
Educational attainment			**0.48**			0.08
No education	51 (6.57%)	164 (16.00%)		104 (15.85%)	135 (11.82%)	

At least some primary	365 (47.65%)	604 (58.90%)		323 (49.57%)	593 (52.07%)	
At least some secondary or higher	351 (45.78%)	257 (25.10%)		226 (34.58%)	411 (36.10%)	
Working status			**0.14**			0.00
Didn't work or worked for no pay in last 12 mo.	355 (46.34%)	544 (53.06%)		338 (51.79%)	591 (51.87%)	
Worked for cash/cash-in-kind in the last 12 mo.	412 (53.66%)	481 (46.94%)		315 (48.21%)	548 (48.13%)	
Marital status			**0.12**			0.05
Never married or lived with partner	49 (6.39%)	89 (8.67%)		51 (7.77%)	82 (7.15%)	
Currently married or living with a partner	643 (83.83%)	860 (83.91%)		536 (82.11%)	972 (85.38%)	
Previously married or living with partner	75 (9.78%)	76 (7.42%)		66 (10.12%)	85 (7.47%)	
Age at first birth (in years)	20.03 (0.19)	18.97 (0.13)	**0.30**	19.45 (0.20)	19.49 (0.20)	0.01
Household characteristics						
Household size			**0.71**			0.06
1 to 4 household members	443 (57.76%)	253 (24.70%)		255 (39.07%)	479 (42.09%)	
5 or more household members	324 (42.24%)	772 (75.30%)		398 (60.93%)	660 (57.91%)	
Number of under-5 children in household			**0.20**			0.01
2 or fewer under-5 children	681 (88.83%)	838 (81.75%)		557 (85.35%)	970 (85.16%)	
3 or more under-5 children	86 (11.17%)	187 (18.25%)		96 (14.65%)	169 (14.84%)	
Wealth			**0.49**			0.02
Poorest	119 (15.52%)	338 (32.94%)		175 (26.79%)	284 (24.92%)	
Poorer	149 (19.38%)	212 (20.74%)		124 (19.02%)	210 (18.46%)	
Middle	117 (15.26%)	183 (17.82%)		99 (15.06%)	198 (17.37%)	
Richer	188 (24.49%)	158 (15.42%)		127 (19.53%)	247 (21.73%)	
Richest	194 (25.35%)	134 (13.08%)		128 (19.60%)	200 (17.52%)	
Urbanicity			**0.44**			0.00
Rural	404 (52.71%)	753 (73.50%)		404 (61.87%)	704 (61.80%)	
Urban	363 (47.29%)	272 (26.50%)		249 (38.13%	435 (38.20%)	
Region of residence			**0.19**			0.04
Central	92 (12.01%)	73 (7.12%)		67 (10.27%)	127 (11.11%)	
Coast	73 (9.58%)	108 (10.52%)		75 (11.48%)	115 (10.11%)	
Eastern	65 (8.44%)	135 (13.20%)		72 (11.06%)	119 (10.41%)	
Nairobi	132 (17.21%)	74 (7.24%)		78 (11.87%)	143 (12.59%)	
North Eastern	14 (1.83%)	43 (4.20%)		23 (3.43%)	38 (3.36%)	
Nyanza	81 (10.52%)	154 (15.07%)		77 (11.86%)	150 (13.20%)	
Rift Valley	211 (27.56%)	327 (31.85%)		189 (28.94%)	338 (29.65%)	
Western	99 (12.85%)	111 (10.80%)		72 (11.09%)	109 (9.57%)	

Bold indicates a standardized difference value greater than the 0.1 threshold

[1] Weighted with DHS survey weight

[2] Weighted with the 'migrant status' IPTW-S weight
[3] Proportion of UTD children is reported from the multiply imputed data

Table 2.3 Descriptive statistics of mothers' migration status among women, separately weighted by survey weights and IPTS-S weights

˜	Survey Weighted n (%) (n=1,792)[1]	IPTW x Survey Weighted n (%) (n=1,792)[2]
Migrant status		
Migrant	767 (42.78%)	653 (36.42%)
Non-migrant	1025 (57.22%)	1139 (63.58%)
Migration streams		
Rural-urban migrant	177 (23.05%)	125 (19.15%)
Urban-rural migrant	104 (13.58%)	103 (15.72%)
Rural-rural migrant	300 (39.12%)	301 (46.15%)
Urban-urban migrant	186 (24.25%)	124 (18.98%)
Rural-urban migration stream		
Rural-urban migrant	177 (14.70%)	125 (9.88%)
Non-migrant	1025 (85.30%)	1139 (90.12%)
Urban-rural migration stream		
Urban-rural migrant	104 (9.22%)	103 (8.26%)
Non-migrant	1025 (90.78%)	1139 (91.74%)
Rural-rural migration stream		
Rural-rural migrant	300 (22.63%)	301 (20.91%)
Non-migrant	1025 (77.37%)	1139 (79.09%)
Urban-urban migration stream		
Urban-urban migrant	186 (15.34%)	124 (9.81%)
Non-migrant	1025 (84.66%)	1139 (90.19%)

[1] Weighted with DHS survey weight

[2] Weighted with the 'migrant status' IPTW-S weight

Table 2.4 Balance diagnostics for IPTW weights

	IPTW weight mean	**IPTW weight standard deviation**	**IPTW weight minimum value**	**IPTW weight maximum value**	**IPTW-S weight mean**	**IPTW-S weight standard deviation**	**IPTW-S weight minimum value**	**IPTW-S weight maximum value**	**Number of covariates with standardized difference >0.1 before IPTW**	**Largest standardized difference value before IPTW**	**Number of covariates with standardized difference >0.1 after IPTW**	**Largest standardized difference value after IPTW**
Migrant status[1]	1.01	0.78	0.41	10.00	0.93	1.35	0.02	22.06	12	0.99	0	0.08
Rural-urban migrants[2]	1.01	0.73	0.16	16.16	0.87	0.95	0.02	10.07	13	1.21	8	0.23
Urban-rural migrants[2]	1.01	0.51	0.17	12.90	0.88	0.94	0.03	16.04	10	0.87	7	0.36
Rural-rural migrants[2]	1.01	0.62	0.29	9.68	0.86	0.97	0.03	14.43	6	0.79	3	0.21
Urban-urban migrants[2]	0.97	0.61	0.15	18.98	0.87	1.05	0.02	12.56	12	1.57	9	0.73

[1] A total of 15 covariates were included in this analysis

[2] A total of 13 covariates were included in this analysis

Table 2.5 Results of logistic regression examining the relationship between maternal migration and FIC, among entire sample and stratified by migration stream

	Survey weighted								IPTW-S weighted							
	n	**cOR[1]**	**95% CI**	**p-value**	**n**	**aOR**	**95% CI**	**p-value**	**n**	**OR**	**95% CI**	**p-value**	**n**	**aOR**	**95% CI**	**p-value**
Migrant status – Entire sample[2]	1,792				1,792				1,792				1,792 [3]			
Migrant		**1.46**	**(1.06, 2.01)**	**0.02**		0.96	(0.67, 1.37)	0.84		0.92	(0.65, 1.31)	0.66		0.87	(0.61, 1.24)	0.46
Non-migrant		1.00	ref			1.00	ref			1.00	ref			1.00	ref	
Rural-urban migration stream[4]	1,202				1,202				1,179				1,179 [5]			
Rural-urban migrant		1.47	(0.75, 2.87)	0.26		0.78	(0.41, 1.50)	0.46		1.09	(0.58, 2.04)	0.79		1.02	(0.54, 1.93)	0.95
Non-migrant		1.00	ref			1.00	ref			1.00	ref			1.00	ref	
Urban-rural migration stream[4]	1,130				1,130				1,142				1,142 [6]			
Urban-rural migrant		1.78	(0.95, 3.35)	0.07		1.25	(0.66, 2.37)	0.50		1.22	(0.45, 3.32)	0.69		1.35	(0.51, 3.55)	0.55
Non-migrant		1.00	ref			1.00	ref			1.00	ref			1.00	ref	
Rural-rural migration stream[4]	1,325				1,325								1,323 [7]			
Rural-rural migrant		**1.53**	**(1.05, 2.24)**	**0.03**		1.32	(0.85, 2.04)	0.21	1,323					1.25	(0.80, 1.94)	0.32
Non-migrant		1.00	ref			1.00	ref			1.24	(0.77, 1.99)	0.38		1.00	ref	
Urban-urban migration stream[4]	1,211				1,211				1,172				1,172 [8]			
Urban-urban migrant		1.23	(0.71, 2.15)	0.47		0.66	(0.35, 1.24)	0.20		1.23	(0.66, 2.31)	0.52		0.79	(0.41, 1.52)	0.47
Non-migrant		1.00	ref			1.00	ref							1.00	ref	

Bold indicates a statistically significant value at the 0.05 level

[1] Crude odds ratio

[2] Adjusted odds ratio accounts for child's age, child's sex, child's birth order, maternal age, religion, ethnicity, education, work status, marital status age at first birth, household size, number of under-5 children in the household, wealth quintile, region of residence, and current urbanicity

[3] Weighted with 'migrant status' IPTW-S weight

[4] Adjusted odds ratio accounts for all variables included in the migrant status analysis except current urbanicity and region

[5] Weighted with 'rural-urban migration stream' IPTW-S weight

[6] Weighted with 'urban-rural migration stream' IPTW-S weight

[7] Weighted with 'rural-rural migration stream' IPTW-S weight

[8] Weighted with 'urban-urban migration stream' IPTW-S weight

Table 2.6 Distributions of observed, imputed, and combined (observed + imputed) up-to-date vaccination variable in 15 randomly selected imputations

Imputation number	Proportion with up-to-date vaccination Observed values	Proportion with up-to-date vaccination Imputed values	Proportion with up-to date vaccination Combined (observed + imputed) values
8	0.69	0.40	0.62
18	0.69	0.40	0.61
20	0.69	0.43	0.62
25	0.69	0.38	0.61
30	0.69	0.42	0.62
31	0.69	0.38	0.61
36	0.69	0.42	0.62
45	0.69	0.44	0.63
59	0.69	0.41	0.62
71	0.69	0.41	0.62
80	0.69	0.37	0.61
83	0.69	0.47	0.63
85	0.69	0.41	0.62
93	0.69	0.41	0.62
99	0.69	0.39	0.61

Table 2.7 Characteristics of individuals with and without vaccination dates[1]

	Has vaccination dates n (%) (n=1,348)	**Does not have vaccination dates n (%) (n=444)**
	Reported as mean (sd) or n (%)	
Child characteristics		
Age (in months)	17.15 (0.15)	17.60 (0.26)
Gender		
Male	694 (51.47%)	243 (54.69%)
Female	654 (48.53%)	201 (45.31%)
Birth order		
First birth	341 (25.32%)	119 (26.85%)
Second birth	305 (22.64%)	114 (25.57%)
Third birth	245 (18.17%)	76 (17.08%)
Fourth or higher birth	457 (33.87%)	135 (30.50%)
Fully vaccinated (FIC)	1079 (80.14%)	278 (62.50%)
Has a vaccination card	1348 (100%)	24 (5.51%)
Maternal characteristics		
Age (in years)	27.586 (0.32)	26.97 (0.51)
Religion		
Protestant/other Christian	965 (71.61%)	321 (72.19%)
Roman Catholic	234 (17.38%)	60 (13.50%)
Muslim	95 (7.05%)	49 (11.08%)
No religion/other religion	54 (3.96%)	14 (3.23%)
Ethnicity		
Kikuyu	257 (19.08%)	86 (19.40%)
Luhya	191 (14.14%)	75 (16.79%)
Kalenjin	184 (13.64%)	51 (11.59%)
Luo	142 (10.55%)	70 (15.84%)
Other ethnic groups	574 (42.59%)	162 (36.38%)
Educational attainment		
No education	179 (13.26%)	59 (13.38%)
At least some primary	709 (52.62%)	208 (46.75%)
At least some secondary or higher	460 (34.12%)	177 (39.87%)

Working status		
Didn't work or worked for no pay in last 12 mo.	719 (53.32%)	210 (47.35%)
Worked for cash or cash-in-kind in the last 12 mo.	629 (46.68%)	234 (52.65%)
Marital status		
Never married or lived with partner	94 (6.95%)	38 (8.65%)
Currently married or living with a partner	1159 (86.01%)	350 (78.68%)
Previously married or living with partner	95 (7.04%)	56 (12.67%)
Age at first birth (in years)	19.58 (0.18)	19.17 (0.26)
Household characteristics		
Household size		
1 to 4 household members	588 (43.61%)	147 (33.06%)
5 or more household members	760 (56.39%)	297 (66.94%)
Number of under-5 children in household		
2 or fewer under-5 children	1153 (85.58%)	374 (84.15%)
3 or more under-5 children	195 (14.42%)	70 (15.85%)
Wealth		
Poorest	346 (25.65%)	113 (25.47%)
Poorer	278 (20.65%)	56 (12.63%)
Middle	211 (15.64%)	86 (19.24%)
Richer	299 (22.16%)	76 (17.17%)
Richest	214 (15.90%)	113 (25.49%)
Urbanicity		
Rural	866 (64.26%)	242 (54.46%)
Urban	482 (35.74%)	202 (45.54%)
Region of residence		
Central	134 (9.96%)	59 (13.36%)
Coast	159 (11.81%)	31 (6.95%)
Eastern	167 (12.38%)	24 (5.38%)
Nairobi	161 (11.92%)	60 (13.55%)
North Eastern	32 (2.41%)	28 (6.37%)
Nyanza	160 (11.86%)	68 (15.30%)
Rift Valley	406 (30.09%)	121 (27.30%)
Western	129 (9.57%)	53 (11.79%)

[1] Calculated in the original, unimputed data set and weighted by 'migrant status' IPTW-S weight

Table 2.8 Results of logistic regressions examining the relationships between maternal migration and UTD, among entire sample and stratified by migration stream

	Survey weighted								IPTW-S weighted							
	n	**cOR[1]**	**95% CI**	**p-value**	**n**	**aOR**	**95% CI**	**p-value**	**n**	**OR**	**96% CI**	**p-value**	**n**	**aOR**	**95% CI**	**p-value**
Migrant Status - Entire sample[2]	1,790				1,790				1,790				1,790 [3]			
Migrant		**1.41**	**(1.02, 1.95)**	**0.04**		0.94	(0.63, 1.40)	0.75		0.99	(0.68, 1.44)	0.96		0.97	(0.66, 1.43)	0.89
Non-migrant		1.00	ref			1.00	ref			1.00	ref			1.00	ref	
Rural-urban migration stream[4]	1,200				1,200				1,177				1,178 [5]			
Rural-urban migrant		1.54	(0.79, 3.00)	0.21		0.79	(0.39, 1.62)	0.53		1.46	(0.76, 2.80)	0.26		1.31	(0.64, 2.71)	0.46
Non-migrant		1.00	ref			1.00	ref			1.00	ref			1.00	ref	
Urban-rural migration stream[4]	1,128				1,128				1,140				1,140 [6]			
Urban-rural migrant		1.43	(0.77, 2.65)	0.26		0.95	(0.49, 1.86)	0.89		1.16	(0.43, 3.10)	0.77		1.20	(0.44, 3.26)	0.72
Non-migrant		1.00	ref			1.00	ref			1.00	ref			1.00	ref	
Rural-rural migration stream[4]	1,324				1,324				1,321				1,321 [7]			
Rural-rural migrant		1.45	(0.97, 2.16)	0.07		1.25	(0.77, 2.05)	0.36		1.25	(0.75, 2.09)	0.40		1.26	(0.76, 2.10)	0.38
Non-migrant		1.00	ref			1.00	ref			1.00	ref			1.00	ref	
Urban-urban migration stream[4]	1,210				1,210				1,170				1,170 [8]			
Urban-urban migrant		1.24	(0.68, 2.27)	0.48		0.60	(0.30, 1.20)	0.15		1.19	(0.59, 2.40)	0.63		0.75	(0.37, 1.53)	0.42
Non-migrant		1.00	ref			1.00	ref			1.00	ref			1.00	ref	

Bold indicates a statistically significant value at the 0.05 level

[1] Crude odds ratio

[2] Adjusted odds ratio accounts for child's age, child's sex, child's birth order, maternal age, religion, ethnicity, education, work status, marital status age at first birth, household size, number of under-5 children in the household, wealth quintile, region of residence, and current urbanicity

[3] Weighted with 'migrant status' IPTW-S weight

[4] Adjusted odds ratio accounts for all variables included in the migrant status analysis except current urbanicity and region

[5] Weighted with 'rural-urban migration stream' IPTW-S weight

[6] Weighted with 'urban-rural migration stream' IPTW-S weight

[7] Weighted with 'rural-rural migration stream' IPTW-S weight

[8] Weighted with 'urban-urban migration stream' IPTW-S weight

Table 2.9 Sensitivity analyses comparing results of imputed analysis with complete case analysis and setting all children with missing vaccination cards to be UTD or not UTD[1]

	Multiply imputed model[2] aOR (95% CI)	All children without vaccination dates excluded[3] cOR (95% CI)	All children without vaccination dates excluded[3] aOR (95% CI)	All children without vaccination dates set to 'not UTD'[3] aOR (95% CI)	All children without vaccination dates set to 'UTD'[3] aOR (95% CI)
Migrant status					
Migrant	0.97 (0.66, 1.43)	1.05 (0.71, 1.57)	0.98 (0.65, 1.47)	0.85 (0.62, 1.16)	1.13 (0.78, 1.64)
Non-migrant	ref	ref	ref	ref	ref
n	1,790 (in 100 multiply-imputed data sets)	1,347	1,347	1,790	1,790

[1] All models adjusted odds ratio accounts for child's age, child's sex, child's birth order, maternal age, religion, ethnicity, education, work status, marital status age at first birth, household size, number of under-5 children in the household, wealth quintile, region of residence, and current urbanicity

[2] Analysis conducted in multiply-imputed data with IPTW-S weights

[3] Analysis conducted in original, not imputed data set with IPTW-S weights

Table 2.10 Balance diagnostics for IPTW weights for migration stream sensitivity analyses in which non-migrants in destination are set as referent group

	IPTW weight mean	IPTW weight standard deviation	IPTW weight minimum value	IPTW weight maximum value	IPTW-S weight mean	IPTW-S weight standard deviation	IPTW-S weight minimum value	IPTW-S weight maximum value	Number of covariates with standardized difference >0.1 before IPTW[1]	Largest standardized difference value before IPTW	Number of covariates with standardized difference >0.1 after IPTW[1]	Largest standardized difference value after IPTW
Rural-urban migrants[2]	1.00	0.61	0.42	6.40	1.00	1.57	0.02	20.28	7	0.94	5	0.33
Urban-rural migrants[3]	1.01	0.70	0.15	14.80	0.88	1.00	0.03	18.40	11	0.96	12	0.39
Rural-rural migrants[3]	1.02	0.72	0.33	10.28	0.84	0.90	0.03	10.35	9	0.88	1	0.15
Urban-urban migrants[2]	0.97	0.56	0.47	7.12	1.02	1.43	0.02	10.73	7	0.81	4	0.20

[1] A total of 13 covariates were included in this analysis

[2] Reference group is urban non-migrants

[3] Reference group is rural non-migrants

Table 2.11 Results of sensitivity analysis logistic regressions examining relationship between maternal migration and FIC stratified by migration stream, with non-migrants in destination set as reference group

	Survey weighted								ITPW-S weighted			
	n	**cOR[1]**	**95% CI**	**p-value**	**n**	**aOR**	**95% CI**	**p-value**	**n**	**aOR**	**95% CI**	**p-value**
Rural-urban migrants[2]	448				448				448 [3]			
Rural-urban migrant		0.98	(0.45, 2.13)	0.95		0.77	(0.40, 1.49)	0.44		0.85	(0.46, 1.58)	0.61
Non-migrant		1.00	ref			1.00	ref			1.00	ref	
Urban-rural migrants[2]	858				858				874 [4]			
Urban-rural migrant		**2.03**	**(1.07, 3.84)**	**0.03**		1.22	(0.61, 2.44)	0.57		1.05	(0.41, 2.72)	0.91
Non-migrant		1.00	ref			1.00	ref			1.00	ref	
Rural-rural migrants[2]	1,054				1,054				1039 [5]			
Rural-rural migrant		**1.74**	**(1.18, 2.58)**	**0.005**		1.36	(0.85, 2.18)	0.21		1.10	(0.69, 1.77)	0.69
Non-migrant		1.00	ref			1.00	ref			1.00	ref	
Urban-urban migrants[2]	458				458				460 [6]			
Urban-urban migrant		0.82	(0.42, 1.60)	0.56		0.57	(0.27, 1.19)	0.14		0.60	(0.27, 1.34)	0.21
Non-migrant		1.00	ref			1.00	ref			1.00	ref	

Bold indicates a statistically significant value at the 0.05 level

[1] Crude odds ratio

[2] Adjusted odds ratio accounts for wealth quintile, maternal age, and binary indicators for child’s age, child’s sex, child’s birth order, religion, ethnicity, education, work status, marital status age at first birth, household size, number of under-5 children in the household, wealth quintile

[3] Weighted with 'rural-urban migration stream' IPTW-S weight

[4] Weighted with 'urban-rural migration stream' IPTW-S weight

[5] Weighted with 'rural-rural migration stream' IPTW-S weight

[6] Weighted with 'urban-urban migration stream' IPTW-S weight

Table 2.12 E-values to assess the potential impact of unmeasured confounding

Regression model	IPTW-S weighted aOR[1] (95% CI)	Point estimate e-value[2]	Confidence interval e-value[3]
FIC vaccination models			
Migrant status	0.87 (0.61, 1.24)	1.35	1.00
Rural-urban migration stream	1.02 (0.54, 1.93)	1.11	1.00
Urban-rural migration stream	1.35 (0.51, 3.55)	1.60	1.00
Rural-rural migration stream	1.25 (0.80, 1.94)	1.48	1.00
Urban-urban migration stream	0.79 (0.41, 1.52)	1.50	1.00
UTD vaccination models			
Migrant status	0.97 (0.66, 1.43)	1.14	1.00
Rural-urban migration stream	1.31 (0.64, 2.71)	1.55	1.00
Urban-rural migration stream	1.20 (0.44, 3.26)	1.42	1.00
Rural-rural migration stream	1.26 (0.76, 2.10)	1.49	1.00
Urban-urban migration stream	0.75 (0.37, 1.53)	1.58	1.00

[1] Adjusted odds ratio

[2] This value represents the magnitude of the association between an unmeasured confounder and both exposure (migrant status or migration stream) and the outcome (FIC or UTD vaccination) necessary to shift the aOR to the null value of 1.00. For example, the observed odds ratio of 0.87 could be explained away (shifted to the null value of 1.00) by an unmeasured confounder that was associated with both migrant status and FIC vaccination by an odds ratio of 1.35-fold each, above and beyond the measured confounders, but weaker confounding could not do so.

[3] This value represents the magnitude of the association between an unmeasured confounder and both exposure (migrant status or migration stream) and the outcome (FIC or UTD vaccination) necessary to shift the CI to include the null value of 1.00. This value is 1 for all models, since all 95% confidence intervals already include 1 and therefore no additional unmeasured confounding would be necessary to shift the confidence interval to include 1.

Figure 2.1 Directed Acyclic Graph demonstrating theorized relationships between migration and vaccination

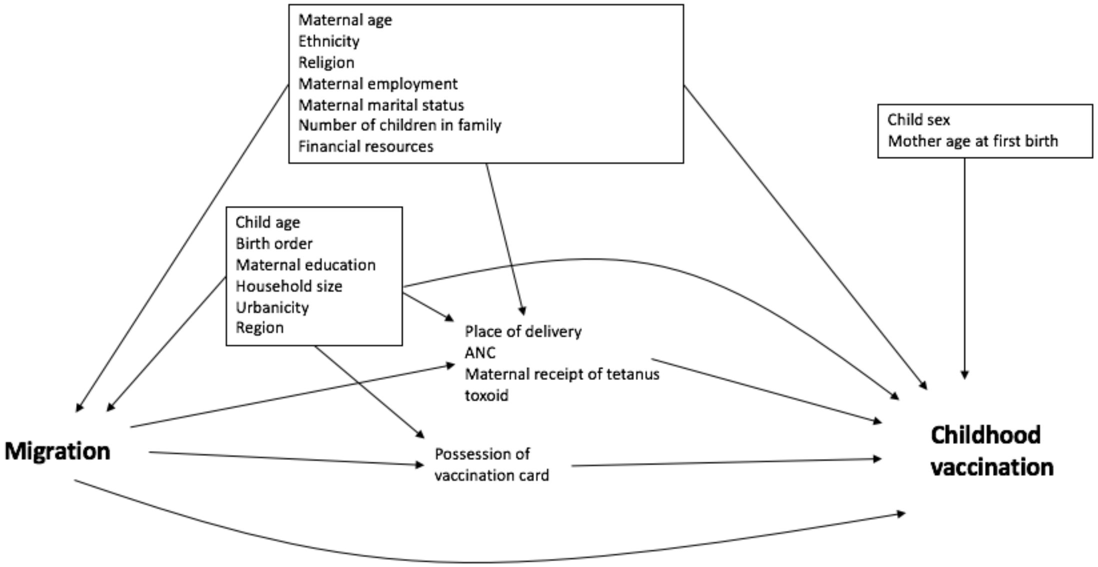
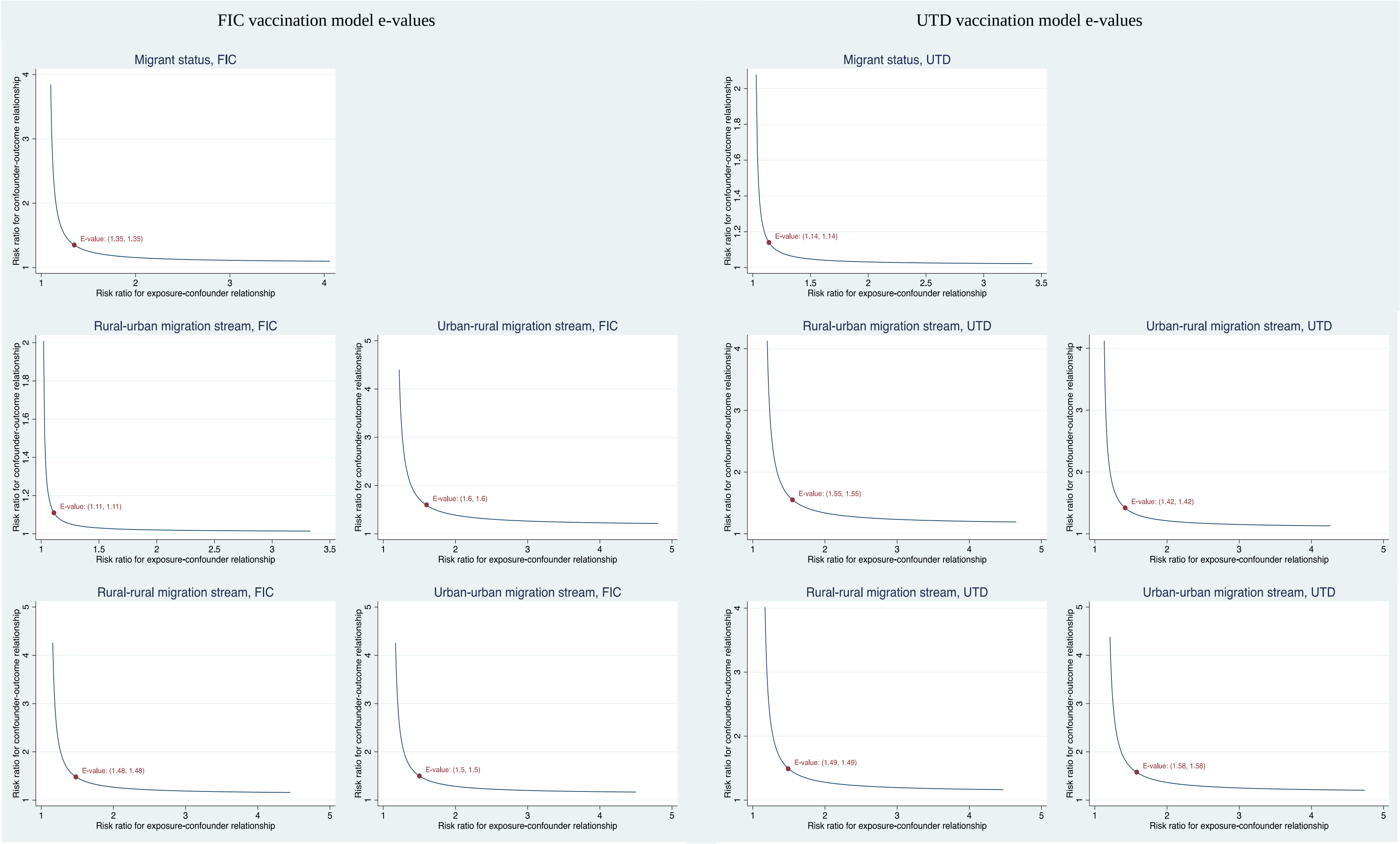


Figure 2.2 Figures of e-values for migrant status and migration stream analyses



References

1. Porth JM, Treleaven E, Fleischer NL, Mutua MK, Boulton ML. The influence of maternal migration on child vaccination in Kenya: An inverse probability of treatment-weighted analysis. *Int J Infect Dis*. 2021. doi:10.1016/j.ijid.2021.03.067
2. UNICEF. Under-five mortality. https://data.unicef.org/topic/child-survival/under-five-mortality/. Published 2020. Accessed September 18, 2020.
3. World Health Organization. Immunization coverage. https://www.who.int/news-room/fact-sheets/detail/immunization-coverage. Published 2020. Accessed September 18, 2020.
4. Central Intelligence Agency. CIA World Factbook | Kenya. Central Intelligence Agency Library. https://www.cia.gov/the-world-factbook/countries/kenya. Published 2020. Accessed March 13, 2021.
5. International Organization for Migration. *Migration in Kenya: A Country Profile 2018*. Nairobi; 2018.
6. United Nations. Goal 3 Targets and Indicators. https://sdgs.un.org/goals/goal3. Published 2020. Accessed December 27, 2020.
7. WHO/UNICEF. Immunization. https://data.unicef.org/topic/child-health/immunization/. Published 2019. Accessed December 12, 2020.
8. National Bureau of Statistics - Kenya, ICF International. *Kenya 2014 Demographic and Health Survey*. Vol 6.; 2015. doi:10.5261/2013.GEN1.04
9. Acevedo-Garcia D, Sanchez-Vaznaugh E V., Viruell-Fuentes EA, Almeida J. Integrating social epidemiology into immigrant health research: A cross-national framework. *Soc Sci Med*. 2012;75(12):2060-2068. doi:10.1016/j.socscimed.2012.04.040
10. Madhavan S, Clark S, Araos M, Beguy D. Distance or location? How the geographic distribution of kin networks shapes support given to single mothers in urban Kenya. *Geogr J*. 2018;184(1):75-88. doi:10.1111/geoj.12230
11. Clark S, Madhavan S, Kabiru C. Kin support and child health: Investigating two approaches in an African slum. *Soc Sci Res*. 2018;76(August):105-119. doi:10.1016/j.ssresearch.2018.08.001
12. Kiros GE, White MJ. Migration, community context, and child immunization in Ethiopia. *Soc Sci Med*. 2004;59(12):2603-2616. doi:10.1016/j.socscimed.2004.04.009
13. Kusuma YS, Kumari R, Pandav CS, Gupta SK. Migration and immunization: Determinants of childhood immunization uptake among socioeconomically disadvantaged migrants in Delhi, India. *Trop Med Int Heal*. 2010. doi:10.1111/j.1365-3156.2010.02628.x
14. Smith-Greenaway E, Madhavan S. Maternal migration and child health: An analysis of disruption and adaptation processes in Benin. *Soc Sci Res*. 2015;54:146-158. doi:10.1016/j.ssresearch.2015.06.005
15. Awoh AB, Plugge E. Immunisation coverage in rural-urban migrant children in low and middle-income countries (LMICs): A systematic review and meta-analysis. *J Epidemiol Community Health*. 2016;70(3):305-311. doi:10.1136/jech-2015-205652
16. Antai D. Migration and child immunization in Nigeria: Individual- and community-level contexts. *BMC Public Health*. 2010;10:116. doi:10.1186/1471-2458-10-116
17. Atake EH. The impacts of migration on maternal and child health services utilisation in

Sub-Saharan Africa: evidence from Togo. *Public Health*. 2018;162:16-24. doi:10.1016/j.puhe.2018.05.010

18. Riosmena F, Kuhn R, Jochem WC. Explaining the Immigrant Health Advantage: Self-selection and Protection in Health-Related Factors Among Five Major National-Origin Immigrant Groups in the United Statews. *Demography*. 2017;54(1):175-200. doi:10.1007/s13524-016-0542-2
19. Acharya K, Lacoul M, Bietsch K. Factors affecting vaccination coverage and retention of vaccination cards in Nepal. *DHS Furth Anal Reports No 121*. 2019.
20. World Health organization. WHO recommendations for routine immunization - summary tables. https://www.who.int/immunization/policy/immunization_tables/en/. Published 2019. Accessed August 4, 2020.
21. Beguy D, Bocquier P, Zulu EM. Circular migration patterns and determinants in Nairobi slum settlements. *Demogr Res*. 2010;23(December 2010):549-586. doi:10.4054/DemRes.2010.23.20
22. Brockerhoff M, Eu H. Demographic and Socioeconomic Determinants of Female Rural to Urban Migration in Sub-Saharan Africa. *Int Migr Rev*. 1993;27(3):557-577.
23. Zulu EM, Beguy D, Ezeh AC, et al. Overview of migration, poverty and health dynamics in Nairobi City’s slum settlements. *J Urban Heal*. 2011;88(SUPPL. 2):185-199. doi:10.1007/s11524-011-9595-0
24. Gibson DG, Ochieng B, Kagucia EW, et al. Individual level determinants for not receiving immunization, receiving immunization with delay, and being severely underimmunized among rural western Kenyan children. *Vaccine*. 2015;33(48):6778-6785. doi:10.1016/j.vaccine.2015.10.021
25. Kamau N, Esamai FO. Determinants of immunisation coverage among children in Mathare Valley, Nairobi. *East Afr Med J*. 2001. doi:10.4314/eamj.v78i11.8949
26. Moïsi JC, Kabuka J, Mitingi D, Levine OS, Scott JAG. Spatial and socio-demographic predictors of time-to-immunization in a rural area in Kenya: Is equity attainable? *Vaccine*. 2010;28(35):5725-5730. doi:10.1016/j.vaccine.2010.06.011
27. Mutua MK, Kimani-Murage E, Ettarh RR. Childhood vaccination in informal urban settlements in Nairobi, Kenya: Who gets vaccinated? *BMC Public Health*. 2011;11(1):6. doi:10.1186/1471-2458-11-6
28. Oyvat C, wa Gĩthĩnji M. Migration in Kenya: beyond Harris-Todaro. *Int Rev Appl Econ*. 2020;34(1):4-35. doi:10.1080/02692171.2019.1620702
29. Rosenbaum PR, Rubin DB. The central role of the propensity score in observational studies for causal effects. *Biometrica*. 1983;70(1):41-55. doi:10.1017/CBO9780511810725.016
30. Rosenbaum PR. Model-based direct adjustment. *J Am Stat Assoc*. 1987;82(398):387-394. doi:10.1080/01621459.1987.10478441
31. Austin PC. An introduction to propensity score methods for reducing the effects of confounding in observational studies. *Multivariate Behav Res*. 2011;46(3):399-424. doi:10.1080/00273171.2011.568786
32. Dugoff EH, Schuler M, Stuart EA. Generalizing observational study results: Applying propensity score methods to complex surveys. *Health Serv Res*. 2014;49(1):284-303. doi:10.1111/1475-6773.12090
33. Morgan SL, Todd JJ. A diagnostic routine for the detection of consequential heterogeneity of causal effects. *Sociol Methodol*. 2008;38(1):231-281. doi:10.1111/j.1467-

9531.2008.00204.x
34. Robins JM, Hernán MÁ, Brumback B. Marginal Structural Models and Causal Inference in Epidemiology. *Epidemiology*. 2000;11(5):550-560. doi:10.1097/00001648-200009000-00011
35. Hernán MA, Robins JM. *Causal Inference: What If*. Boca Raton: Chapman & Hall/CRC; 2020.
36. Austin PC, Stuart EA. Moving towards best practice when using inverse probability of treatment weighting (IPTW) using the propensity score to estimate causal treatment effects in observational studies. *Stat Med*. 2015;34(28):3661-3679. doi:10.1002/sim.6607
37. Linden A. covbal: Stata module for generating covariate balance statistics. 2016.
38. Sun M, Ma R, Zeng Y, Luo F, Zhang J, Hou W. Immunization status and risk factors of migrant children in densely populated areas of Beijing, China. *Vaccine*. 2010;28(5):1264-1274. doi:10.1016/j.vaccine.2009.11.015
39. StataCorp. *Stata Multiple-Imputation Reference Manual*. College Station, TX; 2013.
40. Rubin DB. Multiple Imputation after 18+ Years. *J Am Stat Assoc*. 1996;91(434):473-489. doi:10.1080/01621459.1996.10476908
41. Schafer JL. Multiple imputation: A primer. *Stat Methods Med Res*. 1999;8(1):3-15. doi:10.1191/096228099671525676
42. Pedersen AB, Mikkelsen EM, Cronin-Fenton D, et al. Missing data and multiple imputation in clinical epidemiological research. *Clin Epidemiol*. 2017;9:157-166. doi:10.2147/CLEP.S129785
43. Heeringa SG, West BT, Berglund PA. *Applied Survey Data Analysis*. Second edi. Boca Raton: Taylor & Franci Group, LLC; 2017.
44. Central Intelligence Agency. CIA World Factbook | Ethiopia.
45. Central Intelligence Agency. CIA World Factbook | Nigeria. https://www.cia.gov/library/publications/the-world-factbook/geos/ni.html. Published 2020. Accessed October 13, 2020.
46. Linden A, Mathur MB, VanderWeele TJ. Conducting sensitivity analysis for unmeasured confounding in observational studies using E-values: The evalue package. *Stata J*. 2020;20(1):162-175. doi:10.1177/1536867X20909696
47. Van Der Weele TJ, Ding P. Sensitivity analysis in observational research: Introducing the E-Value. *Ann Intern Med*. 2017;167(4):268-274. doi:10.7326/M16-2607
48. Porth JM, Wagner AL, Tefera YA, Boulton ML. Childhood immunization in Ethiopia: Accuracy of maternal recall compared to vaccination cards. *Vaccines*. 2019;7(2):1-12. doi:10.3390/vaccines7020048
49. International Organization for Migration. *World Migration Report 2020*. Geneva; 2020.

Chapter 3 Childhood Vaccination Timeliness Following Maternal Migration to an Informal Urban Settlement in Kenya

Background: Timely receipt of recommended vaccines is a proven strategy to reduce preventable under-five deaths. Kenya has experienced impressive declines in child mortality from 111 to 43 deaths per 1,000 live births between 1980 and 2019. However, considerable inequities in timely vaccination remain, which unnecessarily increase risk for serious illness and death. Maternal migration is a potentially important driver of timeliness inequities, as the social and financial stressors of moving to a new community may require a woman to delay her child's immunizations. This analysis examined how maternal migration to informal urban settlements in Nairobi, Kenya influenced childhood vaccination timeliness.

Methods: Data came from the Nairobi Urban Health and Demographic Surveillance System, 2002-2018. Migration exposures were migrant status (migrant, non-migrant), migrant origin (rural, urban), and migrant type (first-time, previously resided in settlement). Age at vaccine receipt (vaccination timeliness) was calculated for all basic vaccinations. Accelerated failure time models were used to investigate relationships between migration exposures and vaccination timeliness. Propensity score weighting was used to address confounding.

Results: Over one-third of both migrant and non-migrant children received at least one dose late or not at all. Unweighted models showed migrants had shorter time to OPV1 and DPT1 vaccine receipt compared to non-migrants, but after accounting for confounding only differences in timeliness for DPT1 remained. Timeliness was comparable among migrants with rural and urban-origins and among first-time and circular migrants.

Conclusion: Although a substantial proportion of children in Nairobi’s informal urban settlements do not receive timely vaccination, there is no evidence that maternal migration or women’s migration-related characteristics are associated with delays for most doses. Future research should seek to elucidate potential drivers of low vaccination timeliness in Kenya.

Introduction

Decreasing under-five mortality (U5M) is a key priority for the global public health community, as reflected in the United Nations' Sustainable Development Goal 3, which aims to eliminate preventable under-five deaths and decrease total U5M to fewer than 12 per 1,000 live births by 2030.[1] The global effort to eliminate infectious preventable causes of U5M including tetanus, pertussis, diarrhea, and measles has been made possible by immunization, which has been consistently shown to be a safe, effective, and cost efficient intervention.[2] Improving vaccination programming is especially relevant in the African region, which accounted for over half of the world's 5.2 million under-five deaths in 2019.[3] Encouragingly, between 2000 and 2019 coverage of the third dose of the diphtheria-tetanus-pertussis vaccine (DPT3, a commonly used indicator of vaccination program performance) among children 12-23 months increased from 60% to 81% in the Eastern and Southern African region (ESA).[4]

Historically, researchers have examined cumulative vaccination coverage at certain age intervals (e.g., 12-23 months) that may mask untimely vaccination. More recently, focus has shifted from simply increasing coverage to ensuring timeliness in administration. In contrast to the discrete age intervals used to examine vaccination coverage, vaccine timeliness is often studied as a continuous measure of a child's age at vaccine receipt. Timely doses are then typically defined as doses received within one month of the date recommended by a country's national schedule.[5] Timely vaccine receipt is fundamental to child health as delayed doses may place them at risk for acquiring vaccine preventable diseases for unnecessarily prolonged periods of time. Further, assessment of vaccination timeliness provides a more accurate characterization of a population's susceptibility to diseases such that only examining coverage of children 12-23 months can shroud disease transmission potential among younger children with delayed immunization.[6,7] Successful efforts aimed at realizing the elimination of preventable U5M will require health systems everywhere ensure children receive all recommended vaccines in a timely manner.

Within the ESA region Kenya has emerged as a leading economic and travel center, with substantial internal migration resulting from political turmoil (in particular, 2007-2008 post-election violence), changes in arable land due to climate change, and increased economic and education opportunities in the country's urban centers.[8] Over the last forty years Kenya has experienced dramatic improvements in national DPT3 coverage (increasing from 58% to 92%) and child mortality (decreasing from 111 to 43 deaths per 1,000 live births).[3,4] Despite these impressive advances vaccination timeliness remains low, with only 37% of children ages 12-36 months receiving all basic immunizations on time.[9] Moreover, Kenya is home to vast economic and immunization disparities. Kenya's 2015 Gini index (a measure of income inequality in which higher values indicate more inequality) was 40.8, which was higher than its neighbors Tanzania (37.8) and Ethiopia (35.0).[10] Moreover, less than 1% of Kenya's wealthiest citizens hold more wealth than the remaining 99.9% of the population combined.[11] This income inequality has resulted in significant disparities in healthcare access by socioeconomic status: individuals in the top two quintiles of wealth receive nearly half of health system benefits in Kenya and vaccination timeliness is 3.1 times higher among children from the wealthiest households compared to those from the poorest households.[9,12]

Scholarly interest in investigating the root cause of health inequities, including disparities in timely vaccine receipt, is growing.[9] Given its established relationship to vaccination coverage in some African nations[13,14] maternal migration may be a significant predictor of timeliness disparities, though this relationship has not been explored in sub-Saharan Africa or other regions.

Migration may influence vaccination timeliness via disruption of a woman's social, instrumental, and economic resources. Costs associated with migration (e.g., transportation to new community, time without income as a woman seeks new employment and housing, etc.) may prohibit a woman from taking her child to be vaccinated on the recommended schedule and instead delay doses until she can finance indirect but potentially major vaccination costs like transportation.[13,15]Additionally, moving away from friends and family who provide childrearing advice including information about where and when to vaccinate, emotional support, financial assistance, and logistical help with childcare may hinder a woman's ability to access vaccination services in a timely fashion.[16–18] Given these potential disruptions, a period of adaptation to a new environment may be necessary before a woman can effectively navigate her community and the healthcare system.[14,19] The time-sensitive nature of properly adhering to childhood vaccination schedules would suggest that migration likely has implications for vaccination timeliness.

Internal migration has led to urbanization of the African continent that has accelerated in recent years.[20] Migration in many African nations over the last several decades has resulted in large cities with expansive informal urban settlements (IUSs, or slums) that house large portions of countries' urban and poor populations; in sub-Saharan Africa nearly 60% of urban dwellers live in IUSs.[20] IUSs are characterized by inadequate access to clean water, poor sanitation, low quality housing, overcrowding, and few protections against eviction.[20,21] These conditions combined with lack of quality healthcare, pervasive food insecurity, and the high unemployment and poverty common in IUSs produce a setting highly conducive to the spread of infectious diseases, underlining the critical role of timely vaccination in these venues.[20,21] In Kenya, the proportion of the population living in urban areas almost tripled from 10% in 1970 to 27% in

2018 and is projected to surpass 50% by 2025.[22,23] As a result of this rapid urbanization, Kenya's cities have substantial IUS populations; almost half of all Kenyan urban residents live in IUSs and in Nairobi, the Capital of Kenya, between 60-70% of residents reside in IUSs.[20,21] Residents of IUSs tend to be a highly mobile population, with many individuals moving to IUSs for economic opportunities with the hope of moving up the socioeconomic ladder and eventually out of the IUSs or migrating back home if unsuccessful.[21,24] The combination of low-quality living conditions and high population mobility make IUSs a particularly relevant setting to examine how migration impacts timely uptake of vaccination services.

This study aims to assess the influence of maternal migration to two IUSs in Nairobi, Kenya on childhood vaccination timeliness. Given a migrant's previous experiences likely influence her ability to adapt and take advantage of vaccination services in a timely manner, secondary analyses further characterize the influence of migration by examining how differences in migrant origin (rural/urban) and migrant type (first-time/circular) impact vaccination timeliness.

Methods

Study sample

Data are from the Nairobi Urban Health and Demographic Surveillance System (NUHDSS). NUHDSS is a longitudinal surveillance system collecting data from two of Nairobi's informal urban settlements (IUSs), Korogocho and Viwandani, since 2002 in an effort to understand the health of individuals living in IUSs and its link to poverty and migration.[21] The surveillance catchment area includes approximately 88,974 individuals from 33,462 households and collects a variety of health and demographic measures including births and deaths, in- and out-migrations, and childhood vaccination history.[21] From 2002-2016, household rosters were updated three times per year, and twice yearly starting in 2017.[21] During these data collection rounds interviewers register new children born in the NUHDSS catchment area and connect their participant ID to that of their mothers. Data collectors return two to three times to update child vaccination status. Further details of the NUHDSS data collection activities are published elsewhere.[21]

Located in northern and southern Nairobi, respectively, Korogocho and Viwandani represent two very different IUS populations.[21] Viwandani is situated close to an industrial area and attracts residents who are highly mobile and more highly educated. Korogocho’s population faces higher unemployment but is more stable and includes more families. While economic instability is a characteristic of both communities, chronic poverty in Korogocho is higher than in Viwandani (76% and 54% of households, respectively, remained below the poverty line between 2015-2018).[21]

This analysis included all under-five children who were born in the NUHDSS catchment area between 2002 and 2018, regardless of survival status or availability of a vaccination card (51,123 children). Children who did not have a paired maternal ID because they were not born in the IUS (28,704), who had negative dates of vaccination (i.e., record indicates vaccination date is prior to birthdate, 3,672), whose mothers were either visitors (lived in the NUHDSS for less than 180 days, 94) or international migrants (women who migrated to NUHDSS from outside of Kenya, 54), or who had missing covariate information (3,313) were excluded.

Measures

The primary exposure was mother's migration status, dichotomized into migrants or non-migrants. Migrants were women who moved into the NUHDSS catchment area within one year before the index child's date of birth and non-migrants were women who had always lived in NUHDSS IUSs or migrated into the area more than one year before their index child was born. To explore the heterogeneity of migrants' experiences two additional exposures were used: migrant origin and migrant type. A migrant's origin was defined as the place she lived before moving to the NUHDSS and was categorized as rural or urban (urban included "Nairobi slum," "Nairobi non-slum," and "other urban Kenya" response options). Migrant type was classified as first-time migrant to NUHDSS or circular migrant (had ever previously lived in the NUHDSS since data collection began in 2002). Migrant type only measured whether a woman had previous experience living in the NUHDSS IUSs, but not whether she had previous experience migrating elsewhere, as no information about a woman's previous migration history was collected.

The Kenya Expanded Program on Immunization schedule includes the following 15 doses: one dose of Bacillus Calmette-Guérine vaccine (BCG), four doses of the oral poliovirus vaccine (OPV), three doses of the pentavalent vaccine (including diphtheria, tetanus, pertussis, hepatitis B, and *Haemophilus influenzae* type b antigens), three doses of the pneumococcal conjugate vaccine (PCV), one dose of the inactivated polio vaccine, two doses of the rotavirus vaccine, and two doses of the measles-containing vaccine (schedule in Table 3.1).[25] The NUHDSS only collects information regarding receipt of the following vaccines: BCG (provided at birth), OPV1-3 (6, 10, 14 weeks), DPT1-3 (a precursor to the pentavalent vaccine including diphtheria, tetanus, and pertussis antigens; 6 10, 14 weeks), and measles1 (9 months). Accordingly, this analysis examined timeliness and delay of this subset of vaccines. The primary outcome was vaccination timeliness, operationalized as the time (in days) to receipt of each dose of vaccine. Differences in vaccination delay by migration status were also descriptively assessed. A child was considered delayed if they received a given dose more than 28 days after the recommended date.

Covariates were determined a priori via literature review and included maternal age at index child's birth (under 18, 18-24, 25-34, 35+), education (never attended school, primary, secondary, higher), employment (has worked in last 30 days vs. not), marital status (currently married vs. not), religion (Christian, Muslim, other/no religion), ethnicity (Kikuyu, Kamba, Luhya, Luo, Kisii, other), household wealth (quintiles, calculated by data managers at the African Population and Health Research center using household possessions, housing construction materials, and housing infrastructure [e.g., water access, sanitation] via principal component analysis),[26,27] household size (1-4 members, 5-7, 8 or more), index child's number of siblings (only child, 1 sibling, more than 1 sibling), informal urban settlement (Korogocho, Viwandani), region of origin (Central, Coast, Eastern, Nairobi, North Eastern, Nyanza, Rift Valley, Western), and birth year of index child (2002-2006, 2007-2012, 2013-2018).

Statistical analysis

Descriptive statistics were calculated for sociodemographic characteristics, migration exposures, and vaccination outcomes. Proportions of children with delayed vaccination and median age at vaccination were assessed by migration status. Associations between migration exposures and timeliness of receipt of each vaccine dose were investigated using accelerated failure time (AFT) models with robust standard errors and truncated at 23 months. The AFT model can be used to describe the situation in which there is an acceleration or deceleration in time to event data (in this case, age at vaccination) when comparing an exposed group (i.e., migrants) to an unexposed group.[28,29] Important in this context, AFT models allow for left- and right-censoring.[28] Left-censoring occurred when a mother stated her child had been vaccinated at some point before the interview but could not produce a written date of vaccine receipt and right-censoring was present when a child had not been vaccinated by 23 months of age.[28] Incorporating methods that account for both left- and right-censoring allow the inclusion of children both with and without vaccination cards available, reducing concerns of selection bias that would be present if children without vaccination cards were excluded from the analysis. For children who received BCG, DPT1 or OPV1 on their day of birth, age at vaccination was recoded from 0 to 1 day to allow their inclusion in analyses. Weibull, exponential, log-normal, and log-logistic distributions were assessed. Based on comparison of goodness of fit graphs plotting Cox-Snell residuals against cumulative hazards, the log-logistic distribution was used for the BCG and measles analyses and the exponential distribution was used for the DPT and OPV series analyses. For each exposure/vaccine dose combination (i.e., comparison of BCG timeliness among migrants and non-migrants) four models were run: 1) an unweighted and unadjusted (crude) model in which only the exposure was included in the model, 2) an unweighted adjusted model in which all confounders were included as covariates in the model but propensity weights were not used, 3) a model in which propensity weights were included but no confounders were included as covariates in the model, and 4) a "pseudo doubly robust" model in which propensity weights were used and confounders were included as covariates in the model. The goal of the pseudo doubly robust model is to further account for residual confounding that may remain after inclusion of propensity weights. Inverse survival plots stratified by exposure were generated for each dose.

Migration is a selective process and the characteristics that enable migration may also promote uptake of healthcare services, resulting in substantial confounding.[30] Propensity score weighting was used to assess and address confounding. In propensity score weighting, propensity scores are estimated as the conditional probability of exposure (i.e., being a migrant) and those scores are then used to calculate inverse probability of treatment weights (IPTW).[31,32] The goal is to create a "pseudo-randomized" sample in which the distribution of confounders is similar ("balanced") between the exposed and unexposed observations and subsequent measures of association represent theoretically unconfounded comparisons.[32,33] Stabilized IPTWs were used to increase precision and were calculated as $w = \frac{\Pr[migrant=1]}{propensity\ score}$ for migrants and $w = \frac{1-(\Pr[migrant=1])}{1-propensity\ score}$ for non-migrants.[32,33] Logistic regression models were used to model propensity scores, including the covariates identified above. Separate weights were generated for the migrant status, migrant origin, and migrant type analyses. All analyses were conducted in Stata version 16.1 (College Station, TX, USA).

Sensitivity analyses

An additional analysis was run to explore how a woman's motivation for migrating impacted the results. IPTWs were recalculated and AFT models rerun comparing timeliness among the children of women who moved to the IUS to join family compared to women who migrated for another reason. Another sensitivity analysis examined whether changing the definition of a migrant would influence the results. Women were classified as migrants if they moved to the IUSs within five years before their child's birthdate and non-migrants if they had always lived in the area or moved into the IUS more than five years before their child was born. Using this new definition, new weights were created, and AFT models run.

To evaluate the impact of correlated outcomes for women with multiple children, a final set of sensitivity analyses were conducted in which only the firstborn child of each mother was included. Weights were re-calculated in this sample prior to running the AFT models and generating inverse survival curves.

Ethical approval

The African Population and Health Research Center located in Nairobi, Kenya collects and manages NUHDSS data and received ethical approval for the NUHDSS from the Kenya Medical Research Institute. This analysis received an exemption from the University of Michigan Institutional Review Board as only deidentified data were provided for analysis. The Center approved use of the NUHDSS data for this analysis.

Results

The NUHDSS included 51,123 under-five children born between 2002-2018. Children were excluded for the following reasons: did not have a paired maternal ID (28,704 children), negative age at vaccination (3,672), mother was a visitor or international migrant (148), and missing information on covariates (3,313). The final migrant status analytic sample included 15,286 children and the final migrant origin and type samples included 3,110 and 2,941 children, respectively.

Most children in the sample (65%) had no siblings (Table 3.2). A higher proportion of migrants provided vaccination cards compared to non-migrants (74% vs. 69%) but, among children aged 12-23 months, fewer children of migrants received all basic immunizations compared to children of non-migrants (84% vs. 89%). Among mothers, the majority of migrants were aged 18-24 at the index child's birth (66%) but most non-migrants were aged 25-34 (48%). Many migrant and non-migrant mothers had a primary education (60% of migrants, 60% of non-migrants) and were currently married (84% of migrants, 76% of non-migrants). The majority of both migrant and non-migrant households had fewer than five members (83% vs. 65%) and over half were located in the Viwandani settlement. Less than one-quarter of mothers were migrants (Table 3.3). Among migrants, most migrated from rural areas (67%), were first-time migrants to the NUHDSS (78%), and left their previous residence to be reunited with family or friends (85%).

High levels of vaccination delay were reported, with over one-third of migrant and non-migrant children aged 12-23 months receiving at least one dose late or not at all (Table 3.2). Accordingly, delays in individual doses ranged from 13% for the BCG vaccine to over 33% for measles vaccination (Table 3.4). Children generally received the corresponding OPV and DPT vaccines on the same day, but 8.5%, 8.7%, and 8.8% of children received the first, second, and third doses, respectively, of the OPV and DPT vaccines on different days, likely indicting supply-side issues in vaccine availability (analysis not shown). Among the children who did not receive OPV1 and DPT1 on the same day, most (59%) received DPT1 before OPV1. For nearly all vaccines a slightly higher proportion of non-migrants received delayed doses (or did not receive the dose by 23 months) compared to migrants, though proportions were similar for both groups. The notable exception was the measles dose, in which 41% of migrant children received the dose late or not at all compared to 34% of non-migrant children. The median age at vaccination was comparable for migrants and non-migrants for all vaccines. Among children who received doses late, delays ranged from 9 to 29 days after the end of the recommended vaccination window. Information on receipt of many doses was provided via maternal recall, ranging from 22% of OPV1 doses among migrants to 46% of measles doses among non-migrants. Had standard methods been employed, these children would have been dropped from survival analyses.

All three IPTWs (for migrant status, origin, and type) demonstrated good fit (mean values of 1.00, maximum weight values ranged from 2.61 to 35.70) (Table 3.5). Nearly all covariates demonstrated inadequate balance between migrants and non-migrants before weighting (standardized difference >0.1) and appropriate balance after weighting (Table 3.2). Migrant origin and migrant type weights similarly provided adequate balance after weighting, with all covariate-standardized differences below 0.1 (the only exception being birth year was slightly unbalanced (standardized difference =0.12) after creating migrant type IPTW weights).

Accelerated failure time models indicated timeliness was comparable among migrants and non-migrants for most doses of vaccine (Table 3.6). Unweighted and unadjusted results demonstrated migrants had a shorter time to receipt of the OPV1 and DPT1 vaccines compared to non-migrants, though after accounting for confounding only differences in DPT1 timeliness remained (time ratio: 0.96, 95% CI: 0.93,1.00). Analyses exploring heterogeneity in the migrant experience showed that neither a migrant’s origin (rural, urban) nor type (first-time, circular) affected her child’s age at vaccination in weighted models. Inverse survival curves showing the proportion of children vaccinated with each dose separately among migrants and non-migrants (Figure 1a), urban-origin and rural-origin migrants (Figure 1b), and first-time and circular migrants (Figure 1c) graphically demonstrated similar timeliness between groups.

Sensitivity analysis

Migration motivation AFT models indicated no statistically significant differences in time to vaccination among children of women migrating to reunite with family compared to children of women migrating for other reasons (Table 3.7). Analyses using the five-year cutoff to define migrant status demonstrated slightly different results from the primary analysis (Table 3.7). In crude models, migrant children received the OPV3, DPT2, DPT3, and measles doses significantly later than non-migrant children. However, in final adjusted and weighted models, only BCG timeliness was significantly delayed among migrant children compared to non-migrant children.

When only including each woman's firstborn child the analytic sample sizes decreased to 11,369 (migrant status), 2,921 (migrant origin), and 2,751 (migrant type). Newly calculated IPTWs demonstrated appropriate fit (Table 3.5) and all covariates were adequately balanced upon inclusion of the weights (all standardized differences <0.1). The migrant status, origin, and type AFT models produced largely the same results as the original analyses (Table 3.8). The only notable exception was that when comparing migrants to non-migrants the unadjusted and unweighted crude models indicated migrant children received their measles vaccine significantly later than non-migrant children (attenuated and statistically insignificant in adjusted, weighted final model) and, unlike in the primary analysis, there were no statistically significant differences in BCG timeliness in any of the models. Inverse survival curves demonstrate the similarity in timeliness between migrants and non-migrants (Figure 2a), urban-origin and rural-origin migrants (Figure 2b), and first-time and circular migrants (Figure 2c).

Discussion

Internal migration has increased considerably over the last few decades due largely to conflict, natural disasters, and the search for economic and educational opportunities.[34] Rural-urban migration in particular has contributed to the substantial growth of urban centers and informal urban settlements (IUSs) in sub-Saharan Africa.[20] The disruptive nature of migration - which requires time for a woman to develop a new social network and support system, acquire housing and a job, and learn how to navigate her new community and healthcare system – has been demonstrated to impact the uptake of a variety of maternal and child healthcare services, such as antenatal care and delivery services,[35] and childhood vaccination.[13,14] Expanding upon this previous work, the present analysis explored the impact of maternal migration to informal urban settlements on childhood vaccination timeliness. The many responsibilities required of migrant women were hypothesized to temporarily deplete her financial and instrumental resources, resulting in delay to her child's vaccinations. Maternal migration has been shown to negatively influence child vaccination coverage in Ethiopia, Nigeria, India, and China[13,36,37] whereas in Benin children born in the origin community before migration were less likely to be fully immunized but children born in the destination community after migration were more likely to be immunized, compared to non-migrant children.[14] However, the relationship between maternal migration and vaccination timeliness has not been studied in sub-Saharan Africa. Results of this analysis suggest that though there was substantial vaccination delay in the sample, the timeliness of vaccine receipt was comparable between migrants and non-migrants, rural-origin and urban-origin migrants, and first-time and circular migrants within the two IUSs of Nairobi, Kenya included in this study. The one key exception to this trend was for the first dose of DPT, in which the children of migrants received the dose significantly earlier than the children of non-migrants. However, given the time ratio for the DPT1 dose was so close to the null value of 1.00 (time ratio = 0.96) the result may not be practically significant even though it was statistically significant. Prior analyses exploring migration and vaccination coverage did not include IPTW or strategies to address selection bias, which may also account for the difference in findings in the present analysis.

A substantial proportion of children received their vaccines late. For earlier vaccine doses in the series, nearly 15% of children received doses late or did not receive them at all and this increased to almost half of migrant children and one-third of non-migrant children for the measles vaccine, which is typically given at nine months of age. Results are consistent with a recent analysis of 40 sub-Saharan African countries, which reported only 37% of Kenyan children received all eight basic vaccines on-time.[9] Other analyses from NUHDSS have similarly demonstrated high levels of vaccine delay and missingness overall[27] and among later doses in the series (OPV3, pentavalent3, and measles vaccines).[38] Poverty may be a key factor contributing to low levels of timely vaccine receipt; multiple studies have demonstrated the important role of financial resources in promoting inequities in vaccine timeliness and IUSs are characterized by high unemployment and poverty.[9,27]

Though timely administration of vaccines was low in the IUSs, maternal migration status did not appear to drive these results – final IPTW-weighted results showed time to vaccine receipt was similar between migrant and non-migrant children for all doses except DPT1. Changing the definition of a migrant to those who entered the IUS within five years of childbirth resulted in slightly different results, with migrant children receiving some doses (crude models: OPV3, DPT2, DPT3, measles, weighted and adjusted models: BCG) significantly later than non-migrant children (Table 3.7). These slightly different results underscore the importance of determining a contextually relevant definition of a migrant. It also demonstrates the difficulty in comparing results from studies using differing definitions of migrants. This relationship has been understudied in the African context, though results are consistent with the limited previous studies.[39,40] An analysis from rural Kenya found maternal migration status to be a predictor of timeliness in bivariate models, with the children of migrants vaccinated earlier than non-migrants, but results were no longer significant in final adjusted models.[39] Additionally, research from Israel comparing vaccination timeliness of the children of Eritrean migrants and native Israelis reported migrant children received the hepatitis A vaccine significantly later than non-migrant children, but the timeliness of all other doses was similar between migrants and non-migrants.[40] Results from the present study are somewhat surprising given previous work on the extensive barriers to healthcare access for migrant women in Kenya - including harassment, discrimination, language barriers, required documentation, and additional costs, which collectively would seem to increase the probability that migrant women would be less likely to repeatedly utilize healthcare services, including childhood immunization.[41] Given that 85% of women in the sample migrated to the NUHDSS IUSs to be with family and friends, it is likely that they are entering their new community with reasonably strong networks and therefore may not be as disrupted by the migration process as women migrating for other reasons. However, the analysis using motivation for migration as the exposure found no difference in time to vaccination by reason for migration.

Among migrants, no differences in time to vaccination were found between rural-origin and urban-origin migrants or between first-time and circular migrants. The relationship between migrant origin and vaccination timeliness had not yet been explored, but an analysis from Ethiopia suggests that migration stream (origin/destination) differentially influences vaccination coverage.[13] Associations between migrant status as a first-time or circular migrant and timely vaccination have been similarly understudied. In the current analysis, it was hypothesized that a migrant's previous experiences living in an urban area or an IUS in which transportation, navigation, and healthcare access are likely different from rural areas, or previous experiences living the NUHDSS communities where women may be able to reestablish old networks would shorten the migrant's adaptation period and would make obtaining timely receipt of vaccines easier. Surprisingly, these outwardly advantageous experiences did not influence time to vaccination. This may indicate that women are arriving to the IUSs with stronger networks than anticipated, or perhaps one year of residence in the IUS was long enough to acclimate to the new community.

Limitations and strengths

This paper has limitations. Though NUHDSS is a rich data source, unmeasured confounding likely remains. Approximately 7% of children had multiple vaccination records, in which case the last record was selected to allow the most complete report of vaccination. Though this represents a small portion of children, there is a possibility that examining later records for some children may bias the final results analyses were truncated at 23 months in an effort to reduce this potential source of bias. Both in- and out-migration are common in the NUHDSS settlements and individuals who migrate out of the IUS may be less likely to utilize healthcare services. In this case, selection bias due to selective loss to follow-up may have been present. However, only 172 children were lost to follow up before 23 months of age without providing a vaccination date so censoring weights were deemed unnecessary. Finally, over half of the children in the original sample were removed due lack of a record match with a maternal ID.

This occurred because maternal and child IDs are only linked for children born in the NUHDSS catchment area. Therefore, this analysis only included children born in the NUHDSS settlements and it was not possible to examine whether the relationship between migration and vaccination timeliness varied for children born before vs. after migration into the IUS.

This analysis also has important strengths. This analysis is the first to explore the relationship between maternal migration and vaccination timeliness in the African region and, by exploring migrant origin and migrant type as exposures, acknowledged that migrants' diverse experiences may differentially influence vaccination timeliness. The nature of the surveillance system allowed for the establishment of temporality between migration and childbirth. Detailed data collection upon in-migration permitted precise confirmation of migration dates and other migration characteristics and subsequent dates of childbirth were linked to a woman's record after she established residency in the IUS. Vaccination information was available among children who did not survive to the typical 12-23-month benchmark, avoiding survivor bias. Statistical techniques were used that allowed inclusion of left-censored children in order to avoid the selection bias that can occur when these children are excluded. Finally, the use of propensity score weighting to assess and address confounding ensured measured confounders were appropriately balanced between migrants and non-migrants.

Conclusions

This analysis examined the relationship between maternal migration and childhood vaccination timeliness. Though high levels of untimely vaccination were observed, no differences in vaccination timeliness were found by migrant status (exception: DPT1), origin, or type when using models that accounted for both left- and right-censoring and adequately addressed confounding with propensity score weighting. However, this analysis was only conducted in two informal urban settlements in a one city; future studies should investigate these relationships in other types of urban settings and using regional or nationally representative data sources. Further exploration of other migrant characteristics, such as motivations for migrating or timing of migration (before/after childbirth), and previous experiences at healthcare clinics, may enhance the comprehension of factors influencing vaccination timeliness. A better understanding of these factors will facilitate continued progress in ensuring all children receive their immunizations at the appropriate time to keep them healthy and free from preventable causes of death.

Table 3.1 Kenya childhood vaccination schedule (2018)

Vaccine	Birth	6 weeks	10 weeks	14 weeks	9 months	18 months
Bacillus Calmette-Guérine vaccine (BCG)	X					
Oral Polio Vaccine (OPV)	X	X	X	X		
Inactivated Polio Vaccine (IPV)			X			
DPT-HepB-Hib (Pentavalent) vaccine		X	X	X		
Pneumococcal vaccine (PCV)		X	X	X		
Rotavirus vaccine (RV)		X	X			
Measles and Rubella (MR)					X	X

[1] Receipt of this dose not collected in NUHDSS

[2] In NUHDSS, only first dose of measles vaccine is collected

Table 3.2 Descriptive statistics of children and mothers included in the NUHDSS by maternal migration status, unweighted and weighted by migrant status IPTW weight

		Unweighted (n=15,286)			IPTW-Weighted (n=15,286)	
	Migrants (%) (n=3,119)	**Non-migrants (%) (n=12,167)**	**Standardized difference**	**Migrants (%) (n=3,101)**	**Non-migrants (%) (n=12,185)**	**Standardized difference**
Child characteristics						
Number of siblings			**0.55**			0.003
Only child	64.48%	39.80%		44.85%	44.94%	
1 sibling	24.91%	33.62%		33.70%	31.83%	
More than 1 sibling	10.61%	26.58%		21.45%	23.23%	
Child's birth year			0.04			0.06
2002-2006	15.74%	19.76%		17.18%	18.79%	
2007-2012	51.94%	46.97%		46.91%	48.10%	
2013-2018	32.32%	33.27%		35.92%	33.11%	
Child vaccination						
Has a vaccination card	73.87%	68.69%	---	72.03%	69.02%	---
Received all vaccinations (among children 12-23 mo.)[1]	84.38%	88.57%	---	62.62%	88.55%	---
Received at least one dose late or not at all (among children 12-23 mo.)[1]	37.50%	36.69%	---	51.35%	35.92%	---
Received all doses late or not at all (among children 12-23 mo.)[1]	3.91%	2.81%	---	2.28%	2.68%	---
Maternal and household characteristics						
Maternal age at index child's birth			**0.63**			0.08
Under 18	6.32%	3.84%		4.00%	4.28%	
18-24	65.50%	37.94%		43.88%	43.71%	
25-34	26.23%	47.51%		43.04%	43.10%	
35+	1.96%	10.72%		9.07%	8.91%	
Maternal education			**0.14**			0.01
Never attended school	1.86%	5.61%		4.07%	4.86%	
Primary	59.76%	60.41%		61.27%	60.24%	
Secondary	36.04%	31.91%		32.61%	32.78%	
Higher than secondary	2.34%	2.06%		2.05%	2.11%	
Maternal employment			**0.38**			0.06
Has worked in the last 30 days	32.41%	50.80%		50.31%	47.13%	
Has not worked in the last 30 days	67.59%	49.20%		49.69%	52.87%	
Maternal marital status			**0.19**			0.10

Currently married	83.94%	76.27%		75.50%	77.87%	
Not currently married	16.06%	23.73%		24.50%	22.13%	
Religion			0.03			0.05
Christian	95.10%	88.12%		92.24%	89.27%	
Muslim	3.39%	9.97%		6.73%	8.64%	
Other religion / no religion	1.51%	1.91%		1.04%	2.09%	
Ethnicity			0.08			0.04
Kikuyu	21.00%	27.65%		27.09%	26.26%	
Kamba	30.68%	22.08%		23.82%	23.82%	
Luhya	19.46%	16.30%		17.50%	16.98%	
Luo	16.19%	15.58%		15.67%	15.70%	
Kisii	5.58%	5.57%		6.35%	5.62%	
Other ethnic group	7.09%	12.81%		9.56%	11.62%	
Family wealth			**0.15**			0.05
Poorest	19.14%	16.77%		18.76%	17.31%	
Poorer	22.41%	19.82%		20.64%	20.34%	
Middle	22.15%	20.69%		21.82%	21.01%	
Richer	20.36%	20.47%		18.71%	20.39%	
Richest	15.93%	22.25%		20.07%	20.96%	
Household size			**0.42**			0.02
1-4 members	83.46%	65.23%		71.35%	69.11%	
5-7 members	14.08%	28.00%		23.04%	25.02%	
8 or more members	2.47%	6.77%		5.62%	5.87%	
Informal urban settlement			**0.21**			0.04
Korogocho	37.16%	47.54%		44.92%	45.43%	
Viwandani	62.84%	52.46%		55.08%	54.57%	
Region of origin			0.10			0.02
Central	10.58%	7.93%		8.91%	8.52%	
Coast	0.77%	0.49%		0.79%	0.56%	
Eastern	25.62%	12.74%		15.48%	15.30%	
Nairobi	29.69%	58.45%		49.96%	52.43%	
North Eastern	0.71%	0.89%		0.98%	0.88%	
Nyanza	15.23%	9.54%		11.18%	10.77%	
Rift Valley	3.91%	2.58%		3.21%	2.86%	
Western	13.50%	7.37%		9.50%	8.69%	

Bold indicates standardized difference value greater than 0.1

[1] Basic vaccinations include 1 dose of BCG, 3 doses of OPV, 3 doses of DPT, and 1 dose of measles

Table 3.3 Descriptive statistics of mothers’ migration status (unweighted)

Variable	Proportion
Migrant status	
Migrant	20.40%
Non-migrant	79.60%
Migrant origin[1]	
Rural	66.59%
Urban	33.41%
Migrant type[1]	
First time migrant to NUHDSS	78.20%
Circular migrant	21.80%
Days in IUS[1,2]	7.32 (3.14)
Type of residence from which migrant moved[1]	
Nairobi slum	10.61%
Nairobi non-slum	19.16%
Other urban Kenya	3.63%
Rural Kenya	66.59%
Reason for leaving previous residence[1]	
To be with family/friends	84.85%
Living conditions	3.24%
Poor job prospects	9.02%
Other reason	2.89%

[1] Only calculated among migrants

[2] Reported as mean (standard deviation)

Table 3.4 Descriptive statistics of childhood vaccine receipt, separately among migrants and non-migrants (unweighted)

Vaccine dose	KEPI recommendation (in days)	Start of delay	Coverage (%)[1]	Receipt reported via maternal recall (%)[1]	Doses delayed or not given (%)[1]	Observed median age at vaccination (in days) Median (p25-p75)[2]	Observed median age at vaccination among those delayed (in days) Median (p25-p75)[2]	Number of days between median age at vaccination and start of delay, among those delayed
Migrants								
BCG	birth (0 days)	>28 days	96.31%	24.98%	13.43%	7 (3-15)	40 (33-56)	12
OPV 1	6 weeks (42 days)	>70 days	94.01%	21.95%	12.83%	45 (42-48)	81 (75-96)	11
OPV 2	10 weeks (70 days)	>98 days	88.93%	22.45%	20.88%	75 (71-80)	110.5 (104-128)	12.5
OPV 3	14 weeks (98 days)	>126 days	84.47%	23.93%	28.02%	106 (101-113)	143.5 (134-171.5)	17.5
DPT 1	6 weeks (42 days)	>70 days	94.75%	22.43%	10.59%	45 (42-48)	79 (75-93)	9
DPT 2	10 weeks (70 days)	>98 days	89.23%	22.55%	19.34%	75 (71-80)	110.5 (104-127)	12.5
DPT 3	14 weeks (98 days)	>126 days	85.37%	24.90%	26.20%	106 (101-113)	141 (133-164)	15
Measles	9 months (274 days)	>302 days	81.96%	39.22%	40.91%	279.5 (273-293)	331 (318-354)	29
Non-migrants								
BCG	birth (0 days)	>28 days	95.04%	28.36%	14.80%	6 (3-13)	43 (34-57)	15
OPV 1	6 weeks (42 days)	>70 days	93.49%	26.70%	14.88%	45 (42-49)	83 (76-99)	13
OPV 2	10 weeks (70 days)	>98 days	89.20%	28.66%	23.39%	75 (71-92)	112.5 (104-130)	14.5
OPV 3	14 weeks (98 days)	>126 days	84.00%	31.62%	33.78%	106 (101-115)	147 (134-172)	21
DPT 1	6 weeks (42 days)	>70 days	94.14%	27.27%	12.94%	45 (42-49)	83 (76-103)	13
DPT 2	10 weeks (70 days)	>98 days	89.34%	28.68%	22.27%	75 (71-81)	114 (2104-132)	16
DPT 3	14 weeks (98 days)	>126 days	84.72%	32.28%	32.31%	106 (101-115)	147 (134-174.5)	21
Measles	9 months (274 days)	>302 days	88.23%	45.55%	34.00%	279 (273-291)	324 (311-352)	22

[1] Calculated among children old enough to receive vaccine (i.e., recommended age and older)

[2] Reported as median (25th percentile – 75th percentile)

Table 3.5 Balance diagnostics for IPTW weights

	IPTW weight mean	IPTW weight standard deviation	IPTW weight minimum value	IPTW weight maximum value
Main analysis				
Migrant status IPTW weights	1.00	0.69	0.26	35.70
Migrant origin IPTW weights	1.00	0.02	0.47	2.61
Migrant type IPTW weights	1.00	0.55	0.24	10.10
Sensitivity analysis - migrant motivation				
Migrant motivation IPTW weights	1.03	0.86	0.15	15.39
Sensitivity analysis – 5-year migrant status				
Migrant status (5 years) IPTW weights	0.99	1.17	0.41	39.57
Sensitivity analysis among firstborn children				
Migrant status IPTW weights	1.00	0.51	0.35	15.08
Migrant origin IPTW weights	1.00	0.23	0.46	2.46
Migrant type IPTW weights	1.00	0.33	0.20	6.86

Table 3.6 Results of accelerated failure time models, comparing migrants vs. non-migrants, urban-origin vs. rural origin migrants, and first-time vs. circular migrants

Vaccine dose	Unweighted cTR[1] (95% CI)	Unweighted p-value	Unweighted aTR[2] (95% CI)	Unweighted p-value	IPTW-weighted TR (95% CI)	IPTW-weighted p-value	IPTW-weighted aTR[2] (95% CI)	IPTW-weighted p-value
Migrants vs. non-migrants (migrant status)[3]								
BCG	1.04 (0.99, 1.10)	0.15	1.06 (1.00, 1.11)	0.06	0.98 (0.88, 1.08)	0.65	1.00 (0.91, 1.08)	0.92
OPV 1	**0.96 (0.93, 0.99)**	**0.02**	0.99 (0.96, 1.02)	0.59	0.97 (0.93, 1.01)	0.16	0.97 (0.93, 1.01)	0.14
OPV 2	0.99 (0.96, 1.03)	0.65	1.01 (0.98, 1.05)	0.53	0.99 (0.94, 1.04)	0.69	0.99 (0.94, 1.03)	0.54
OPV 3	1.01 (0.97, 1.06)	0.56	1.01 (0.96, 1.06)	0.71	1.12 (0.96, 1.30)	0.13	1.07 (0.99, 1.16)	0.08
DPT 1	**0.96 (0.93, 0.99)**	**0.004**	0.98 (0.95, 1.01)	0.16	**0.96 (0.93, 1.00)**	**0.04**	**0.96 (0.93, 1.00)**	**0.04**
DPT 2	0.99 (0.96, 1.03)	0.73	1.01 (0.97, 1.04)	0.77	0.99 (0.94, 1.04)	0.63	0.98 (0.94, 1.03)	0.49
DPT 3	1.02 (0.98, 1.06)	0.39	1.01 (0.97, 1.06)	0.60	1.04 (0.97, 1.10)	0.26	1.03 (0.97, 1.09)	0.40
Measles	**1.09 (1.03, 1.16)**	**0.01**	1.06 (0.98, 1.14)	0.18	1.09 (0.96, 1.23)	0.21	1.03 (0.93, 1.15)	0.55
Urban-origin vs. rural-origin migrants (migrant origin)[4,5]								
BCG	**0.86 (0.77, 0.96)**	**0.01**	0.97 (0.87, 1.07)	0.53	0.95 (0.85, 1.07)	0.41	0.96 (0.87, 1.06)	0.44
OPV 1	0.99 (0.94, 1.05)	0.85	0.99 (0.94, 1.05)	0.75	0.99 (0.93, 1.05)	0.73	0.99 (0.94, 1.05)	0.73
OPV 2	1.02 (0.95, 1.09)	0.57	1.03 (0.96, 1.10)	0.44	1.03 (0.96, 1.10)	0.48	1.03 (0.96, 1.10)	0.37
OPV 3	1.02 (0.94, 1.10)	0.66	1.04 (0.96, 1.12)	0.34	1.02 (0.94, 1.11)	0.59	1.04 (0.96, 1.12)	0.36
DPT 1	1.01 (0.96, 1.07)	0.61	1.01 (0.96, 1.07)	0.61	1.01 (0.96, 1.08)	0.64	1.01 (0.96, 1.07)	0.60
DPT 2	1.00 (0.94, 1.07)	0.97	1.01 (0.95, 1.08)	0.77	1.01 (0.94, 1.08)	0.79	1.01 (0.95, 1.09)	0.67
DPT 3	1.02 (0.94, 1.10)	0.69	1.04 (0.96, 1.12)	0.38	1.02 (0.94, 1.11)	0.57	1.03 (0.96, 1.12)	0.39
Measles	1.09 (0.95, 1.26)	0.22	1.08 (0.92, 1.28)	0.34	1.05 (0.91, 1.21)	0.51	1.09 (0.92, 1.28)	0.34
First-time vs. circular migrants (migrant type)[6]								
BCG	1.06 (0.93, 1.22)	0.38	0.95 (0.83, 1.09)	0.49	0.98 (0.82, 1.16)	0.77	0.95 (0.81, 1.11)	0.51
OPV 1	1.06 (0.99, 1.14)	0.10	1.03 (0.96, 1.11)	0.45	1.03 (0.95, 1.11)	0.47	1.04 (0.97, 1.12)	0.26
OPV 2	1.02 (0.93, 1.10)	0.72	1.02 (0.93, 1.12)	0.64	1.01 (0.89, 1.14)	0.89	1.03 (0.93, 1.15)	0.57

OPV 3	0.96 (0.87, 1.06)	0.39	0.93 (0.84, 1.04)	0.20	0.91 (0.80, 1.03)	0.13	0.93 (0.83, 1.05)	0.24
DPT 1	1.03 (0.96, 1.10)	0.41	1.01 (0.94, 1.08)	0.83	1.00 (0.93, 1.07)	0.96	1.01 (0.95, 1.08)	0.69
DPT 2	1.02 (0.94, 1.11)	0.69	1.03 (0.94, 1.13)	0.53	1.01 (0.89, 1.14)	0.89	1.04 (0.93, 1.15)	0.49
DPT 3	0.97 (0.88, 1.06)	0.47	0.95 (0.86, 1.06)	0.36	0.94 (0.83, 1.06)	0.32	0.96 (0.86, 1.08)	0.52
Measles	**0.80 (0.67, 0.96)**	**0.02**	1.02 (0.83, 1.25)	0.88	0.6 (0.75, 1.23)	0.78	1.03 (0.83, 1.28)	0.80

[1] Crude time ratio. Model only includes exposure

[2] Adjusted time ratio. The following confounding covariates were included in the model: index child's number of siblings, maternal age at index child's birth, maternal education, maternal employment status, maternal religion, maternal ethnicity, family wealth, household size, informal urban settlement, region of origin, and birth year

[3] Weighted with the ‘migrant status’ IPTW weight

[4] Weighted with the ‘migrant origin’ IPTW weight

[5] Adjusted time ratios include all confounders in (2) except region of origin

[6] Weighted with the ‘migrant type’ IPTW weight

Table 3.7 Sensitivity analysis of accelerated failure time models, comparing women who migrated to join family vs. for 'other' reason, and comparing migrants vs. non-migrants when changing definition of migrant to moved within 5 years before childbirth

Vaccine dose	Unweighted cTR[1] (95% CI)	Unweighted p-value	Unweighted aTR[2] (95% CI)	Unweighted p-value	IPW-weighted TR (95% CI)	IPTW-weighted p-value	IPTW-weighted aTR[2] (95% CI)	IPTW-weighted p-value
Women who migrated to join family vs. for 'other' reason (migrant motivation)[3]								
BCG	0.98 (0.83, 1.17)	0.86	0.95 (0.81, 1.13)	0.58	0.97 (0.82, 1.16)	0.77	0.94 (0.80, 1.12)	0.51
OPV 1	1.00 (0.91, 1.10)	0.99	1.01 (0.92, 1.10)	0.86	1.01 (0.92, 1.10)	0.91	1.01 (0.93, 1.10)	0.77
OPV 2	0.99 (0.89, 1.09)	0.80	0.98 (0.89, 1.08)	0.70	1.00 (0.91, 1.10)	0.99	0.99 (0.90, 1.09)	0.82
OPV 3	1.01 (0.90, 1.14)	0.83	1.02 (0.90, 1.14)	0.79	1.02 (0.91, 1.15)	0.75	1.02 (0.90, 1.14)	0.77
DPT 1	1.00 (0.91, 1.10)	0.95	1.01 (0.92, 1.10)	0.87	1.00 (0.91, 1.10)	0.99	1.01 (0.93, 1.10)	0.82
DPT 2	0.98 (0.88, 1.08)	0.63	0.96 (0.87, 1.06)	0.47	0.99 (0.90, 1.09)	0.82	0.97 (0.88, 1.07)	0.56
DPT 3	1.00 (0.90, 1.13)	0.94	1.00 (0.89, 1.12)	0.99	1.01 (0.90, 1.14)	0.83	1.00 (0.89, 1.12)	0.99
Measles	1.07 (0.87, 1.32)	0.50	1.08 (0.84, 1.39)	0.54	1.07 (0.87, 1.32)	0.51	1.06 (0.82, 1.37)	0.65
Migrants vs. non-migrants (migrant status - 5 years)[4]								
BCG	0.99 (0.94, 1.04)	0.68	**1.14 (1.08, 1.20)**	**<0.001**	**1.18 (1.10, 1.27)**	**<0.001**	**1.18 (1.11, 1.27)**	**<0.001**
OPV 1	0.98 (0.95, 1.01)	0.20	1.01 (0.98, 1.05)	0.41	1.00 (0.97, 1.04)	0.85	1.01 (0.97, 1.05)	0.69
OPV 2	1.03 (1.00, 1.06)	0.05	1.02 (0.98, 1.06)	0.27	1.01 (0.97, 1.05)	0.80	1.00 (0.96, 1.05)	0.93
OPV 3	**1.13 (1.09, 1.17)**	**<0.001**	**1.05 (1.01, 1.10)**	**0.02**	**1.07 (1.00, 1.14)**	**0.04**	1.05 (1.00, 1.12)	0.07
DPT 1	0.99 (0.96, 1.02)	0.48	1.02 (0.99, 1.05)	0.28	1.01 (0.98, 1.05)	0.51	1.02 (0.98, 1.05)	0.36
DPT 2	**1.04 (1.01, 1.07)**	**0.01**	1.01 (0.98, 1.05)	0.44	1.00 (0.96, 1.04)	0.90	1.00 (0.96, 1.04)	0.88
DPT 3	**1.12 (1.09, 1.16)**	**<0.001**	**1.05 (1.01, 1.10)**	**0.02**	1.03 (0.98, 1.09)	0.20	1.02 (0.97, 1.08)	0.38
Measles	**1.22 (1.16, 1.28)**	**<0.001**	0.96 (0.89, 1.03)	0.28	0.99 (0.92, 1.06)	0.73	0.93 (0.86, 1.01)	0.07

[1] Crude time ratio. Model only includes exposure

[2] Adjusted time ratio. The following covariates were included in the model: index child's number of siblings, maternal age at index child's birth, maternal education, maternal employment status, maternal religion, maternal ethnicity, family wealth, household size, informal urban settlement, region of origin, and birth year

[3] Weighted with the 'migrant motivation' IPTW weight

[4] Weighted with the '5-year migrant status' IPTW weight

Table 3.8 Sensitivity analysis results of accelerated failure time models, comparing migrants vs. non-migrants, urban-origin vs. rural origin migrants, and first-time vs. circular migrants, among firstborn children

Vaccine dose	Unweighted cTR[1] (95% CI)	Unweighted p-value	Unweighted aTR[2] (95% CI)	Unweighted p-value	IPTW-weighted TR (95% CI)	IPTW-weighted p-value	IPTW-weighted aTR[2] (95% CI)	IPTW-weighted p-value
Migrants vs. non-migrants (migrant status)[3]								
BCG	1.03 (0.97, 1.10)	0.30	1.05 (0.99, 1.12)	0.09	0.99 (0.92, 1.08)	0.89	1.01 (0.94, 1.08)	0.85
OPV 1	0.97 (0.94, 1.00)	0.09	0.99 (0.95, 1.02)	0.44	0.97 (0.93, 1.01)	0.14	0.97 (0.93, 1.01)	0.10
OPV 2	1.01 (0.98, 1.05)	0.47	1.01 (0.97, 1.05)	0.59	1.00 (0.96, 1.05)	0.97	0.99 (0.95, 1.04)	0.67
OPV 3	1.04 (1.00, 1.09)	0.08	1.00 (0.95, 1.05)	0.99	1.03 (0.98, 1.09)	0.23	1.02 (0.96, 1.07)	0.57
DPT 1	**0.96 (0.93, 0.99)**	**0.02**	0.97 (0.94, 1.01)	0.11	**0.96 (0.92, 0.99)**	**0.02**	**0.96 (0.92, 0.99)**	**0.01**
DPT 2	1.01 (0.98, 1.05)	0.45	1.00 (0.96, 1.04)	0.98	0.99 (0.95, 1.04)	0.67	0.98 (0.94, 1.02)	0.37
DPT 3	1.04 (1.00, 1.09)	0.05	1.00 (0.96, 1.05)	0.90	1.03 (0.97, 1.09)	0.30	1.01 (0.96, 1.07)	0.66
Measles	**1.14 (1.07, 1.22)**	**<0.001**	1.04 (0.96, 1.14)	0.31	1.06 (0.97, 1.16)	0.21	1.02 (0.91, 1.13)	0.75
Urban-origin vs. rural-origin migrants (migrant origin)[4,5]								
BCG	**0.84 (0.76, 0.94)**	**0.003**	0.95 (0.86, 1.06)	0.36	0.93 (0.83, 1.04)	0.19	0.94 (0.85, 1.05)	0.29
OPV 1	1.00 (0.94, 1.06)	0.99	0.99 (0.94, 1.05)	0.76	0.99 (0.93, 1.06)	0.76	0.99 (0.93, 1.05)	0.72
OPV 2	1.03 (0.96, 1.10)	0.42	1.03 (0.96, 1.10)	0.37	1.03 (0.96, 1.11)	0.41	1.03 (0.97,1.11)	0.32
OPV 3	1.01 (0.93, 1.09)	0.83	1.02 (0.95, 1.11)	0.56	1.01 (0.93, 1.10)	0.76	1.02 (0.95, 1.11)	0.51
DPT 1	1.02 (0.96, 1.08)	0.55	1.01 (0.96, 1.07)	0.70	1.01 (0.95, 1.08)	0.71	1.01 (0.96, 1.07)	0.71
DPT 2	1.01 (0.95, 1.08)	0.71	1.01 (0.95, 1.09)	0.67	1.02 (0.95, 1.09)	0.65	1.02 (0.95, 1.09)	0.59
DPT 3	1.02 (0.94, 1.10)	0.71	1.03 (0.95, 1.11)	0.50	1.02 (0.94, 1.11)	0.35	1.03 (0.95, 1.12)	0.46
Measles	1.06 (0.93, 1.22)	0.39	1.05 (0.89, 1.25)	0.53	1.03 (0.90, 1.19)	0.65	1.05 (0.89, 1.24)	0.56
First-time vs. circular migrants (migrant type)[6]								
BCG	1.08 (0.93, 1.26)	0.32	0.99 (0.86, 1.15)	0.94	1.02 (0.86, 1.20)	0.85	1.00 (0.85, 1.17)	0.98
OPV 1	1.07 (0.99, 1.16)	0.09	1.06 (0.98, 1.15)	0.13	1.06 (0.98, 1.15)	0.15	1.06 (0.98, 1.15)	0.13
OPV 2	1.03 (0.94, 1.13)	0.52	1.06 (0.96, 1.17)	0.28	1.06 (0.94, 1.19)	0.32	1.07 (0.96, 1.20)	0.23

OPV 3	0.96 (0.86, 1.07)	0.47	0.98 (0.88, 1.09)	0.71	0.96 (0.85, 1.09)	0.54	0.98 (0.87, 1.10)	0.71
DPT 1	1.04 (0.97, 1.13)	0.28	1.05 (0.97, 1.13)	0.21	1.04 (0.96, 1.12)	0.32	1.05 (0.97, 1.13)	0.25
DPT 2	1.02 (0.93, 1.12)	0.64	1.06 (0.96, 1.17)	0.22	1.06 (0.95, 1.19)	0.32	1.08 (0.96, 1.20)	0.19
DPT 3	0.99 (0.89, 1.10)	0.88	1.01 (0.90, 1.13)	0.86	1.00 (0.88, 1.13)	0.94	1.01 (0.90, 1.14)	0.86
Measles	**0.81 (0.67, 0.98)**	**0.03**	1.06 (0.86, 1.31)	0.59	1.02 (0.82, 1.26)	0.88	1.10 (0.89, 1.36)	0.39

[1] Crude time ratio. Model only includes exposure

[2] Adjusted time ratio. The following confounding covariates were included in the model: maternal age at index child's birth, maternal education, maternal employment status, maternal religion, maternal ethnicity, family wealth, household size, informal urban settlement, region of origin, and birth year

[3] Weighted with the 'migrant status' IPTW weight

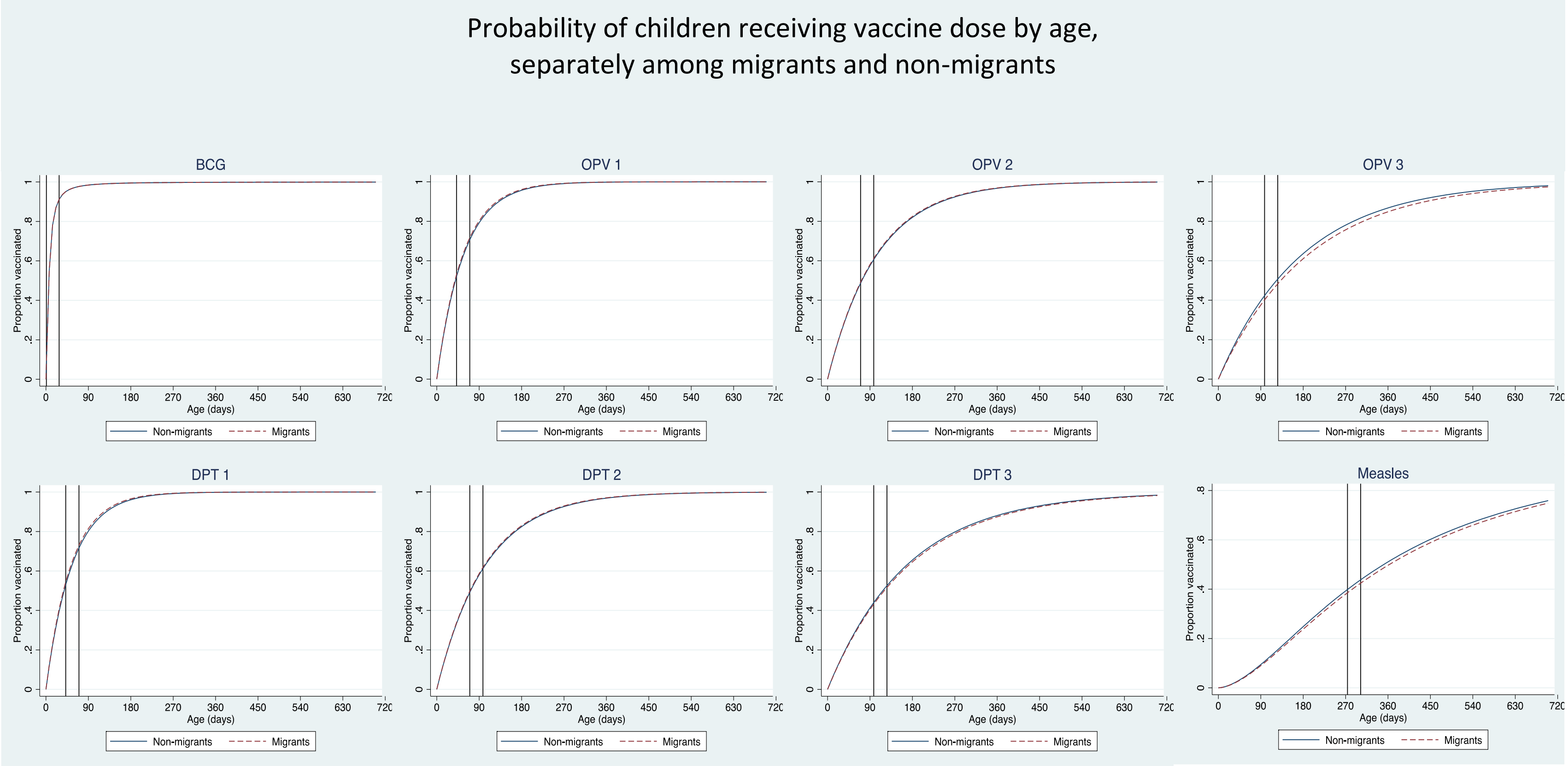
[4] Weighted with the 'migrant origin' IPTW weight

[5] Adjusted time ratios include all confounders in (2) except region of origin

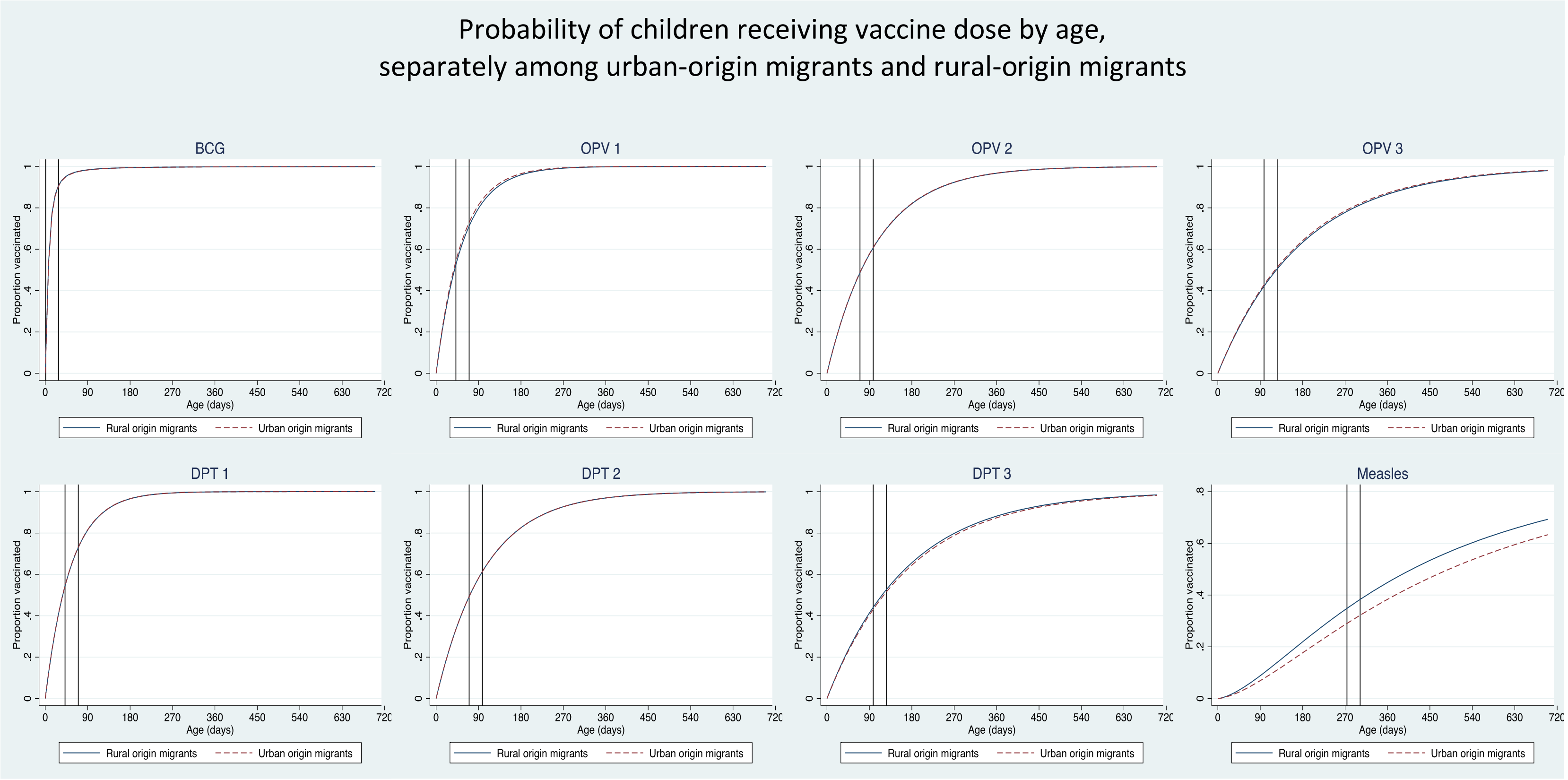
[6] Weighted with the 'migrant type' IPTW weight

Figure 3.1 Inverse survival curves comparing proportion of children who received each vaccine dose by child's age. Vertical lines indicate the age window during which vaccine receipt is recommended.

(a) Migrants vs non-migrants



(b) Urban origin vs. rural-origin migrants



(c) First-time vs. circular migrants

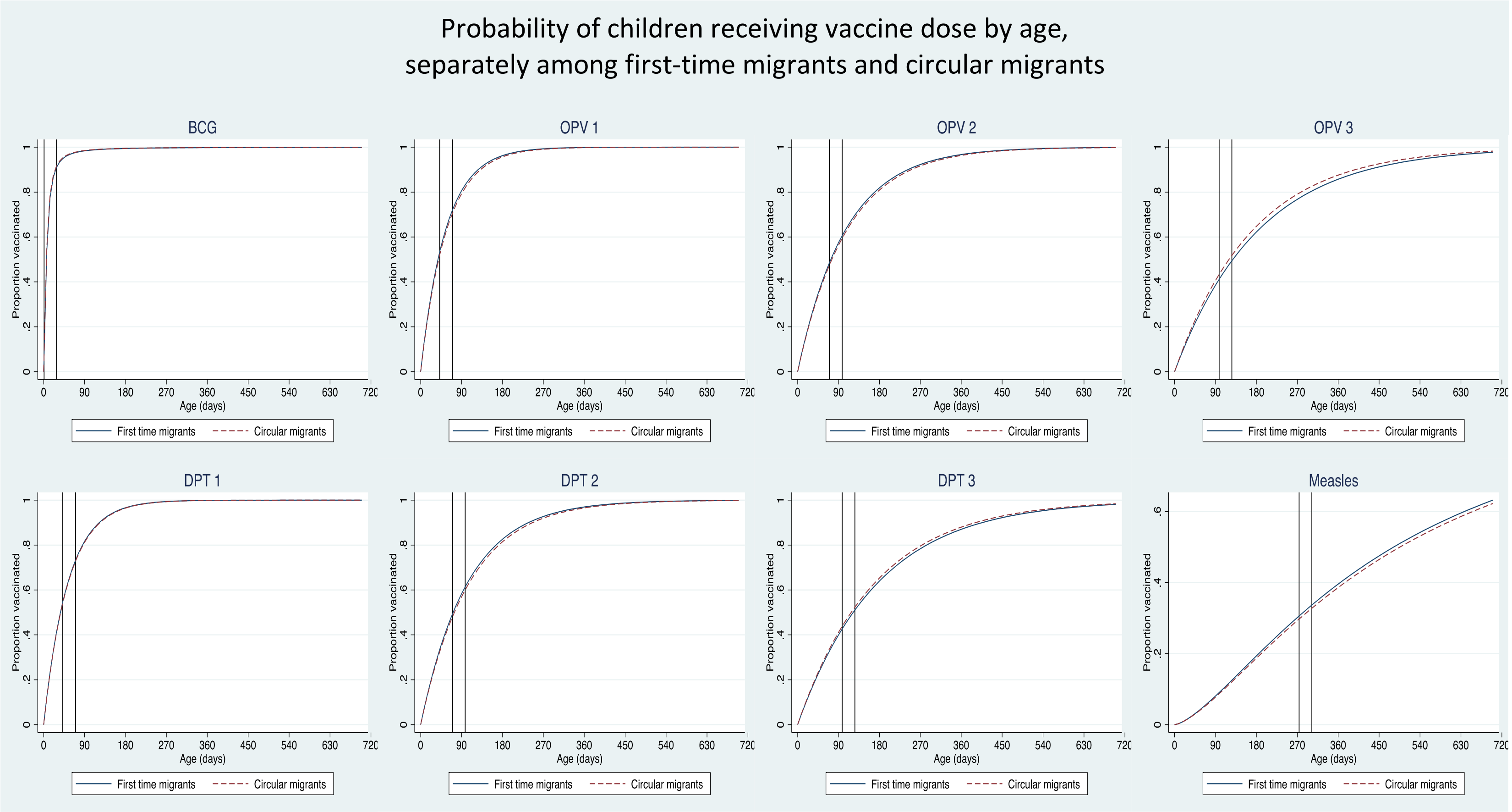
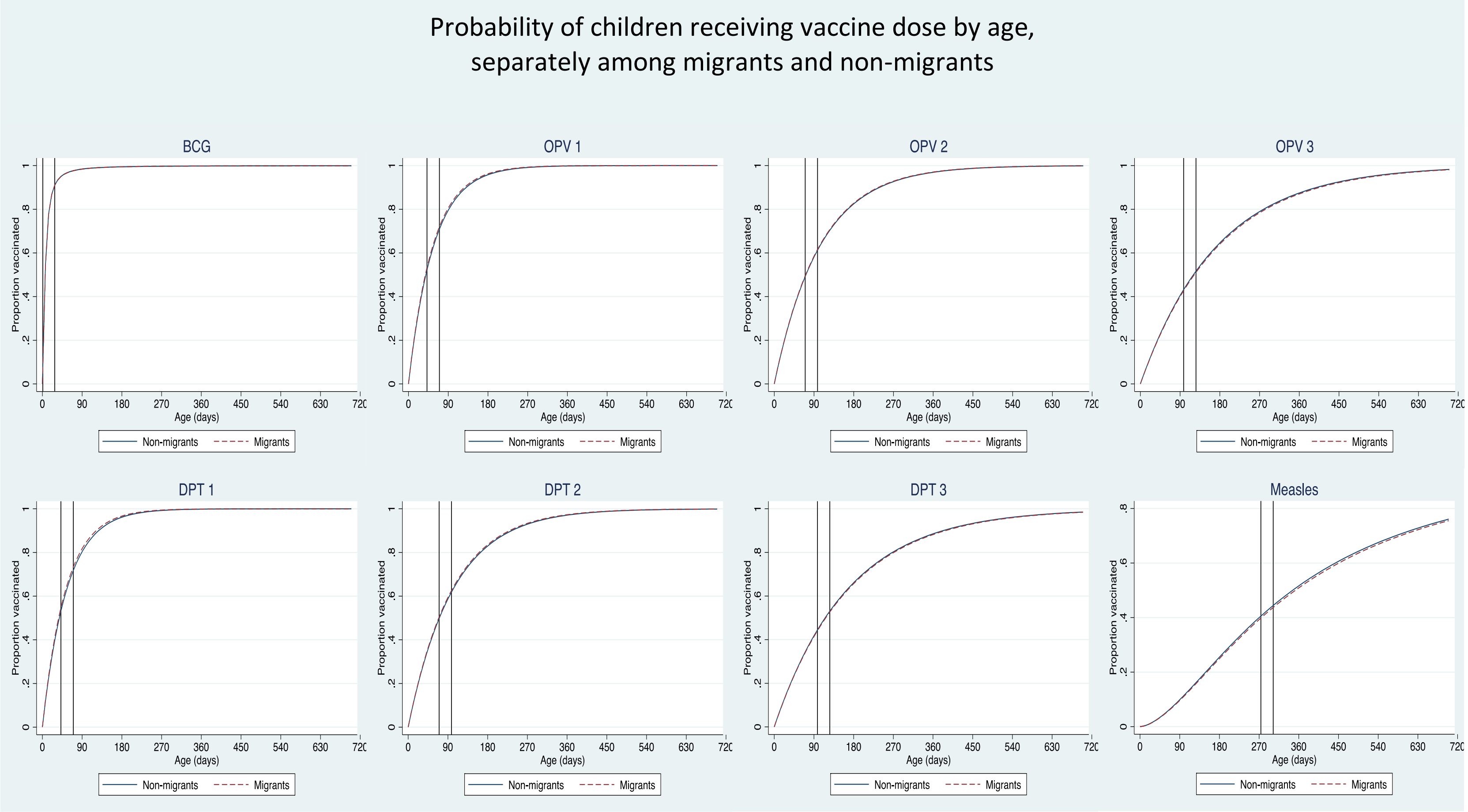
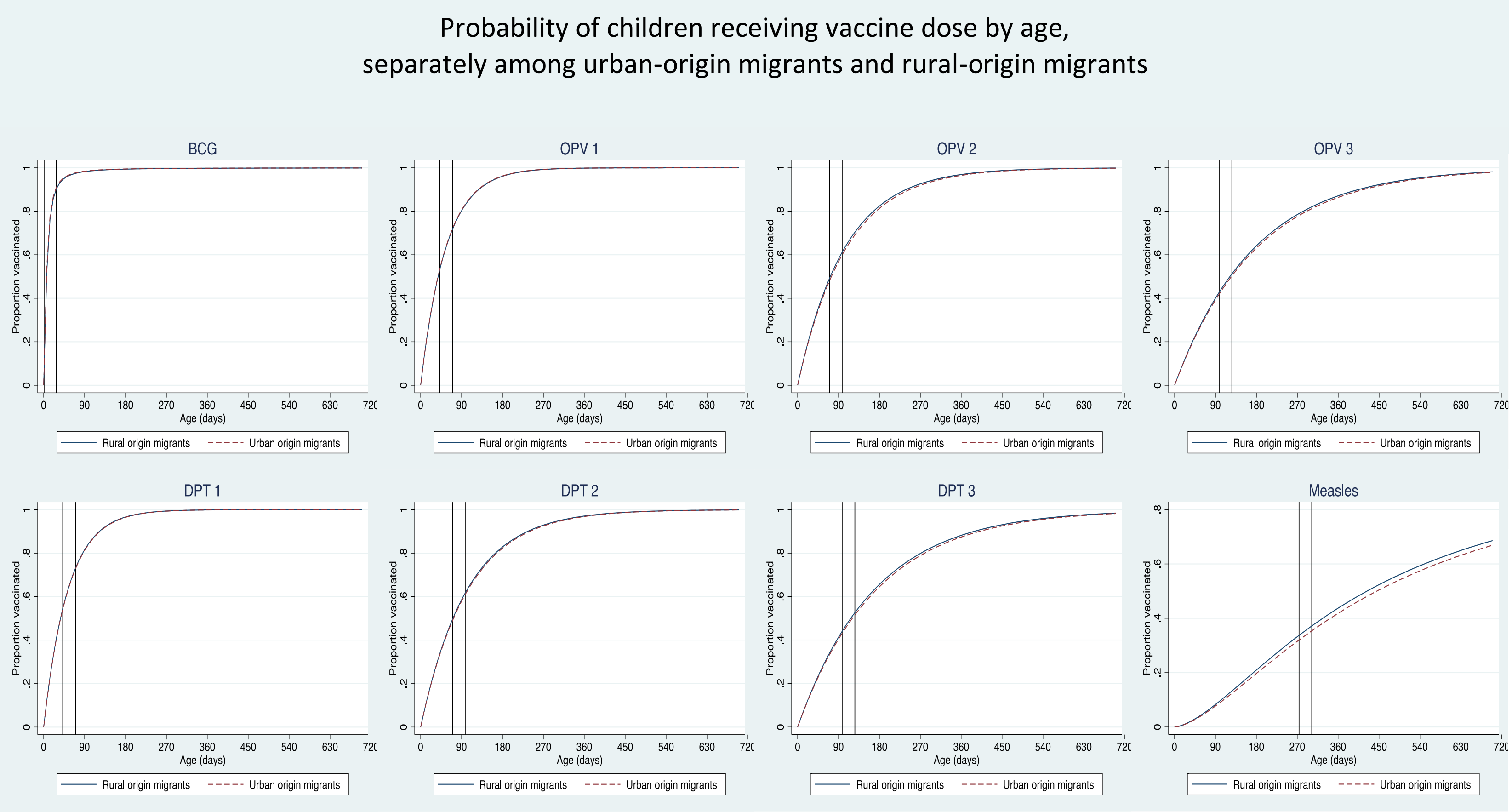


Figure 3.2 Inverse survival curves comparing proportion of children who received each vaccine dose by child's age from sensitivity analysis in which only firstborn children were included. Vertical lines indicate the age window during which vaccine receipt is recommended.

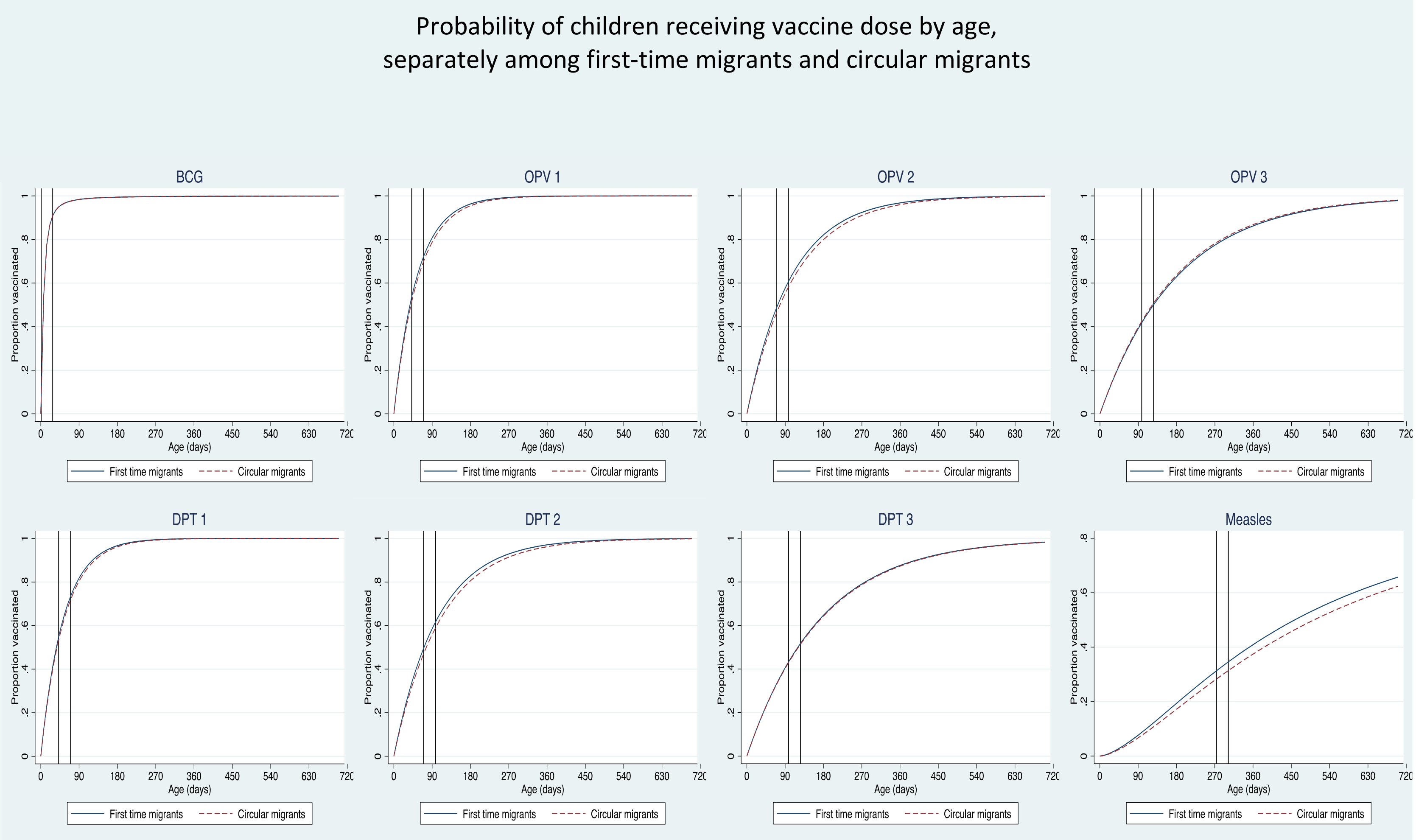
(a) Migrants vs. non-migrants



(b) Urban-origin vs. rural-origin migrants



(c) First-time vs. circular migrants



References

1. United Nations. Goal 3 Targets and Indicators. https://sdgs.un.org/goals/goal3. Published 2020. Accessed December 27, 2020.
2. World Health Orgranization. *Immunisation Agenda 2030: A Global Strategy to Leave No One Behind (Draft Three)*. Geneva, Switzerland; 2019. https://www.who.int/immunization/sage/meetings/2019/october/2_ia2030_SAGE_submission.pdf?ua=1.
3. UNICEF. Under-five mortality. https://data.unicef.org/topic/child-survival/under-five-mortality/. Published 2020. Accessed September 18, 2020.
4. WHO/UNICEF. Immunization. https://data.unicef.org/topic/child-health/immunization/. Published 2019. Accessed December 12, 2020.
5. Masters NB, Wagner AL, Boulton ML. Vaccination timeliness and delay in low- and middle-income countries: a systematic review of the literature, 2007-2017. *Hum Vaccin Immunother*. 2019. doi:10.1080/21645515.2019.1616503
6. Grant CC, Roberts M, Scragg R, et al. Delayed immunisation and risk of pertussis in infants: unmatched case-control study. *BMJ*. 2003;326(7394):852-853. doi:10.1136/bmj.326.7394.852
7. Glanz JM, Newcomer SR, Narwaney KJ, et al. A population-based cohort study of undervaccination in 8 managed care organizations across the United States. *JAMA Pediatr*. 2013;167(3):274-281. doi:10.1001/jamapediatrics.2013.502
8. International Organization for Migration. *Migration in Kenya: A Country Profile 2018*. Nairobi; 2018.
9. Mutua MK, Mohamed SF, Porth JM, Faye CM. Inequities in On-Time Childhood Vaccination: Evidence From Sub-Saharan Africa. *Am J Prev Med*. 2020;60(1):S11-S23. doi:10.1016/j.amepre.2020.10.002
10. The World Bank. Gini index (World Bank estimate). https://data.worldbank.org/indicator/SI.POV.GINI?contextual=default&end=2015&locations=KE-XO-ET-TZ&most_recent_value_desc=false&start=1992. Published 2019. Accessed April 15, 2020.
11. Oxfam International. Kenya: extreme inequality in numbers. https://www.oxfam.org/en/kenya-extreme-inequality-numbers. Published 2017. Accessed April 15, 2020.
12. Chuma J, Maina T, Ataguba J. Does the distribution of health care benefits in Kenya meet the principles of universal coverage? *BMC Public Health*. 2012;12(1):20. doi:10.1186/1471-2458-12-20
13. Kiros GE, White MJ. Migration, community context, and child immunization in Ethiopia. *Soc Sci Med*. 2004;59(12):2603-2616. doi:10.1016/j.socscimed.2004.04.009
14. Smith-Greenaway E, Madhavan S. Maternal migration and child health: An analysis of disruption and adaptation processes in Benin. *Soc Sci Res*. 2015;54:146-158. doi:10.1016/j.ssresearch.2015.06.005
15. Kusuma YS, Kumari R, Pandav CS, Gupta SK. Migration and immunization: Determinants of childhood immunization uptake among socioeconomically disadvantaged migrants in Delhi, India. *Trop Med Int Heal*. 2010. doi:10.1111/j.1365-3156.2010.02628.x
16. Clark S, Madhavan S, Kabiru C. Kin support and child health: Investigating two approaches in an African slum. *Soc Sci Res*. 2018;76(August):105-119.

doi:10.1016/j.ssresearch.2018.08.001

17. Madhavan S, Clark S, Araos M, Beguy D. Distance or location? How the geographic distribution of kin networks shapes support given to single mothers in urban Kenya. *Geogr J*. 2018;184(1):75-88. doi:10.1111/geoj.12230
18. Clark S, Madhavan S, Cotton C, Beguy D, Kabiru C. Who Helps Single Mothers in Nairobi? The Role of Kin Support. *J Marriage Fam*. 2017;79(4):1186-1204. doi:10.1111/jomf.12404
19. Goodburn C. Rural-urban migration and gender disparities in child healthcare in China and India. *Dev Change*. 2014;45(4):631-655. doi:10.1111/dech.12098
20. United Nations Human Settlements Programme (UN-Habitat). *World Cities Report 2020: Unpacking the Value of Sustainable Urbanization*. Nairoib, Kenya; 2020. doi:10.18356/c41ab67e-en
21. Wamukoya M, Kadengye DT, Iddi S, Chikozho C. The Nairobi Urban Health and Demographic Surveillance of slum dwellers, 2002–2019: Value, processes, and challenges. *Glob Epidemiol*. 2020;2:100024. doi:10.1016/j.gloepi.2020.100024
22. United Nations Population Division. Urban population (% of total population) - Kenya. The World Bank. https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=KE. Published 2019. Accessed December 27, 2020.
23. UN Habitat. Overview - Kenya. https://unhabitat.org/kenya. Published 2020. Accessed December 27, 2020.
24. Beguy D, Bocquier P, Zulu EM. Circular migration patterns and determinants in Nairobi slum settlements. *Demogr Res*. 2010;23(December 2010):549-586. doi:10.4054/DemRes.2010.23.20
25. Adetifa IMO, Karia B, Mutuku A, et al. Coverage and timeliness of vaccination and the validity of routine estimates: Insights from a vaccine registry in Kenya. *Vaccine*. 2018;36(52):7965-7974. doi:10.1016/j.vaccine.2018.11.005
26. African Population and Health Research Center (APHRC). NUHDSS-Household amenities and characteristics information for all households 2002-2015. http://microdataportal.aphrc.org/index.php/catalog/54/related-materials. Published 2021. Accessed April 11, 2021.
27. Mutua MK, Mohamed SF, Iddi S, Muyingo S, Mwangi B, Kadengye D. Do inequalities exist in the disadvantaged populations? Levels and trends of full and on-time vaccination coverage in two Nairobi urban informal settlements. *Glob Epidemiol*. 2020;2. doi:10.1016/j.gloepi.2020.100044
28. Boulton ML, Carlson BF, Wagner AL, Porth JM, Gebremeskel B, Abeje Y. Vaccination timeliness among newborns and infants in Ethiopia. *PLoS One*. 2019;14(2):1-13. doi:10.1371/journal.pone.0212408
29. Mutua MK, Ochako R, Ettarh R, Ravn H, Echoka E, Mwaniki P. Effects of low birth weight on time to BCG vaccination in an urban poor settlement in Nairobi, Kenya: An observational cohort study. *BMC Pediatr*. 2015;15(1):1-8. doi:10.1186/s12887-015-0360-5
30. Riosmena F, Kuhn R, Jochem WC. Explaining the Immigrant Health Advantage: Self-selection and Protection in Health-Related Factors Among Five Major National-Origin Immigrant Groups in the United Statews. *Demography*. 2017;54(1):175-200. doi:10.1007/s13524-016-0542-2

31. Rosenbaum PR. Model-based direct adjustment. *J Am Stat Assoc*. 1987;82(398):387-394. doi:10.1080/01621459.1987.10478441
32. Austin PC. An introduction to propensity score methods for reducing the effects of confounding in observational studies. *Multivariate Behav Res*. 2011;46(3):399-424. doi:10.1080/00273171.2011.568786
33. Rosenbaum PR, Rubin DB. The central role of the propensity score in observational studies for causal effects. *Biometrica*. 1983;70(1):41-55. doi:10.1017/CBO9780511810725.016
34. International Organization for Migration. *World Migration Report 2020*. Geneva; 2020.
35. Cotton C. Migration and young women's access to maternal healthcare in sub-Saharan Africa. *Heal Place*. 2019;55(January):136-144. doi:10.1016/j.healthplace.2018.12.006
36. Antai D. Migration and child immunization in Nigeria: Individual- and community-level contexts. *BMC Public Health*. 2010;10:116. doi:10.1186/1471-2458-10-116
37. Awoh AB, Plugge E. Immunisation coverage in rural-urban migrant children in low and middle-income countries (LMICs): A systematic review and meta-analysis. *J Epidemiol Community Health*. 2016;70(3):305-311. doi:10.1136/jech-2015-205652
38. Mutua MK, Kimani-Murage E, Ngomi N, Ravn H, Mwaniki P, Echoka E. Fully immunized child: Coverage, timing and sequencing of routine immunization in an urban poor settlement in Nairobi, Kenya. *Trop Med Health*. 2016;44(1):1-12. doi:10.1186/s41182-016-0013-x
39. Moïsi JC, Kabuka J, Mitingi D, Levine OS, Scott JAG. Spatial and socio-demographic predictors of time-to-immunization in a rural area in Kenya: Is equity attainable? *Vaccine*. 2010;28(35):5725-5730. doi:10.1016/j.vaccine.2010.06.011
40. Mor Z, Aharon AA, Sheffer R, Nehama H. Growth, developmental achievements and vaccines timeliness of undocumented migrant children from Eritrea compared with Israelis. *PLoS One*. 2018;13(3):1-11. doi:10.1371/journal.pone.0193219
41. Arnold C, Theede J, Gagnon A. A qualitative exploration of access to urban migrant healthcare in Nairobi, Kenya. *Soc Sci Med*. 2014;110:1-9. doi:10.1016/j.socscimed.2014.03.019

Chapter 4 Migration to an Informal Urban Settlement and its Impact on Receipt of Maternal Childbirth Care in Nairobi, Kenya: An Exploration of Migrant Adaptation

Background: Reducing the burden of maternal mortality to fewer than 70 deaths per 100,000 live births has been identified as a global priority in the United Nations' Sustainable Development Goals. Kenya has made progress in achieving reductions in maternal mortality although with a maternal mortality ratio of 342 deaths per 100,000 live births, further improvement is needed. Ensuring women have universal access to deliver in a health facility with a skilled birth attendant is a key strategy to decrease maternal deaths. Migration has been proposed as a barrier to uptake of maternal childbirth services, as relocation may disrupt a woman's social and economic resources, requiring a period of adaptation before healthcare services can be effectively used. This analysis aimed to explore the relationship between migrant women's adaptation to living in an informal urban settlement and receipt of recommended childbirth care in Nairobi, Kenya.

Methods: Data from the Nairobi Urban Health and Demographic Surveillance System (2002-2018) were analyzed. Logistic regressions were employed to assess the relationship between migrant adaptation (operationalized as the continuous number of years between migration and childbirth) and use of recommended childbirth care, an outcome combining place of delivery and skilled birth attendance. To analyze whether this relationship varied by migration characteristics (migrant origin, migrant type, migration companions, migration motivation), additional regressions assessing adaptation-migration characteristic interactions were run.

Results: Nearly all women (93%) received recommended childbirth care. Unadjusted models suggested that the odds of receiving recommended childbirth care increased as women adapted (cOR: 1.08, 95% CI: 1.05, 1.11), although the relationship was not statistically significant with inclusion of confounders (aOR: 1.02, 95% CI: (0.98, 1.06). The relationship between adaptation and the use of recommended childbirth services does not appear to be modified by characteristics of migration on either the multiplicative or additive scale.

Conclusion: Results indicate that giving birth in a health facility with a skilled attendant was widespread and not associated with migrant adaptation; receipt of recommended childbirth care was high among women who migrated shortly before childbirth and remained high for women who adapted to their new environment before becoming pregnant and delivering. Future research should seek to identify groups of women who do not receive maternal childbirth care to ensure childbirth is safe for all women.

Introduction

In 2017, almost 300,000 women died during or soon after pregnancy and childbirth globally, translating to a maternal mortality ratio of 211 maternal deaths per 100,000 live births with approximately two-thirds of these deaths occurring in sub-Saharan Africa.[1] Maternal death typically results from severe bleeding, infection, and/or complications during delivery, which can frequently be averted with well- known, widely available, and relatively inexpensive interventions (e.g. injections to reduce bleeding risk or early identification and treatment of infection).[1] Because most maternal deaths are preventable if women receive appropriate care during and after pregnancy and childbirth, the United Nations Sustainable Development Goal (SDG) 3.1 set an ambitious target of reducing the average global maternal mortality ratio to less than 70 deaths per 100,000 live births by 2030.[2] While the sub-Saharan Africa region registered an impressive 40% decline in maternal deaths between 2000 and 2017, the region is still far from achieving this target.[1]

Women are less likely to experience preventable maternal morbidity and mortality during pregnancy and childbirth if they deliver in a health facility with the assistance of a skilled birth attendant (SBA).[1] Ideally, when a woman delivers in a health facility her care providers have access to the resources necessary for rapid assessment and treatment of complications that arise during childbirth or can facilitate referral and transport to a higher level facility if needed.[3] In the Eastern and Southern African regions the proportion of deliveries occurring in health facilities has improved from 37% to 65% over the past twenty years, while falling below the global average of 78% and the ultimate goal of universal use.[3] Similarly, having an SBA during childbirth ensures women have a skilled health provider who is knowledgeable and equipped to anticipate and manage problems during childbirth. The World Health Organization defines SBAs as accredited health professionals who have access to necessary equipment and medical supplies to provide care, who have been trained to provide appropriate care for normal deliveries, and who are able to recognize and treat or refer complicated deliveries.[4] Although traditional birth attendants can play an important role in supporting pregnant women, they are not considered SBAs as they often lack the necessary expertise and equipment to identify and address obstetric emergencies. Like facility-based delivery, the proportion of deliveries accompanied by an SBA in Eastern and Southern Africa has improved markedly from 41% to 63% over the last two decades.[3]

Kenya is an important economic, technologic, and regional and international travel hub in the African region[5,6] and according to the World Bank, transitioned from a low- to a middle-income economy in 2014 following years of sustained economic growth.[5,7] Kenya has also experienced an impressive improvement in its human development index value (HDI is a composite measure of national life expectancy, education, and income ranging from 0 to 1) increasing from 0.46 to 0.60 in the last twenty years.[8] Although this ranks Kenya globally at 143 of 189 countries, it nonetheless exceeds the sub-Saharan African average HDI value (0.55) demonstrating substantial progress with improving health metrics.[8] An important contributor to Kenya's life expectancy is maternal mortality, which has seen a substantial decline from 678 to 342 deaths per 100,000 live births between 2003 and 2017.[1] While Kenya's 2017 maternal mortality ratio was lower than sub-Saharan Africa's average of 534 deaths, it remains above the aforementioned global average and SDGs goals.[1,9] Kenya's total fertility rate (TFR) has seen a similar decline, from 4.9 children per woman in 2003 to 3.4 in 2018.[10] Contributing to Kenya's maternal mortality burden were the roughly 40% of deliveries in that took place outside of a health facility and one-third not attended by an SBA.[11] These figures are particularly concerning in informal urban settlements (IUSs, or slums), whose highly mobile populations typically have less access to high quality healthcare services and worse health outcomes than the general population.[12] For example, a survey of IUSs in Nairobi reported only 69% of children aged 12-23 months had received all recommended vaccinations and one-third of mothers had less than the four prenatal care visits recommended at the time of the survey.[13]

Migration has been proposed to contribute to underuse of healthcare services during pregnancy and childbirth. In sub-Saharan Africa, internal migration (migration within a country's borders) among mothers has been linked to reduced use of prenatal care and presence of a skilled birth attendant during childbirth.[14] It has been posited that migration to a new community may disrupt the social, instrumental, and economic aspects of a woman's life as she moves to a new area and must acquire employment and housing while also learning to navigate her new community. Emotional, financial, and logistical support, which would provide a woman with the childcare assistance and encouragement to seek delivery care from an SBA at a health facility, may be reduced when physically isolated from extended family members.[15,16] These disruptions are immediate and women may require a period of adaptation before they are able to effectively find, afford, and avail themselves of healthcare services. As such, it was hypothesized that increased time living in the destination community before giving birth (representing increased adaptation) would be associated with an increased probability of receiving recommended delivery care.

Though it was hypothesized that this relationship is positive overall, the characteristics of a woman's migration experience – such as migrant origin, migrant type, migration companions, and motivation for migrating – may influence the association between adaptation and use of childbirth services. It was hypothesized that the relationship between time spent in the destination before giving birth and use of childbirth services would differ for women migrating from rural communities and women migrating from urban communities, with urban-origin migrants demonstrating a stronger relationship between adaptation and childbirth care (i.e., a larger increase in the probability of utilizing childbirth services per year spent in the destination community) compared to rural-origin migrants. Differences in transportation and healthcare access are very different in rural and urban areas meaning it may take rural-origin migrants a longer period of adaptation before successfully identifying and using childbirth services. Further, women migrating from rural to urban areas may experience exposure to ideas about normative behavior in terms of using skilled healthcare providers during pregnancy and childbirth, which could lead to an increase in facility delivery and SBA at childbirth as women develop relationships in their new community.[14,17] However, developing these relationships and internalizing new birthing norms takes time, further supporting the supposition that rural-origin women may take a longer period of time to adapt before using recommended childbirth services. Analogously, the relationship between adaptation and use of childbirth services may be different for women who have previously lived in the destination community, left it, and are now returning (a "circular migrant") compared to women migrating to a community for the first time. Women who have previous experience living in a community may be able to take advantage of her knowledge of the area and her existing social ties to the community to utilize childbirth services. Therefore, it was hypothesized that the relationship between adaptation and receipt of childbirth care would be stronger among circular migrants compared to first-time migrants. The association between adaptation and healthcare use may also vary depending on whether a woman migrates alone or with companions. As women who migrate alone do not have others migrating with them to help navigate the new community and healthcare system, it was hypothesized that the relationship between adaptation and use of childbirth services would be weaker for women migrating alone compared to women migrating with others from her family. Finally, it was hypothesized that a woman's experience adapting may vary depending on her reason for migrating. For example, women who migrate to join family and friends likely have an established financial and emotional support system in the destination community, meaning it may take her less time to adapt. However, women migrating in anticipation of job prospects may need more time to secure employment and a local social support system before having the ability to utilize recommended childbirth services. It was therefore hypothesized that the association between adaptation and use of childbirth care would be strongest for women migrating to reunite with family and friends and weakest for women migrating in search of economic opportunities.

This analysis aimed to examine the relationship between migrant adaptation (defined as the amount of time between in-migration and childbirth, with greater time indicating greater adaptation) and the use of recommended childbirth services in two informal urban settlements in Nairobi, Kenya. To more fully explore any heterogeneity in this relationship, secondary analyses stratified regressions by migrant origin (rural, urban), migrant type (first-time, circular), migration companions (alone, with others) and migration motivation (to be with family or friends, living conditions, good job prospects, other reason).

Methods

Data source

Data came from the Nairobi Urban Health and Demographic Surveillance System (NUHDSS), a longitudinal surveillance system collecting information from residents of two informal urban settlements (IUSs, Korogocho and Viwandani) in Nairobi.[18] NUHDSS data collection began with a census of two of the four sub-districts in Korogocho and one of the two sub-districts in Viwandani in 2002 and now includes biannual interviews with all individuals residing in those sub-districts (approximately 88,974 individuals from 33,462 households).[18] During data collection interviewers ask participants about a variety of health and demographic topics including births and deaths, in- and out-migrations, and changes in sociodemographic characteristics such as marital status and education. When children are born in the NUHDSS catchment area they are registered with a participant ID that is linked to their mother's ID and mothers are asked questions about the delivery, including birth setting and any delivery assistance. Korogocho and Viwandani were each included in NUHDSS to represent distinct IUS experiences. Viwandani is located near an industrial area in southern Nairobi and is home to a highly mobile and more educated population in search of nearby economic opportunities.[18] Conversely, Korogocho is situated in northern Nairobi and has a more stable population. Though residents of both settlements experience economic instability, unemployment and chronic poverty are much higher in Korogocho than in Viwandani.[18] The TFR in the NUHDSS communities was estimated at 3.1 children per woman (2003-2012), which is higher than Nairobi's average value of 2.8 children (2008-2009) but lower than Kenya's 2012 national TFR of 4.1 children per woman.[19–21] Further details of the NUHDSS data collection and settlement characteristics have been published elsewhere.[18,20]

This analysis aimed to assess the childbirth experiences of migrant women who lived and gave birth in the IUS. Accordingly, women who were visitors, international migrants (women who migrated to NUHDSS from outside Kenya), non-migrants, delivered outside of Nairobi, or had missing information on confounders or the outcome were excluded. The total sample contained 19,882 pregnancy records and following exclusions the analytic sample included 11,041 pregnancy records from 8,943 women.

Measures

Migrant adaptation was treated as the exposure in this analysis, defined as the continuous number of years between a woman's date of migration into the IUS and the date of childbirth. A greater number of years was considered to be indicative of greater adaptation. The outcome was receipt of recommended skilled childbirth care. This outcome was a composite measure of place of delivery and presence of a skilled birth attendant at childbirth, though it should be noted there was no way to judge the technical quality of care provided. A woman was considered to have received recommended childbirth care if childbirth occurred in a health facility and was attended by an SBA (doctor, clinical officer, nurse, midwife, nurse aid). If a woman gave birth at home, en route to a health facility, or another location and/or if her childbirth was attended by a traditional birth attendant, neighbor, relative, friend, or no one she was considered not to have received recommended childbirth care. Heterogeneity of the relationship between adaptation and receipt of recommended delivery services was explored by migrant origin (urban, rural), migration companions (alone, with others), migrant type (ever previously lived in the NUHDSS settlements since data collection began in 2002 [circular migrant] or first-time migrant to the IUSs), and reason for migrating to the IUS (to be with family/friends, living conditions, anticipated job prospects, other).

Confounders included woman's age at delivery of her index child (under 18 years, 18-24, 25-34, 35 or older), ethnicity (Kikuyu, Kamba, Luhya, Luo, Kisii, other), religion (Christian, Muslim, other/no religion), highest level of school attended (never attended, primary, secondary, higher than secondary), working status (worked for pay in the last 30 days, did not), marital status (currently married, not), parity (first birth, not first birth), household size (1-4 members, 5-7, 8 or more), household wealth (by quintiles), IUS (Korogocho, Viwandani), and the maternity care policy environment when the childbirth occurred[22–25] (2004-2009 [before the vouchers and during the voucher rollout], January 1, 2010 – May 31, 2013 [vouchers were fully implemented but the free maternity care policy had not yet been enacted], June 1, 2013 – December 31, 2016 [vouchers fully implemented and the free maternity care policy was in effect], and 2017-2018 [only the free maternity care policy in effect]).

Statistical methods

In addition to descriptive statistics of sociodemographic and migration characteristics, binary and multivariable logistic regressions adjusting for confounders were employed to examine the relationship between adaptation and childbirth. Standard errors that allow for intragroup correlation among pregnancies from the same mother were employed.[26] The average marginal effect of time in the IUS was predicted. The average marginal effects for the effect of time in the IUS represents the instantaneous rate of change. This can be interpreted as the influence on the predicted probability of receiving recommended childbirth care for a one-year increase in time in the IUS.[21,27,28] Adjusted predicted probabilities of receiving recommended childbirth care after living in the IUS were derived from multivariable regressions and plotted. These predicted probabilities can be interpreted as the average probability of receiving recommended childbirth care when all participants' time in the IUS is set to a particular value (for example, the average probability of receiving recommended childbirth care if all individual's time in the IUS before childbirth was set at one year).[27,28]

To explore potential heterogeneity in the relationship between adaptation and receipt of recommended childbirth care, stratified regressions were run and interactions on both the multiplicative and additive scales were assessed. Multivariable logistic regressions were stratified by (1) migrant origin, (2) migration companions, (3) migrant type, and (4) migration motivation. To examine interactions on the multiplicative scale, four multivariable logistic regressions were run, each including a different interaction term between time in the IUS and each of the four modifiers listed above. Interactions on the additive scale were investigated by calculating average marginal effects of the relationship between adaption and childbirth services among different levels of stratifying variables. All analyses were conducted in Stata version 16.1 (College Station, TX, USA).

Sensitivity analysis

Regressions with other functional forms of the exposure (amount of time between migration and childbirth) were run and AIC values were obtained and compared. Functional forms examined included the following: continuous (the original analysis), continuous with a natural logarithm transformation, quadratic, spline with a knot at five years between migration and childbirth, quartiles, categorical (<5 years, 5-9.99 years, 10+ years), and binary (<1 year, 1+ years).

As a mothers' experiences with childbirth care are likely correlated, additional sensitivity analyses were conducted in which only a woman's first delivery was included to explore the impact of correlated outcomes. Both unstratified and stratified models were re-run in this sample and predicted probabilities and marginal effects were estimated.

Ethical approval

The African Population and Health Research Center collects and manages NUHDSS data. The Center received ethical approval for NUHDSS from the Kenya Medical Research Institute (KEMRI) and approved the use of NUHDSS for this analysis. The University of Michigan Institutional Review Board provided this analysis an exemption, as only de-identified data were provided for analysis.

Results

The NUHDSS contains information on 19,882 pregnancies resulting in a live birth registered between 2004 and 2018. During data cleaning 4,882 records were removed as they could not be matched to records in other NUHDSS data sets that contained information on confounders. Additional exclusions included: international migrants (57 records), visitors to the IUS (70), non-migrants (2,434), delivered outside of Nairobi (1,012), and missing information on confounders (380) or delivery services (6). The final sample for this study was comprised 11,041 pregnancy records, among 8,943 women.

Most of the women were aged 18-24 years at the time of delivery (45%), Christian (77%), and married (81%) (Table 4.1). A majority of mothers had attended only primary school (57%) and had not worked in the last 30 days (54%). Their families were small (74% had 1-4 household members) but for most women the index childbirth was not their first (70%). Very high levels of recommended childbirth care receipt were observed in these two IUSs, with over 90% of women both delivering at a health facility and having a skilled attendant at birth. Conversely, approximately 6% of women neither delivered in a health facility nor had an SBA at delivery. Only one childbirth occurred with an SBA outside of a health facility and 137 deliveries occurred in which a woman gave birth in a health facility but did not have an SBA present. A dramatic increase in receipt of recommended care in these two IUSs has occurred between 2006 and 2018 (Figure 4.1).

Women lived in the IUS for an average of 3.24 years before delivering the index child (Table 4.2). Over three-quarters of women were first-time migrants to the NUHDSS settlements (78%) and most migrated from rural areas of Kenya (60%). Women often migrated with others in their household (59%) and overwhelmingly stated the most important reason for migrating to the IUS was to be with family and friends (83%).

The crude, unstratified model demonstrated a significant relationship between time in the IUS before delivery and receipt of all recommended childbirth services, with a one-year increase in time between migration and delivery associated with an 8% higher odds of receiving recommended childbirth care (cOR: 1.08, 95% CI: 1.05, 1.11), although this relationship was insignificant when confounders were included (aOR: 1.02, 95% CI: (0.98, 1.06) (Table 4.3). The average marginal effect of time between migration and delivery was 0.0010 (95% CI: -0.0014, 0.0035), meaning a one-year increase in time between migration and childbirth was associated with a 0.001 unit increase in the predicted probability of receiving recommended delivery care, adjusting for confounders. Figure 4.2 demonstrates a trend of increasing predicted probability of receiving recommended childbirth care (calculated from adjusted models) as the number of years between migration and delivery increases but overlapping confidence intervals signify the increase is not statistically significant.

Both multiplicative- and additive-scale interaction models indicated that the association between adaptation and use of childbirth services was not modified by characteristics of the migration experience (Tables 4.3 and 4.4, respectively). Of note, results suggested that the association between adaptation and use of childbirth services was statistically significant for circular migrants who had previous experience living in the settlement; a one-year increase in time between migration and childbirth was associated with a 0.0059-unit (95% CI: 0.00066, 0.011) increase in the predicted probability of receiving recommended delivery care, but this value was not statistically significantly different from the average marginal effect of first-time migrants, indicating there was no statistically significant difference in predicted probability of receiving recommended childbirth care for first-time versus circular migrants.

Sensitivity analyses

The analytic sample decreased to 8,943 when limited to just women's first childbirth. Investigation of the functional form of the time between migration and childbirth indicated that operationalizing the exposure as a categorical variable provides a slightly better fit than a continuous variable (AIC 5154.94 vs. 5156.78, respectively, Table 4.5). However, final conclusions regarding the relationship between migration and use of recommended childbirth care did not change with differing functional forms of the exposure.

Unstratified crude and adjusted analyses produced results almost identical to the original analysis (Table 4.6). Predicted probabilities of receiving recommended childbirth care were similar to those in the original analysis, though slightly lower (Figure 4.3). Stratified models similarly demonstrated results comparable to the original analysis. Interactions on both the multiplicative (Table 4.6) and additive (Table 4.7) scales provided results largely similar to the original analysis. The only exception was the circular migrant result, which was not statistically significant when only examining firstborn children.

Discussion

Internal migration has become increasingly common globally – including in sub-Saharan Africa – contributing to rapid urbanization and the proliferation of informal urban settlements (IUSs).[12] Migration has been linked to the uptake of maternal and child healthcare services in low- and middle-income countries, including pregnancy and delivery care[14,29,30] and childhood vaccination.[31–33] Traditionally, migration has been posited to decrease use of healthcare services, at least initially, as the act of migration may disrupt important economic and social resources. It has been hypothesized that as women spend more time in and adapt to their community the utilization of healthcare services would increase, but current research has yielded mixed results, finding null,[14,29,30] positive[33] and negative[14] associations between the amount of time a woman has spent in a destination community and the use of maternal and child healthcare services. The relationship between adaptation and healthcare use is complex and these mixed findings demonstrate the importance of considering the context in which migration occurs. Additionally, there is a lack of consistency in studies of adaptation and healthcare use, with different analyses using varied definitions of recent and settled migrants, which complicates comparison of existing studies. The present analysis found that, within two IUSs of Nairobi, adaptation is not associated with a significant increase in the uptake of recommended childbirth care and this relationship does not appear to be modified by characteristics of a woman's migration experience.

A remarkably high proportion (93%) of women in the NUHDSS delivered in a health facility with a skilled birth attendant (SBA) present. When examined by year, the probability of receiving this care increased substantially from approximately 67% in 2006 to nearly 99% in 2018. Similarly high levels of facility delivery in these IUSs have been reported previously.[34] It should be noted that, though not an exceptionally high number, almost 1% of deliveries in the

NUHDSS occurred while women were en route to a health facility. This suggests women recognized that they should deliver at a health facility but were unable to make it to a facility in time. Though data was not available regarding why these women were not already at facilities at the time of childbirth, this problem could likely be remedied by interventions such as educating women on the signs of imminent delivery, helping women develop a birth plan, encouraging them not to delay seeking delivery care, and ensuring they have the ability to quickly travel to a facility if precipitous labor begins.[35,36]

This impressively high uptake of delivery services is likely due to aggressive efforts on the part of the Kenyan Ministry of Health and others to remove financial barriers to birthing in health facilities. In 2006 Kenya introduced a voucher program in several areas of Kenya, including the two NUHDSS settlements, that aimed to ensure poor women with few financial resources to cover the cost of pregnancy and delivery care were able to take advantage of these resources.[23,24,37] This Vouchers for Health program, which ran until late 2016, subsidized the cost of pregnancy and childbirth services for eligible poor women by providing low-cost vouchers that enabled them to receive four antenatal care appointments, childbirth in a health facility, and postnatal care at select public and private health facilities and referral hospitals.[23,24,37] Women only paid 200 Ksh (~US$2.50) to receive the voucher and health facilities were reimbursed for care by a fund established by the Kenya Ministry of Planning and the German Development Bank.[23,24,37] As many individuals in the NUHDSS settlements face chronic poverty, many women in these IUSs were eligible for these vouchers, resulting in a substantial increase in facility deliveries while the program was being piloted.[23,24,37] Subsequently, a presidential directive was enacted on June 1, 2013 that removed maternal delivery fees at public health facilities to promote greater reductions in maternal mortality throughout the country.[22] The maternity service policy directed public health facilities to provide childbirth services to all women at no-charge, with the health facilities' costs to be paid by the national Ministry of Health.[22,24] Though the implementation of this policy has produced challenges with medical supplies stock-outs and staffing issues, this policy reportedly caused an immediate and dramatic increase in the number of facility deliveries seen in Kenya by removing financial barriers for all women, not only the most impoverished.[22,24,25,38] This focus on increasing access to delivery care throughout Kenya appears to have improved equity in childbirth care access for migrants. Supplemental analysis demonstrates that although these interventions did not significantly change probability that the most established migrants (i.e., those who lived in the IUS for 15.5 years before childbirth) would deliver in a health facility with an SBA, among the most recent migrants who lived in the IUS for only 6 months before childbirth, the probability of receiving recommended childbirth care increased with the implementation of the voucher program and again with the introduction of the free maternity care policy (Table 4.8, Figure 4.4).

Adaptation does not appear to influence whether a woman gives birth in a health facility with an SBA in this setting. Previous literature regarding the relationship between adaptation and maternal and child healthcare use is mixed. A multi-country analysis of young female migrants from 27 sub-Saharan African countries explored the influence of migrant adaptation on skilled birth attendance.[14] It reported that the probability of having an SBA at childbirth was significantly higher for recent urban-urban migrants (those who moved between urban areas within three years before childbirth) compared to urban non-migrants but this advantage disappeared among settled urban-urban migrants, suggesting a negative impact of adaptation.[14] Conversely, while recent rural-urban migrants had a slightly lower probability of having an SBA at childbirth there were no statistically significant differences in skilled birth attendance between these recent migrants and settled rural-urban migrants or urban non-migrants.[14] If these nationally-representative trends hold for IUSs, it is possible that the null – but positive – association between adaptation and receipt of recommended childbirth care found in the present study may be largely influenced by the high proportion rural-origin migrants living in NUHDSS. Analyses of rural-urban migrants living in India[30] and Bangladesh[29] reported that while recent migrants had lower utilization of a multitude of maternal healthcare services, in final adjusted models there was no significant difference in facility delivery or skilled birth attendance when comparing recent and settled migrants. The present analysis' null results are puzzling given adaptation is positively and significantly associated with receipt of prenatal care[30] and child immunization services[33] in India and Benin. Perhaps the null findings from this analysis demonstrate that women view receipt of appropriate childbirth care as more important and urgent than prenatal care and immunization services, both of which can be delayed if need be, while childbirth cannot. This increased urgency and importance may prompt women to prioritize finding a facility for childbirth even if they have only recently migrated to the area.

Though the influence of many migration characteristics has been underexplored in the literature with regards to use of childbirth care, it was hypothesized that a migrant's origin, migration companions, whether she was a circular or first time migrant, and her primary reason for migrating would each influence the relationship between adaptation and uptake of childbirth care. Whether a woman migrated from a rural area or a different urban area of Kenya is thought to influence her experience adapting to a new community, as transportation and healthcare access are substantially different in rural and urban areas. The study of 27 countries in sub-Saharan Africa found evidence of differential relationships between adaptation and use of an SBA for urban-urban and rural-urban migrants.[14] For similar reasons, previous experience living in the destination community would also likely impact adaptation, as the ability to draw on local social ties and knowledge of the area likely shortening the amount of time required for a woman to refamiliarize herself with the community. Results of this analysis did not find either migrant origin or whether a woman had previously lived in the NUHDSS modified the relationship between adaptation and use of childbirth services. Whether a woman migrated with companions was also hypothesized to influence use of childbirth services, as women migrating alone may not have the social network available to help them adapt quickly. This analysis did not find modification by migration companions, but qualitative work from Ethiopia suggests that women who migrate alone are actually more likely to make use of facility delivery and skilled birth attendants, as they do not have a support system in their new community to assist them in a home birth.[39] Conversely, women who migrated into the IUS in order to reunite with family and friends likely have a stronger social network in the destination community than women who migrated for other reasons (such as a search for economic opportunities). Having an established social network in the new community could make it easier for women to locate and access health facilities, but it could also enable women to give birth at home if they have family members or friends available to assist in a home birth. This analysis did not demonstrate a significant difference in the relationship between adaptation and delivery service use by reason for migration, perhaps due to the multitude of ways in which migration motivations can influence healthcare use. Future qualitative work in the NUHDSS settlements should explore the adaptation experiences of migrant women to determine if other characteristics of the migration process influence delivery care.

Limitations and strengths

This analysis has important limitations. Though analyses adjusted for key confounders, unmeasured confounding is likely present. Information on prenatal and postnatal care, which would have provided a more complete understanding of the care women receive before, during, and immediately after childbirth, was not available. While information regarding place of delivery and birth attendance was available, these measures were simplistic, as they lack any information on the quality of the facility services. Report of who attended the childbirth is similarly subject to quality issues. Women may not remember who was present or may not have known the qualifications of her birth attendant. An additional limitation is related to the women excluded from the analysis. This analysis only captured the childbirth experiences of women who gave birth in the IUSs and therefore only represents the relationship between migration and use of delivery services for women who remain in the IUS to give birth and should not be generalized to all migrant women. Women who returned to their hometowns for childbirth may be more likely to utilize traditional birthing practices and less likely to give birth in a health facility with an SBA. Additionally, there is a risk of potential selection bias due to exclusion of women missing information on confounders or birthing data. Finally, due to the very high level of uptake of birthing services there may have been a lack of sufficient heterogeneity in the outcome to detect a difference in use of birthing services among women with varied time between migration and childbirth.

This analysis also had notable strengths. Precise temporal ordering of migration and childbirth was possible due to the longitudinal nature of the NUHDSS. Additionally, the availability of specific migration-related information, including migration timing, origin, motivation, and with whom women migrated, allowed for a deeper and more precise analysis of the ways in which migrant adaptation is related to use of recommended childbirth services than is possible through the use of most publicly available data sources. Substantively, this analysis is the first to provide an in-depth examination of the relationship between migrant adaptation and the use of recommended childbirth services, and whether that relationship varies by important characteristics of the migration experience.

Conclusions

This analysis found very high use of recommended childbirth services in two IUSs in Nairobi, Kenya, likely the result of a history of voucher programs and national policies that have made safe childbirth affordable to women. Migrant adaptation does not appear to be associated with the use of childbirth services in this setting; giving birth in a health facility with an SBA was widespread for women who migrated to the IUS shortly before delivery and remained high as women spent more time in and adapted to their new environment before becoming pregnant and delivering. It remains unclear which factors are driving the approximately 10% of women who are not receiving recommended care. Future research should seek to identify groups of women who do not receive this care in an effort to ensure universal uptake of these simple services that make childbirth as safe as possible for women and their children.

Table 4.1 Descriptive statistics of women's sociodemographic characteristics, NUHDSS 2004-2018

Characteristics	Frequency (%)
Received recommended childbirth services	10, 213 (92.50%)
Gave birth in a health facility without skilled birth attendant present at birth	137 (1.24%)
Did not give birth in a health facility but had a skilled birth attendant present at birth	1 (<0.01%)
Did not give birth in a health facility and did not have skilled birth attendant present at birth	690 (6.25%)
Age at delivery of index child (years)	
Under 18	440 (3.99%)
18-24	4,983 (45.13%)
25-34	4,954 (44.87%)
35 and older	664 (6.01%)
Ethnicity	
Kikuyu	2,743 (24.84%)
Kamba	2,834 (25.67%)
Luhya	2,098 (19.00%)
Luo	1,593 (6.45%)
Kisii	712 (6.45%)
Other	1,061 (9.61%)
Religion	
Christian	8,448 (76.51%)
Muslim	600 (5.43%)
Other religion or no religion	1,993 (18.05%)
Education (highest level ever attended)	
Never attended school	376 (3.41%)
Primary school	6,345 (57.47%)
Secondary school	4,066 (36.83%)
Higher than secondary school	254 (2.30%)
Working status (last 30 days)	
Working	5,130 (46.46%)
Not working	5,911 (53.54%)
Marital status	
Currently married	8,990 (81.42%)
Not married	2,051 (18.58%)
Parity	
First child	3,353 (30.37%)
Two or more children	7,688 (69.63%)
Household size	
1-4 members	8,222 (74.47%)
5-7 members	2,400 (21.74%)
8 or more members	419 (3.79%)
Household wealth	
Poorest	1,797 (16.28%)
Poorer	2,339 (21.18%)
Middle	2,356 (21.34%)
Richer	2,419 (21.91%
Richest	2,130 (19.29%)
Settlement	
Korogocho	4,380 (39.67%)
Viwandani	6,661 (60.33%)
Maternity care policy environment when the childbirth occurred	
Pre-voucher and voucher rollout (2004-2009)	1,479 (13.40%)
Full voucher implementation (Jan. 1, 2010 - May 31, 2013)	4,162 (37.70%)
Voucher and free maternity care policy (Jun. 1, 2013 - Dec. 31, 2016)	3,763 (34.08%)
Free maternity care policy only (2017-2018)	1,637 (14.83%)

Table 4.2 Descriptive statistics of women's migration characteristics, NUHDSS 2004-2018

Characteristics	**Frequency (%)**
Number of years between in-migration and childbirth[1]	3.24 (2.89)
Migrant type	
First-time migrant to NUHDSS	8,136 (78.13%)
Circular migrant	2,277 (21.87%)
Migrant origin	
Rural	6,564 (60.14%)
Urban	4,350 (39.86%)
Type of residence from which migrant moved	
Nairobi slum	1,462 (13.40%)
Nairobi non-slum	2,426 (22.23%)
Other urban Kenya	462 (4.23%)
Rural Kenya	6,564 (60.14%)
Most important reason for migrating to NUHDSS DSA	
To be with family/friends	9,059 (82.78%)
Living conditions	1,362 (12.45%)
Good job prospects	404 (3.69%)
Other reason	118 (1.08%)
Migration companions	
Alone	4,538 (41.28%)
Part or all of household or other individual	6,455 (58.72%)

[1] Reported as mean (standard deviation)

Table 4.3 Results of logistic regressions examining the relationship between time spent in the informal urban settlements and use of recommended childbirth services, in the entire sample and stratified by select variables

	cOR[1]	**95% CI**	**p-value**	**aOR[2]**	**95% CI**	**p-value**
Full sample (n=11,041)						
Years between in-migration and childbirth[3]	**1.08**	**(1.05, 1.11)**	**<0.001**	1.02	(0.98, 1.06)	0.40
Stratified by origin (n=10,914)						
Multiplicative scale interaction term (years between in-migration and childbirth x origin)[4]	---	---	---	0.99	(0.92, 1.06)	0.68
Rural origin (n=6,564)						
Years between in-migration and childbirth	**1.08**	**(1.04, 1.12)**	**<0.001**	1.01	(0.96, 1.06)	0.72
Urban origin (n=4,350)						
Years between in-migration and childbirth	**1.06**	**(1.01, 1.11)**	**0.02**	1.02	(0.95, 1.09)	0.58
Stratified by with whom woman in-migrated (10,993)						
Multiplicative scale interaction term (years between in-migration and childbirth x with whom woman in-migrated)[5]	---	---	---	1.03	(0.96, 1.10)	0.41
In-migrated alone (n=4,538)						
Years between in-migration and childbirth	**1.07**	**(1.02, 1.12)**	**0.003**	1.04	(0.97, 1.11)	0.27
In-migrated with others (n=6,455)						
Years between in-migration and childbirth	**1.09**	**(1.05, 1.13)**	**<0.001**	1.01	(0.96, 1.06)	0.72
Stratified by migrant type (n=10,413)						
Multiplicative scale interaction term (years between in-migration and childbirth x migrant type)[6]	---	---	---	**1.10**	**(1.00, 1.20)**	**0.05**
First time migrant to NUHDSS (n=8,136)						
Years between in-migration and childbirth	**1.09**	**(1.05, 1.14)**	**<0.001**	1.00	(0.95, 1.06)	0.87
Circular migrant (n=2,277)						
Years between in-migration and childbirth	**1.18**	**(1.10, 1.26)**	**<0.001**	1.07	(0.99, 1.17)	0.08
Stratified by reason for in-migrating (n=10,943)						
Multiplicative scale interaction term (years between in-migration and childbirth x reason for in-migrating)[7]						
Living conditions (compared to in order to be with family and friends)	---	---	---	0.98	(0.87, 1.11)	0.78
Good job prospects (compared to in order to be with family and friends)	---	---	---	1.05	(0.88, 1.25)	0.61
Other reason (compared to in order to be with family and friends)	---	---	---	0.80	(0.64, 1.01)	0.06
To be with family/friends (n=9,059)						
Years between in-migration and childbirth	**1.08**	**(1.05, 1.11)**	**<0.001**	1.01	(0.97, 1.06)	0.52
Living conditions (n=1,362)						
Years between in-migration and childbirth	1.11	(0.99, 1.24)	0.07	1.04	(0.92, 1.18)	0.56
Good job prospects (n=404, 362)[8]						
Years between in-migration and childbirth	1.10	(0.96, 1.25)	0.16	1.17	(0.93, 1.48)	0.17
Other reason (n=118, 58)[9]						
Years between in-migration and childbirth	0.90	(0.73, 1.11)	0.33	---	---	---

Bold indicates statistical significance at the 0.05 level

[1] Crude odds ratio

[2] Adjusted odds ratio

[3] Adjusted for woman's age, ethnicity, religion, current marital status, education level, working status, household size, parity, household wealth, slum, and maternity care policy environment when the childbirth occurred

[4] Adjusted for all covariates in (3) as well as migrant origin and an exposure x migrant origin interaction term

[5] Adjusted for all covariates in (3) as well as with whom woman migrated and an exposure x with whom woman migrated interaction term

[6] Adjusted for all covariates in (3) as well as migrant type and an exposure x migrant type interaction term

[7] Adjusted for all covariates in (3) as well as reason for in-migrating and an exposure x reason for in-migrating interaction term

[8] Sample size decreased in adjusted model because some levels of maternal age, ethnicity, religion, and education were dropped due to perfectly predicting success

[9] Sample size decreased in adjusted model because some levels of maternal age, ethnicity, education, household size, and religion were dropped due to perfectly predicting success. Sample size too small to compute estimates.

Table 4.4 Average marginal effect of adaptation, in the entire sample and stratified by select variables

	Average marginal effect of adaptation	**95% CI**	**p-value**
Full sample (n=11,041)			
Unstratified	0.0010	(-0.0014, 0.0035)	0.40
Stratified by origin (n=10,914)			
Rural origin	0.0012	(-0.0018, 0.0043)	0.43
Urban origin	0.00020	(-0.0033, 0.0037)	0.91
Stratified by migration companions (10,993)			
Migrated alone	0.0022	(-0.0013, 0.0058)	0.22
Migrated with others	0.00045	(-0.0025, 0.0034)	0.77
Stratified by migrant type (n=10,413)			
First time migrant to NUHDSS	-0.000053	(-0.0033, 0.0032)	0.97
Circular migrant	**0.0059**	**(0.00066, 0.011)**	**0.03**
Stratified by motivation for migrating (n=10,943)			
To be with family/friends	0.0013	(-0.0012, 0.0039)	0.31
Living conditions	0.00023	(-0.0071, 0.0075)	0.95
Good job prospects	0.0050	(-0.0079, 0.017)	0.47
Other reason	-0.012	(-0.028, 0.0028)	0.11

Table 4.5 Results of examination of functional form of the number of years between migration and childbirth

Functional form	**AIC**	aOR[1]	95% CI	p-value
Continuous	5156.78	1.02	(0.98, 1.06)	0.40
Continuous, natural logarithm-transformed	5155.18	1.06	(0.98, 1.15)	0.13
Quadratic	5157.60	1.00	(0.99, 1.00)	0.86
Continuous with spline, knot at time between in-migration and childbirth = 5 years	5155.82	1.06	(0.99, 1.11)	0.07
Quartiles (all compared to quartile 1, indicating the least amount of time between migration and childbirth)	5155.85			
Quartile 2		0.87	(0.71, 1.08)	0.21
Quartile 3		1.12	(0.89, 1.41)	0.31
Quartile 4 - Most time between migration and childbirth		1.02	(0.78, 1.32)	0.89
Categorical (compared to less than 5 years between migration and childbirth)	5154.94			
5 - 9.99 years between migration and childbirth		1.13	(0.90, 1.42)	0.31
10 or more years between migration and childbirth		0.61	(0.36, 1.04)	0.07
Binary (<1 year compared to >=1 year)	5157.61	1.02	(0.84, 1.23)	0.86

[1] Adjusted for woman's age, ethnicity, religion, current marital status, education level, working status, household size, parity, household wealth, slum, and maternity care policy

Table 4.6 Results of logistic regressions examining the relationship between time spent in the informal urban settlements and use of recommended childbirth services, in the entire sample and stratified by select variables, among women's first childbirth

	cOR[1]	95% CI	p-value	aOR[2]	95% CI	p-value
Full sample (n=8,943)						
Years between in-migration and childbirth[3]	**1.06**	**(1.02, 1.09)**	**0.001**	1.02	(0.98, 1.06)	0.34
Stratified by origin (n=8,843)						
Multiplicative scale interaction term (years between in-migration and childbirth x origin)[4]	---	---	---	1.24	(0.97, 1.07)	0.42
Rural origin (n=5,317)						
Years between in-migration and childbirth	**1.06**	**(1.02,1.11)**	**0.004**	1.02	(0.96, 1.07)	0.56
Urban origin (n=3,526)						
Years between in-migration and delivery	1.04	(0.98, 1.10)	0.16	1.01	(0.94, 1.09)	0.73
Stratified by with whom woman in-migrated (n=8,904)						
Multiplicative scale interaction term (years between in-migration and childbirth x with whom woman in-migrated)[5]	---	---	---	1.29	(1.00, 1.67)	0.05
In-migrated alone (n=3,683)						
Years between in-migration and childbirth	1.04	(0.98, 1.10)	0.21	1.02	(0.95, 1.11)	0.52
In-migrated with others (n=5,221)						
Years between in-migration and childbirth	**1.09**	**(1.04, 1.13)**	**<0.001**	1.02	(0.97, 1.07)	0.39
Stratified by migrant type (n=8,460)						
Multiplicative scale interaction term (years between in-migration and childbirth x migrant type)[6]	---	---	---	0.76	(0.56, 1.03)	0.08
First time migrant to NUHDSS (n=6,729)						
Years between in-migration and childbirth	**1.10**	**(1.05, 1.16)**	**<0.001**	1.03	(0.97, 1.10)	0.34
Circular migrant (n=1,731)						
Years between in-migration and childbirth	**1.15**	**(1.06, 1.24)**	**0.001**	1.06	(0.97, 1.17)	0.19
Stratified by reason for in-migrating (n=8,866)						
Multiplicative scale interaction term (years between in-migration and childbirth x reason for in-migrating)[7]						
Living conditions (compared to in order to be with family and friends)	---	---	---	1.00	(0.65, 1.52)	0.98
Good job prospects (compared to in order to be with family and friends)	---	---	---	0.70	(0.35, 1.37)	0.30
Other reason (compared to in order to be with family and friends)	---	---	---	1.94	(0.55, 6.80)	0.30
To be with family/friends (n=7,303)						
Years between in-migration and childbirth	**1.06**	**(1.02, 1.10)**	**0.003**	1.01	(0.97, 1.06)	0.61
Living conditions (n=1,132)						
Years between in-migration and childbirth	**1.15**	**(1.01, 1.31)**	**0.04**	1.06	(0.92, 1.23)	0.40
Good job prospects (n=336, 302)[8]						
Years between in-migration and childbirth	1.07	(0.92, 1.23)	0.39	1.18	(0.97, 1.45)	0.10
Other reason (n=95, 41)[9]						
Years between in-migration and childbirth	0.94	(0.73, 1.20)	0.61	---	---	---

Bold indicates statistical significance at the 0.05 level

[1] Crude odds ratio

[2] Adjusted odds ratio

[3] Adjusted for woman's age, ethnicity, religion, current marital status, education level, working status, household size, household wealth, slum, and maternity care policy environment when the childbirth occurred

[4] Adjusted for all covariates in (3) as well as migrant origin and an exposure x migrant origin interaction term

[5] Adjusted for all covariates in (3) as well as with whom woman migrated and an exposure x with whom woman migrated interaction term

[6] Adjusted for all covariates in (3) as well as migrant type and an exposure x migrant type interaction term

[7] Adjusted for all covariates in (3) as well as reason for in-migrating and an exposure x reason for in-migrating interaction term
[8] Sample size decreased in adjusted model because some levels of ethnicity, education, household size, and maternity care policy environment were dropped due to perfectly predicting success
[9] Sample size decreased in adjusted model because some levels of ethnicity, education, household size, and maternity care policy environment were dropped due to perfectly predicting success. Sample size too small to compute estimates.

Table 4.7 Average marginal effect of adaptation, in the entire sample and stratified by select variables, among women's first childbirth

	Average marginal effect of adaptation	95% CI	p-value
Full sample (n=8,943)			
Unstratified	0.0013	(-0.0014, 0.0041)	0.34
Stratified by origin (n=8,843)			
Rural origin	0.0023	(-0.0013, 0.0059)	0.21
Urban origin	0.00	(-0.0028, 0.0055)	0.53
Stratified by migration companions (n=8,904)			
Migrated alone	0.0028	(-0.0018, 0.0074)	0.24
Migrated with others	0.0020	(-0.0015, 0.0054)	0.26
Stratified by migrant type (n=8,460)			
First time migrant to NUHDSS	0.0028	(-0.0012, 0.0067)	0.18
Circular migrant	0.0056	(-0.00074, 0.012)	0.08
Stratified by motivation for migrating (n=8,866)			
To be with family/friends	0.0021	(-0.0011, 0.0052)	0.20
Living conditions	0.0042	(-0.0045, 0.013)	0.34
Good job prospects	0.0070	(-0.0068, 0.021)	0.32
Other reason	-0.0068	(-0.023, 0.0090)	0.40

Table 4.8 Results of logistic regressions examining the relationship between time spent in the informal urban settlements and use of recommended childbirth services stratified by maternity care policy environment when childbirth occurred

	cOR[1]	95% CI	p-value	aOR[2]	95% CI	p-value
Full sample (n=11,041)						
Multiplicative scale interaction term (years between in-migration and childbirth x maternity care policy environment when the childbirth occurred)[3]						
Full voucher implementation (compared to pre-voucher and rollout period)	---	---	---	0.99	(0.90, 1.08)	0.81
Voucher and free maternity care policy (compared to pre-voucher and rollout period)	---	---	---	**0.89**	**(0.81, 0.99)**	**0.03**
Free maternity care policy alone (compared to pre-voucher and rollout period)	---	---	---	1.00	(0.89, 1.13)	0.99
Pre-voucher and voucher rollout (2004-2009) (n=1,479)[4]						
Years between in-migration and childbirth	1.02	(0.95, 1.10)	0.51	1.02	(0.94, 1.11)	0.70
Full voucher implementation (Jan. 1, 2010 - May 31, 2013) (n=4,162)[4]						
Years between in-migration and childbirth	1.03	(0.98, 1.08)	0.31	1.04	(0.99, 1.11)	0.14
Voucher and free maternity care policy (Jun. 1, 2013 - Dec. 31, 2016) (n=3,763)[4]						
Years between in-migration and childbirth	**0.93**	**(0.87, 0.99)**	**0.02**	0.97	(0.91, 1.04)	0.41
Free maternity care policy only (2017-2018) (n=1,637)[4]						
Years between in-migration and childbirth	1.04	(0.95, 1.14)	0.40	1.12	(1.00, 1.26)	0.06
Among first childbirth (n=8,943)						
Multiplicative scale interaction term (years between in-migration and childbirth x maternity care policy environment when the childbirth occurred)[5]						
Full voucher implementation (compared to pre-voucher and rollout period)	---	---	---	**2.14**	**(1.61, 2.84)**	**<0.001**
Voucher and free maternity care policy (compared to pre-voucher and rollout period)	---	---	---	**13.75**	**(8.92, 21.18)**	**<0.001**
Free maternity care policy alone (compared to pre-voucher and rollout period)	---	---	---	**8.49**	**(4.27, 16.87)**	**<0.001**
Pre-voucher and voucher rollout (2004-2009) (n=1,451)[6]						
Years between in-migration and childbirth	1.03	(0.96, 1.11)	0.40	1.01	(0.93, 1.10)	0.80
Full voucher implementation (Jan. 1, 2010 - May 31, 2013) (n=3,623)[6]						
Years between in-migration and childbirth	1.03	(0.98, 1.09)	0.26	1.03	(0.97, 1.10)	0.27
Voucher and free maternity care policy (Jun. 1, 2013 - Dec. 31, 2016) (n=2,806)[6]						
Years between in-migration and childbirth	**0.92**	**(0.86, 1.00)**	**0.04**	0.96	(0.88, 1.05)	0.40
Free maternity care policy only (2017-2018) (n=1,063, 821)[6,7]						
Years between in-migration and childbirth	1.24	(0.99, 1.55)	0.06	**1.35**	**(1.01, 1.80)**	**0.04**

[1] Crude odds ratio

[2] Adjusted odds ratio

[3] Adjusted for woman's age, ethnicity, religion, current marital status, education level, working status, household size, parity, household wealth, slum, maternity care policy environment when the childbirth occurred, and an exposure x maternity care policy environment when the childbirth occurred interaction term

[4] Adjusted for all covariates in (3) except maternity care policy environment when the childbirth occurred and interaction term

[5] Adjusted for all covariates in (3) except parity
[6] Adjusted for all covariates in (5) except maternity care policy environment when the childbirth occurred and interaction term
[7] Sample size decreased in adjusted model because some levels of maternal age, ethnicity, education were dropped due to perfectly predicting success

Figure 4.1 Proportion of women receiving recommended childbirth care by number of years between migration and childbirth

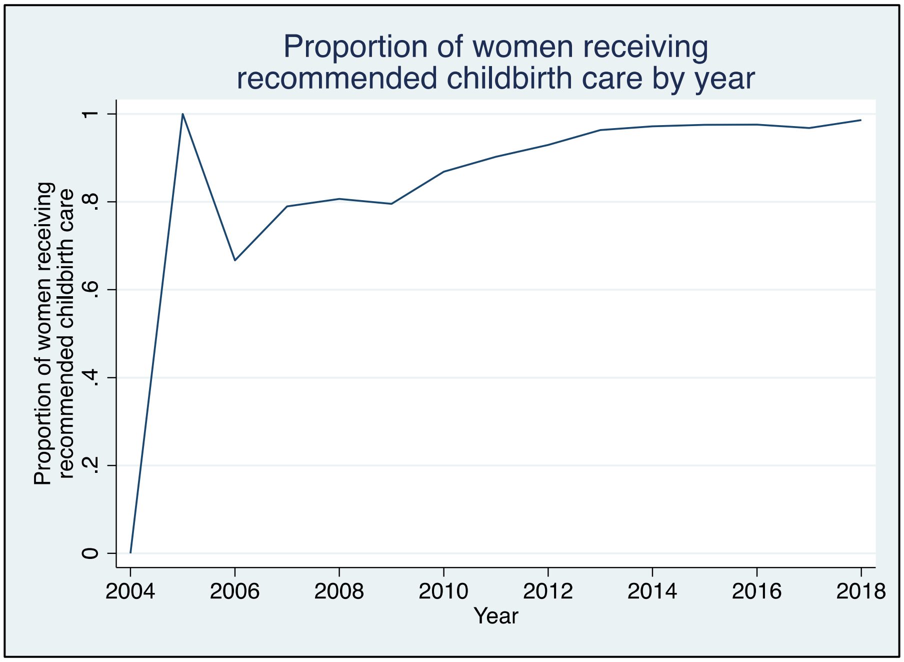


Figure 4.2 Adjusted predicted probabilities of receiving recommended childbirth care by number of years between in-migration and childbirth

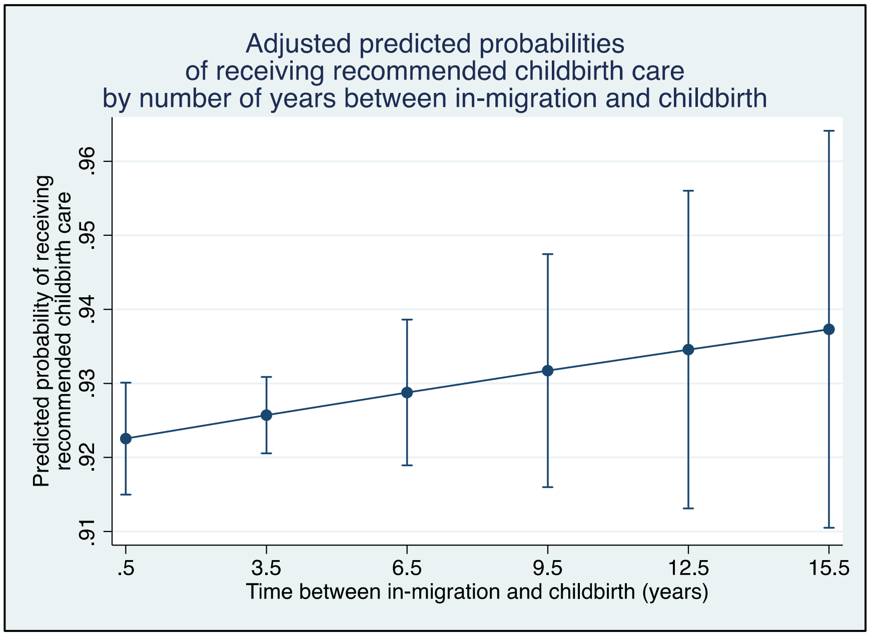


Figure 4.3 Adjusted predicted probabilities of receiving recommended childbirth care by number of years between in-migration and childbirth, among women's first childbirth

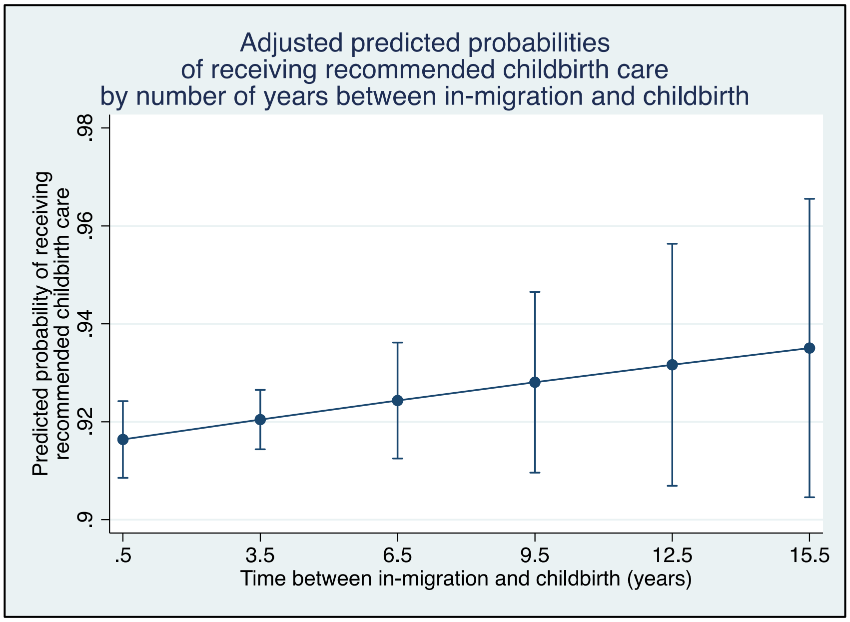
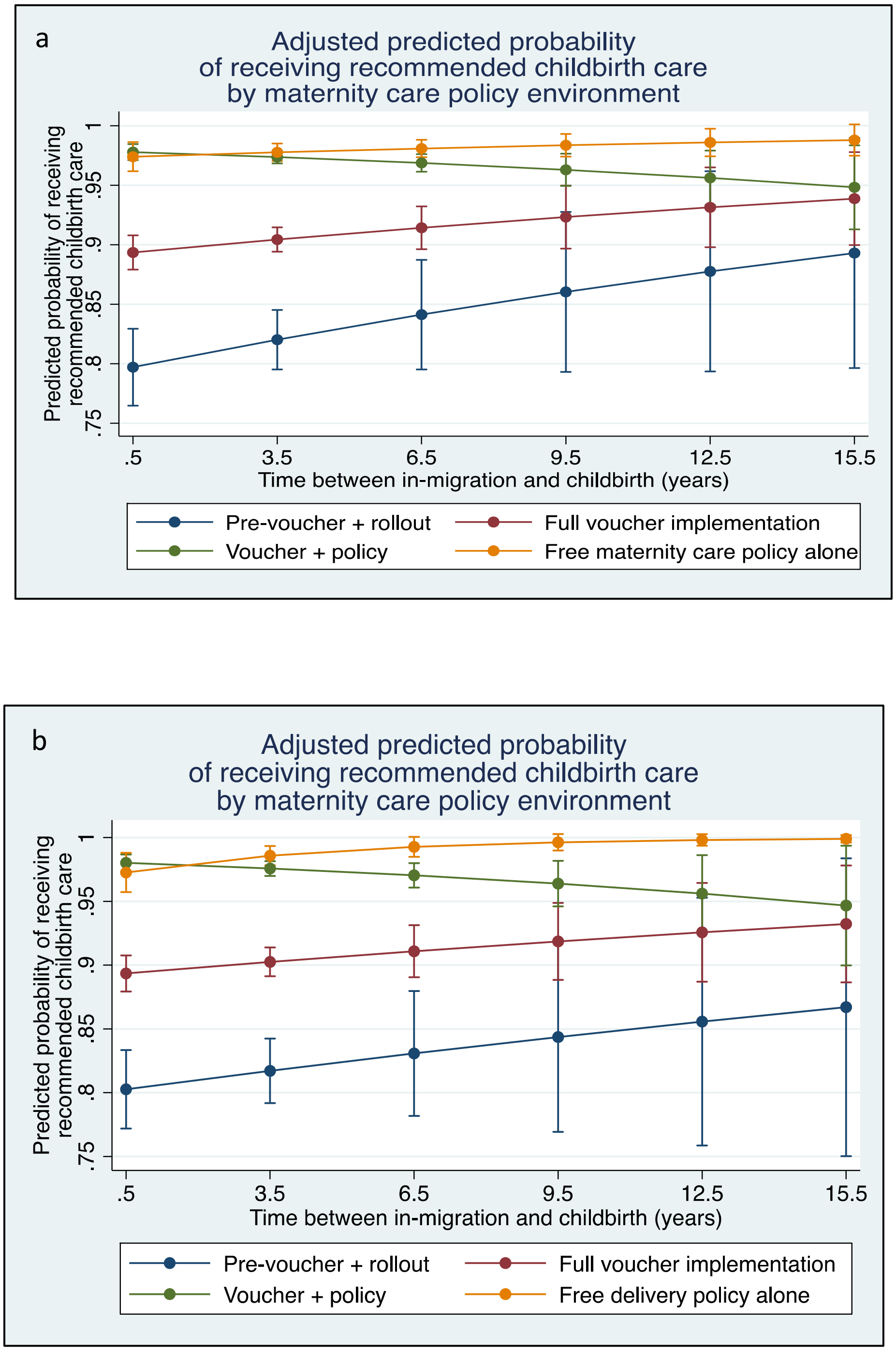


Figure 4.4 Adjusted predicted probability of receiving recommended childbirth care by the number of years between in-migration and childbirth stratified by maternity care policy environment when the childbirth occurred, (a) among full sample and (b) among first birth



References

1. World Health Organization. Maternal Mortality. https://www.who.int/news-room/fact-sheets/detail/maternal-mortality. Published 2018. Accessed February 22, 2021.
2. United Nations. Goal 3 Targets and Indicators. https://sdgs.un.org/goals/goal3. Published 2020. Accessed December 27, 2020.
3. The United Nations Children's Fund (UNICEF). Delivery care. https://data.unicef.org/topic/maternal-health/delivery-care/. Published 2020. Accessed February 22, 2021.
4. WHO, UNFPA, UNICEF, et al. Definition of skilled health personnel providing care during birth: 2018 joint statement by WHO, UNFPA, UNICEF, ICM, ICN, FIGO, and IPA.
5. Central Intelligence Agency. CIA World Factbook | Kenya. Central Intelligence Agency Library. https://www.cia.gov/the-world-factbook/countries/kenya. Published 2020. Accessed March 13, 2021.
6. Shapshak T. Africa's Booming Tech Hubs Are "Backbone of Tech Ecosystem" Having Grown 40% This Year. Forbes. https://www.forbes.com/sites/tobyshapshak/2019/07/11/africas-booming-tech-hubs-are-backbone-of-tech-ecosystem-having-grown-40-this-year/#2bb1d8dd24c2. Published 2019. Accessed October 26, 2020.
7. Copley A. Africa in the News: Kenya Becomes a Middle-Income Country; Mo Ibrahim Index Released; South Sudan Peace Talks Yield Promise. The Brookings Institution. https://www.brookings.edu/blog/africa-in-focus/2014/10/03/africa-in-the-news-kenya-becomes-a-middle-income-country-mo-ibrahim-index-released-south-sudan-peace-talks-yield-promise/. Published 2014. Accessed October 26, 2020.
8. United Nations Development Programme (UNDP). *Human Development Report 2020, Briefing Note - Kenya*.; 2020. http://hdr.undp.org/sites/all/themes/hdr_theme/country-notes/KEN.pdf.
9. The World Bank. Maternal mortality ratio (modeled estimate, per 100,000 live births) - Kenya, Sub-Saharan Africa.
10. The World Bank. Fertility rate, total (births per woman) - Kenya.
11. The United Nations Children's Fund (UNICEF), World Health Organization (WHO). UNICEF Data Warehouse - Cross-sector indicators.
12. United Nations Human Settlements Programme (UN-Habitat). *World Cities Report 2020: Unpacking the Value of Sustainable Urbanization*. Nairoib, Kenya; 2020. doi:10.18356/c41ab67e-en
13. African Population and Health Research Center (APHRC). *Population and Health Dynamics in Nairobi's Informal Settlements: Report of the Nairobi Cross-Sectional Slums Survey (NCSS) 2012*.; 2014.

14. Cotton C. Migration and young women's access to maternal healthcare in sub-Saharan Africa. *Heal Place*. 2019;55(January):136-144. doi:10.1016/j.healthplace.2018.12.006

15. Clark S, Madhavan S, Kabiru C. Kin support and child health: Investigating two approaches in an African slum. *Soc Sci Res*. 2018;76(August):105-119. doi:10.1016/j.ssresearch.2018.08.001

16. Madhavan S, Clark S, Araos M, Beguy D. Distance or location? How the geographic distribution of kin networks shapes support given to single mothers in urban Kenya. *Geogr J*. 2018;184(1):75-88. doi:10.1111/geoj.12230

17. Lindstrom DP, Muñoz-Franco E. Migration and maternal health services utilization in rural Guatemala. *Soc Sci Med*. 2006;63(3):706-721. doi:10.1016/j.socscimed.2006.02.007

18. Wamukoya M, Kadengye DT, Iddi S, Chikozho C. The Nairobi Urban Health and Demographic Surveillance of slum dwellers, 2002–2019: Value, processes, and challenges. *Glob Epidemiol*. 2020;2:100024. doi:10.1016/j.gloepi.2020.100024

19. Kenya National Bureau of Statistics (KNBS); ORC Macro. Kenya Demographic and Health Survey 2008-09. 2010:1-314.

20. Beguy D, Elung'ata P, Mberu B, et al. Health & Demographic Surveillance System Profile: The Nairobi Urban Health and Demographic Surveillance System (NUHDSS). *Int J Epidemiol*. 2015;44(2):462-471. doi:10.1093/ije/dyu251

21. Williams R. Marginal effects for continuous variables. https://www3.nd.edu/~rwilliam/xsoc73994/Margins02.pdf. Published 2021. Accessed March 31, 2021.

22. Ministry of Health Kenya. *Implementing Free Maternal Health Care in Kenya-Challenges, Strategies and Recommendations*.; 2013.

23. Janisch CP, Albrecht M, Wolfschuetz A, Kundu F, Klein S. Vouchers for health: A demand side output-based aid approach to reproductive health services in Kenya. *Glob Public Health*. 2010;5(6):578-594. doi:10.1080/17441690903436573

24. Dennis ML, Abuya T, Campbell OMR, et al. Evaluating the impact of a maternal health voucher programme on service use before and after the introduction of free maternity services in Kenya: a quasi-experimental study. *BMJ Glob Heal*. 2018;3(2):1-11. doi:10.1136/bmjgh-2018-000726

25. Lang'At E, Mwanri L, Temmerman M. Effects of implementing free maternity service policy in Kenya: An interrupted time series analysis. *BMC Health Serv Res*. 2019;19(1):1-10. doi:10.1186/s12913-019-4462-x

26. StataCorp. *Vce_option*. https://www.stata.com/manuals/rvce_option.pdf#rvce_option.

27. Williams R. Using the margins command to estimate and interpret adjusted predictions and marginal effects. *Stata J*. 2012;12(2):308-331. doi:10.1177/1536867x1201200209

28. StataCorp. Margins - Marginal means, predictive margins, marginal effects. https://www.stata.com/manuals/rmargins.pdf. Accessed March 31, 2021.

29. Razzaque A, Clair K, Chin B, et al. Association of Time since Migration from Rural to Urban Slums and Maternal and Child Outcomes: Dhaka (North and South) and Gazipur City Corporations. *J Urban Heal*. 2020;97(1):158-170. doi:10.1007/s11524-019-00395-9

30. Kusuma YS, Kumari R, Kaushal S. Migration and access to maternal healthcare: Determinants of adequate antenatal care and institutional delivery among socio-economically disadvantaged migrants in Delhi, India. *Trop Med Int Heal*. 2013;18(10):1202-1210. doi:10.1111/tmi.12166

31. Awoh AB, Plugge E. Immunisation coverage in rural-urban migrant children in low and middle-income countries (LMICs): A systematic review and meta-analysis. *J Epidemiol Community Health*. 2016;70(3):305-311. doi:10.1136/jech-2015-205652

32. Kiros GE, White MJ. Migration, community context, and child immunization in Ethiopia. *Soc Sci Med*. 2004;59(12):2603-2616. doi:10.1016/j.socscimed.2004.04.009

33. Smith-Greenaway E, Madhavan S. Maternal migration and child health: An analysis of disruption and adaptation processes in Benin. *Soc Sci Res*. 2015;54:146-158. doi:10.1016/j.ssresearch.2015.06.005

34. Atahigwa C, Kadengye DT, Iddi S, Abrams S, Van Rie A. Trends and determinants of health facility childbirth service utilization among mothers in urban slums of Nairobi, Kenya. *Glob Epidemiol*. 2020;2:100029. doi:10.1016/j.gloepi.2020.100029

35. Mulogo E, Witte K, Bajunirwe F, et al. Birth plans and health facility based delivery in rural Uganda. *East Afr Med J*. 2006;83(3):74-83. doi:10.4314/eamj.v83i3.9401

36. Gitonga E, Muiruri F. Determinants of health faciilty delivery among women in Tharaka Nithi county, Kenya. *Pan Afr Med J*. 2016;25 (Suppl(9):9. doi:10.11604/pamj.supp.2016.25.2.10273

37. Bellows B, Kyobutungi C, Mutua MK, Warren C, Ezeh A. Increase in facility-based deliveries associated with a maternal health voucher programme in informal settlements in Nairobi, Kenya. *Health Policy Plan*. 2013;28(2):134-142. doi:10.1093/heapol/czs030

38. Gitobu CM, Gichangi PB, Mwanda WO. The effect of Kenya's free maternal health care policy on the utilization of health facility delivery services and maternal and neonatal mortality in public health facilities. *BMC Pregnancy Childbirth*. 2018;18(1):1-11. doi:10.1186/s12884-018-1708-2

39. Mirkuzie AH. Exploring inequities in skilled care at birth among migrant population in a metropolitan city Addis Ababa, Ethiopia; A qualitative study. *Int J Equity Health*. 2014;13(1):1-12. doi:10.1186/s12939-014-0110-6

Chapter 5 Discussion

This dissertation investigated the relationship between maternal migration and the use of maternal and child healthcare services in Kenya. The influence of migration on childhood vaccination was examined using data from the nationally representative Kenya Demographic and Health Survey. Additionally, the impact of migration into Nairobi's informal urban settlements on vaccination timelines and maternal childbirth services was analyzed using data from the Nairobi Urban Health and Demographic Surveillance System. This concluding chapter will summarize key findings from each of the three aims and discuss them in the context of existing literature. It will then outline important conceptual and methodological limitations and strengths of the dissertation and close with a discussion of the public health implications of this work and considerations for future research directions.

Summary of findings in context

Aim 1: The influence of maternal migration on child vaccination status in Kenya: An inverse probability of treatment-weighted analysis

The first dissertation aim investigated the relationships between maternal migration and childhood vaccination status using 2014 Kenya Demographic and Health Survey (DHS) data. The primary analysis assessed whether a mother's migration status (migrant, non-migrant) influenced whether her child received all recommended childhood vaccines and whether her child received all recommended vaccinations by 12 months of age (up-to-date vaccination, or

UTD). Secondary analyses examined whether a woman's migration stream (e.g., rural-urban) differentially influenced her child's vaccination outcomes.

Results indicated that prior to inclusion of inverse probability of treatment weights the distribution of confounders varied substantially between migrants and non-migrants. Crude models indicated the association between maternal migration and childhood vaccination was statistically significant; the odds of having a child who was fully vaccinated or had up-to-date vaccination were 1.46 and 1.41 times higher, respectively, among migrant women compared to non-migrant women. However, once the uneven distribution of confounding factors was balanced between migrants and non-migrants, these associations were no longer statistically significant. Secondary migration stream analyses compared vaccination status among the children of migrants with a particular migration route (for example, those with a rural origin and an urban destination) to the children of non-migrants. None of the migration stream analyses produced results that were statistically significant. Additionally, measures of association for each migration stream were not significantly different from one another. Together, these results suggest that differences in vaccination uptake between migrants and non-migrants is unlikely due to the act of migration itself and instead more likely reflected that migrants in this sample disproportionately had characteristics that enabled healthcare utilization, such as higher wealth and more education.

These results deviate from much of the current literature examining the relationship between maternal migration and childhood vaccination in low- and middle-income countries, which largely reports that the children of migrants are less likely to be vaccinated than the children of non-migrants. A systematic review including 11 papers examining the relationship between rural-urban migration and childhood vaccination reported that in all included studies (solely from China, India, and Nigeria), the children of rural-urban migrants were less likely to be fully vaccinated than both urban non-migrants and the general population.[1] Specifically within the African region, evidence generally supports the hypothesis that migrants are less likely to be vaccinated than non-migrants. An analysis from Ethiopia demonstrated that the children of rural-rural migrants were significantly less likely to be fully vaccinated compared to the children of rural non-migrants and a study from Nigeria reported that the children of rural-urban migrants were less likely to be fully vaccinated than the children of both rural and urban non-migrants.[2,3] However, evidence from Benin suggests that the relationship between maternal migration and whether a child received any vaccinations depends on the timing between migration and childbirth.[4] In this analysis, children born in the home community before migration were less likely to be fully vaccinated whereas children born after migration in the destination community more likely to be fully vaccinated, compared to non-migrant children.[4]

Differences between the findings of this dissertation and the prior published research are likely due to a combination of cultural and methodological differences. Though all located on the African continent, Benin, Ethiopia, Kenya, and Nigeria each have unique social, cultural, and economic contexts that may make the experience of migration and adaptation very different for women residing in these different countries. Additionally, there is no standardized definition of a migrant including at what point a woman has lived in a community long enough to be considered a non-migrant. As an example of this heterogeneity, each of the aforementioned analyses employed a different definition of migration. While this dissertation considered a woman to be a migrant if she moved within five years before the survey, the study from Ethiopia[3] labeled women as migrants if they were not living in the community where they were born; the Nigerian[2] analysis considered women migrants if they moved across administrative boundaries at any point in the ten years before the survey; and the analysis from Benin[4] only specified whether the woman moved before or after her child was born. As each analysis defined migration differently it is difficult to make direct comparisons of the results. Finally, existing studies only included confounders as covariates in their final models but did not confirm whether this adjustment produced an adequate balance of confounding characteristics between migrants and non-migrants. The inverse probability of treatment weighting method used in aim 1 addresses this limitation by allowing the analyst to examine distributions of confounders among migrants and non-migrants before and after weighting and confirm appropriate balance was achieved. As this dissertation demonstrated, studies of migration and healthcare utilization are subject to considerable confounding bias and therefore analyses of this relationship should assess the degree of balance attained by their analytic methods.

Aim 2: Childhood vaccination timeliness following maternal migration to an informal urban settlement in Kenya

The second dissertation aim analyzed the association between migration to informal urban settlements in Nairobi, Kenya and the timely receipt of childhood vaccines using data from the Nairobi Urban Health and Demographic Surveillance System (NUHDSS) between 2002 and 2018. The primary analysis evaluated the influence of a mother's migration status (migrant, non-migrant) on her child's vaccination timeliness. Characteristics of the migration experience may influence a woman's ability to adapt and promptly access vaccination and other health services; therefore, secondary analyses investigated the impact of a migrant's origin (urban, rural) and previous experience migrating to the settlement (first-time migrant, circular) on her child's timely receipt of vaccines.

This aim identified high levels of vaccination delay among both migrant and non-migrant children, ranging from approximately 11% of children receiving the DPT1 vaccine late or not at all to over 30% of children receiving the measles dose late or not at all. The proportion of children who did not receive timely doses was similar between migrants and non-migrants except for the measles vaccine, in which 40% of migrants compared to 34% of non-migrants did not receive the dose on time. Though a substantial proportion of children in the sample did not receive timely vaccinations, there was no evidence that maternal migration was a principal factor in these delays. The only exception was for the first dose of the DPT vaccine, in which migrant children received the dose slightly earlier than non-migrant children. Analyses of migration status, migrant origin, and migrant type all produced statistically insignificant results after accounting for confounders.

Previous work examining vaccination timeliness in the NUHDSS and in nationally representative Kenyan data show low levels of timely vaccination similar to Aim 2 results.[5–7] An analysis of a subset of children from the NUHDSS catchment area from 2007-2014 reported substantial delays, with only 67% of children fully vaccinated by 12 months of age, though timeliness of individual doses was not assessed.[7] Another study leveraging 2003-2015 NUHDSS data examined dose timeliness and demonstrated concerningly low levels of timely vaccine receipt among children in the settlements, with the proportion of children receiving all vaccines on-time increasing from 30% in 2003 to 42% in 2015.[6] It has additionally been demonstrated using Kenyan Demographic and Health Survey data that only 37% of Kenyan children aged 12-36 months received all eight basic vaccines as recommended.[5] This value is far behind the highest-achieving countries in sub-Saharan Africa (Burundi, Eswatini, and Namibia had the three highest proportions of timely-vaccinated children at 59%, 56%, and 53%, respectively), but

Kenya fared better than neighbors Ethiopia (9%) and Tanzania (25%).[5] The Aim 2 analysis adds to this previous body of work by including children without vaccination cards in the sample and reporting estimates of both median age at vaccination and the proportion of children with untimely vaccine receipt by individual doses.

Results are also congruent with the limited existing studies examining the relationship between migration and childhood vaccination timeliness. Work from rural Kenya examining predictors of time-to-vaccination reported that migrants, defined as those who migrated into the demographic surveillance site between 2000-2006, had higher vaccination rates compared to non-migrants in bivariate models, but migration status lost its significance in fully adjusted models.[8] While helpful to compare results to another study from Kenya, given that migration status was simply included as another potential predictor in the models, rather than a predetermined exposure, considerable confounding of the migration-vaccination timeliness relationship likely remains. More similar to the present analysis, a project from Israel compared vaccination timeliness among native Israelis and the children of Eritrean migrants.[9] The authors reported that the children of Eritrean migrants received the hepatitis A vaccine significantly later than non-migrant Israelis, but the timing of all other childhood doses were comparable between migrant and non-migrant children.[9] While studies examining the relationship between migration status and childhood vaccination timeliness are quite limited, the authors are unaware of any studies that have investigated how characteristics of the migration experience, including migrant origin and whether a woman is a first-time or circular migrant, may influence vaccination timeliness. Therefore, Aim 2 analyses address an existing gap in the migration and vaccination literature.

Aim 3: Migration to an informal urban settlement and its impact on receipt of maternal childbirth care in Nairobi, Kenya: An exploration of migrant adaptation

The third dissertation aim analyzed the relationship between migrant adaptation and the use of recommended childbirth services, as utilization of these services is associated with more positive birth outcomes and longer-term maternal and infant health. This aim leveraged NUHDSS data on births that occurred between 2004 and 2018. The primary analysis assessed the influence of migrant adaptation, defined as the number of years between migration into the settlement and childbirth, on the use of delivery at a health facility with a skilled birth attendant (SBA). To explore heterogeneity in this relationship, secondary analyses stratified regressions by the following characteristics of the migration experience: migrant origin (rural, urban), migrant type (first-time migrant, circular migrant), migration companions (alone, with others), and motivation for migrating (to be with family or friends, living conditions, job prospects, other reasons).

Receipt of recommended childbirth care (a measure combining facility delivery and use of an SBA) was very high in this sample, with over 90% of women giving birth in a health facility with an SBA. When examined by year, an impressive positive trend is apparent – the probability of delivering in a health facility with an SBA increased from just 67% in 2006 to nearly 99% in 2018. The crude model showed a positive significant association between migrant adaptation and receipt of recommended childbirth services, with a one-year increase in time between migration into the settlement and childbirth associated with an 8% higher odds of receiving recommended childbirth care, but this relationship lost statistical significance upon inclusion of confounders. Both multiplicative and additive interaction models suggested the relationship between migrant adaptation and uptake of maternal delivery services was not statistically significantly modified by characteristics of the migration experience.

This striking increase in delivery care has been reported by another analysis from the NUHDSS. A study using 2003-2015 NUHDSS data reported that 81% of deliveries overall occurred in health facilities and when examined by year this proportion increased from 68% in 2003 to 95% in 2015.[10] The latest available Demographic and Health Survey data from Kenya reports a similar trend in the uptake of childbirth services nationally, though improvements are not as substantial as those seen in the NUHDSS; between 2003 and 2014 the proportion of women who gave birth in a health facility increased from 40% to 64% and the proportion of women who delivered with an SBA increased from 42% to 65%.[11] Progress towards the goal of universal facility delivery and skilled birth attendance is largely due to a 2013 presidential decree that the Ministry of Health would cover the cost of maternity care provided at public facilities, making facility delivery free to women in these health centers.[12]

Adaptation demonstrated a statistically significant relationship with childbirth care in unadjusted regressions but statistically insignificant in final adjusted regressions. This is consistent with previous work in this area. A recent Bangladeshi study examined the use of maternal and child healthcare services among women who migrated from rural areas to one of Dhaka's IUSs.[13] In bivariate analyses, the authors reported that increased time living in the slum was significantly associated with increases in the likelihood of both delivering in a health facility and having a doctor present during childbirth.[13] However, similar to Aim 3 results, these statistically significant differences were not present after confounder adjustment. Likewise, research from Delhi, India found that the proportion of women who delivered in a hospital was lower among rural-urban migrants (54%) compared to Delhi's general population (64%) but hospital delivery utilization was similar between recent migrants to Delhi (46%) and settled migrants who had lived in Delhi for at least five years (47%).[14] Though Aim 3 adaptation results are similar to findings from Bangladesh and India, the exceptionally high uptake of recommended childbirth services in the NUHDSS was unique, and perhaps an important contributor to the null findings.

The impact of characteristics of the migration experience, such as migration companions and migration motivations, on healthcare utilization has been underexplored in the literature but the influence of migrant origin has received some scholarly interest. A 2019 study by Cotton examining 27 countries in sub-Saharan Africa assessed how migrant adaptation and migrant origin jointly influence having an SBA present at birth.[15] For migrants who moved between urban areas, recent migration (within the last three years) was associated with a significantly higher probability of having an SBA at birth compared to urban non-migrants. But, as women adapted to their new environment this advantage diminished to the point where settled migrants and non-migrants demonstrated comparable use of SBAs.[15] In contrast to this negative impact of adaptation for urban-urban migrants, Cotton found no statistically significant differences in the use of SBAs when comparing recent rural-urban migrants, settled rural-urban migrants, and urban non-migrants.[15] Conversely, the Aim 3 analyses did not report different adaptation patterns among rural-urban and urban-urban migrants nor did it find the overall negative impact of adaptation reported among urban-urban migrants in the Cotton study. These differing results are likely due to a combination of the widely different contexts (27 nationally representative data sets in the Cotton study compared to two IUSs in the Aim 3 analysis) and the different operationalization of adaptation (Cotton employed a categorical variable of time spent in the new community before birth whereas a continuous adaptation variable was used in this dissertation).

Limitations and strengths

Limitations

Interpretation of this dissertation should be made in the light of important limitations. Dissertation aims did not examine whether the magnitude, direction, or statistical significance of the relationship between migration and healthcare use was different for children born before migration compared to children born after migration. The Aim 1 analysis did not differentiate vaccination outcomes among children born in the origin community before migration from the vaccination outcomes of children born in the destination community after migration. As demonstrated in Benin,[4] if not separated, opposing directionality of the relationship between migration and vaccination among children born before and after migration could make it appear as though the relationship between migration and childhood vaccination is null. In Aim 2, information on childhood vaccination was only available for children born in the NUHDSS settlements, meaning it was not possible to compare the relationship between migration and vaccination for children before and born after migration.

Another limitation is the inability to fully characterize the migration experience and examine potential effect heterogeneity. DHS data collects very limited migration histories, so Aim 1 analyses were only able to explore the influence of migration stream, though other factors such as motivation for migrating likely impact the degree to which a woman's resources are disrupted and her ability to adapt upon arrival to her new home. Further, the DHS only collects simplistic measures of current and previous residences, rendering it impossible to differentiate individuals moving from one rural (urban) area to another rural (urban) from those moving between homes within the same community. Inclusion in the analysis of individuals who simply moved to a new home in the same community would likely attenuate the results as they would not experience the same disruption and adaptation processes as women moving to an entirely new area. Information on the whether or how many times a woman had previously migrated between residences before her most recent move was similarly unavailable as the DHS only asks where a woman lived "just before she moved [to her current residence]." For example, a woman who moved from a rural area to a small urban center to Nairobi would have the same urban-urban migrant designation as a woman who moved from one large urban area like Mombasa to another large urban area like Nairobi even though these are very different migration patterns. The NUHDSS data used in Aims 2 and 3 provided more migration information than the DHS but was still limited. Women were asked whether they migrated alone or with members of their household but specific information on who women migrated with (e.g., her husband or her parents) was not collected. Conversely, very detailed responses were provided regarding a woman's reason for migrating (e.g., to be with family/friends, for a change/independence, fewer civil conflicts) but due to small sample sizes multiple categories had to be combined into the very broad groups (e.g., to be with family/friends, living conditions, good job prospects, and other).

Strengths

Despite the above limitations this dissertation has considerable content area and methodological strengths. This dissertation provided an in-depth analysis of the relationship between migration and the uptake of maternal and child healthcare services in Kenya, a setting in which these relationships have not yet been explored. All three aims acknowledged that characteristics of the migration experience may differentially influence healthcare utilization and provided secondary analyses to explore those differences. In addition to migrant status (Aims 1 and 2), this dissertation incorporated migrant adaptation (Aim 3), migration stream/migrant origin (Aims 1, 2, and 3), whether a woman was a first-time migrant to the area (Aims 2 and 3), with whom a woman migrated (Aim 3), and reason for migrating (Aim 3). The inclusion of this wide variety of migration characteristics allowed for a more nuanced look at how the complicated process of migration impacts healthcare use. Additionally, multiple operationalizations of childhood vaccination status, including full vaccination, up-to-date vaccination, and timely vaccination, were used to explore whether migration differentially impacted varied measures of vaccination uptake. Moreover, much of the current research in this area focuses on whether children aged 12-23 months have received all recommended doses of vaccine. This is a commonly used and important indicator of vaccination program coverage, but it is also necessary to understand how migration status impacts whether children receive all vaccinations by one year (up-to-date vaccination), as recommended by the World Health Organization, or if the children of migrants face increased delays in vaccination receipt compared to non-migrant peers. Up-to-date and delayed vaccination has been studied extensively in low- and middle-income countries but less frequently in relation to migration. Often, analyses of up-to-date and timely vaccination exclude children without written vaccination documentation, as dates of birth and vaccine receipt are used to at what age children received each dose. This leads to another important – and often unaddressed – form of selection bias, as the unavailability of vaccination cards is not random and is likely associated with both sociodemographic and vaccination outcomes.

This dissertation represents an advancement in the examination of the migration-healthcare use relationship as advanced methods were used to address key biases common in this area of research. Inadequate assessment and reduction of selection and confounding biases is a notable limitation of much of the research in this area. Given migration is a selective process and the factors (like education and wealth) that enable migration also promote the use of healthcare services, rigorous accounting for confounding is crucial in order to obtain a minimally biased measure of association. The absence of rigorous accounting for these biases suggests existing studies may be highly vulnerable to biased results. Most analyses of the relationship between migration and healthcare use simply include confounders as covariates in final adjusted models and perform no checks to assure the confounders have been appropriately balanced between migrants and non-migrants. In addition to exploring this relationship in a new context, this dissertation builds upon the literature on migration and healthcare use by applying a methodological advancement to address confounding. Inverse probability of treatment weighting (IPTW) was employed in Aims 1 and 2 to identify and correct confounding bias associated with maternal migration. This method also provided statistical confirmation that weighting adequately balanced the distribution of confounders between migrants and non-migrants, reducing the impact of bias. If IPTW weights do not adequately balance confounders, they can be re-estimated until a pre-established threshold has been met and then effect estimation can proceed. Use of IPTW is an important strength that aimed to reduce an important form of bias in these research questions.

Advanced methods were also employed to reduce potential selection bias that can arise in studies of vaccination timing. Children without vaccination cards are frequently excluded from analyses of up-to-date and timely vaccination as documented vaccination dates are used to determine precisely when children received particular doses. However, the vaccination status of children with and without vaccination cards are unlikely to be comparable. As a result, most studies of vaccine timing can only be generalized to children with vaccination cards, excluding a vulnerable – and potentially sizable, depending on the country – group of children from vaccination research. To address this important gap, Aim 1 used multiple imputation to assign the up-to-date status of children without vaccination cards in an effort to produce a less biased estimate that was more generalizable to children with and without vaccination cards. This allowed a family's characteristics to determine a child's up-to-date status rather than simply assuming children with cards are representative of children without cards. Aim 2 also included children without vaccination cards by utilizing accelerated failure time (AFT) models to assess the relationship between migration status and time to vaccine receipt. AFT models allow the researcher to both left- and right-censor observations in the analysis, meaning information from children who were vaccinated at some undetermined time before the survey interview according to maternal recall (left-censored) and information from children who were not yet vaccinated at the time of interview but could still be vaccinated in the future (right-censored) could be included in the analysis. Another form of selection bias present in analyses of vaccination timing is survivor bias. Most analyses of vaccination timing only include living children aged 12-23 months at the time of the survey, excluding children who did not survive to that age. This can introduce survivor bias to the analysis and potentially over-estimate vaccination coverage, as children who survived to at least one year of age are more likely to have been vaccinated than children who died before their first birthday. As NUHDSS prospectively collects childhood vaccination information, data on the vaccines received by deceased children before they died was available for the Aim 2 analysis, reducing the risk of survivor bias in this analysis. The use of rigorous methods to ensure the inclusion of as many children as possible is a key strength of this dissertation.

Public health implications

Maternal and under-five mortality remains unacceptably high worldwide, but particularly in sub-Saharan Africa, where the majority of these deaths occur.[16,17] To address these and other health and development problems the United Nations' Member States adopted the Sustainable Development Goals in 2015.[18] Goals 3.1 and 3.2 aim to reduce the global maternal mortality ratio to below 70 deaths per 100,000 live births and decrease under-five mortality to below 25 deaths per 1,000 live births, respectively, by 2030.[19] A key strategy to reach these Goals entails countries eliminating preventable causes of maternal and child deaths by improving the access to and utilization of preventive healthcare services, like facility delivery and childhood vaccination. Though Kenya has attempted to increase utilization of these services by removing user fees, universal access has not been achieved. Therefore, it is necessary to investigate potential social factors that may drive inequities in healthcare uptake so policies and interventions can be developed to close utilization gaps. One such social factor that may influence healthcare uptake is maternal migration. Migration has been increasing in the region and research from other low- and middle-income countries indicates that migrant women (and their children) may be a particularly vulnerable group, with indicators of healthcare utilization lagging behind those of their non-migrant peers. This dissertation sought to investigate whether maternal migration was a factor influencing maternal and child healthcare uptake in Kenya.

Results from Aims 1 and 2 demonstrated the substantial progress that remains to be achieved in order to ensure children receive all recommended vaccinations on time. By including children without vaccination cards in analyses the results of these Aims provide more widely generalizable results than much of the existing literature. In fact, when children without vaccination cards were included in the analysis of up-to-date vaccination in Aim 1, the proportion of children with up-to-date vaccination dropped nearly 10 percentage points from 72% to 65%. As vaccination programs begin to increasingly prioritize vaccination timeliness along with ongoing efforts to increase coverage, including children without vaccination cards is necessary to obtain an accurate estimation of work to be done.

Aim 3 found that migrant adaptation did not influence use of recommended childbirth services, probably because such a high proportion of women (over 90%) received this care. Use of these resources increased dramatically between 2004 and 2018, likely as the result of interventions and policies enacted to remove user fees for facility deliveries. In fact, a supplemental analysis demonstrated that although the introduction of these free delivery policies did not impact whether established migrants would deliver in a health facility, the probability that very recent migrants would give birth in a facility with an SBA increased after implementation of these policies. Though perhaps unsurprising, this provides evidence that larger scale policies that make healthcare access more affordable to women have the potential to improve equity in healthcare access and increase uptake among more vulnerable groups. This lesson could seemingly be applied to vaccinations and other preventive healthcare services. Though vaccinations are available for free in Kenya and many other low- and middle-income countries, other indirect costs may make timely vaccine receipt unobtainable for women who need to save up to cover those costs. Policymakers and healthcare system leadership should consider investment in systems than can make the entire vaccine-seeking experience more cost effective, such as eliminating transportation costs or providing free childcare to women. Interventions aimed at making vaccination services even more easily accessible have the potential to both increase vaccination timeliness overall and decrease existing inequities in timely vaccination.

Healthcare utilization is an important mechanism through which the social determinants can influence health outcomes, including disease development and complications in pregnancy and childbirth. A better understanding of the social determinants influencing healthcare seeking behaviors can provide public health officials and policymakers the knowledge to appropriately distribute healthcare services, implement policies that support access to care, and efficiently use limited funding to plan outreach events targeting underserved communities. This dissertation assessed whether the experience of migration places women and their children at elevated risk of underutilization of preventive healthcare services. Findings from this work contribute to a nascent body of evidence suggesting that – both nationally and in some of Nairobi's most disadvantaged informal urban settlements – internal migrants may not be as vulnerable as indicated by studies from other nations. As the public health community works toward the goal of eliminating preventable causes of maternal and under-five death it appears that internal migrants may not need specific, targeted outreach and instead, broader reaching policies may be a more impactful investment.

Future directions

This dissertation assessed the relationships between maternal migration and the utilization of childhood vaccination and maternal childbirth services. Future research should extend these analyses and explore the temporal relationship between migration and healthcare use. Research from Benin[4] suggests that the impact of migration on vaccine use is different for children born before and after their mother migrated. Replication of this finding in other settings is merited as is further exploration of whether migration within specific time intervals before or after childbirth are particularly impactful for the uptake of vaccination or childbirth services. As the migration history and social, cultural, and economic setting of Kenya – and the two informal urban settlements in Nairobi examined in Aims 2 and 3 – are different from other nations in the region and across the globe, additional studies should also seek to replicate the analyses conducted in this dissertation in other settings, particularly where regional or nationally representative data sources are available. Finally, in an effort to obtain a broader understanding of the relationship between migration and healthcare utilization, research should examine how the influence of migration on maternal and child healthcare use has changed over time. With migration becoming an increasingly common occurrence in Kenya, sub-Saharan Africa, and globally, and with governments' continued investment in increasing availability of preventive healthcare services it would be relevant to assess whether accessing healthcare has become easier for migrants over the past few decades. A comparison of trends in the migration-healthcare use relationship and changing migration policies could inform the ways in which non-healthcare policy impacts healthcare utilization and provide evidence to the argument that health should be considered in all new policy development. In addition to further exploring the relationship between migration and healthcare use, future research should examine other social determinants that may drive disparities in vaccination and childbirth care uptake.

The ultimate goal of this research is to explore factors that may impact healthcare uptake in order to inform the development of interventions to increase access to care. Future studies should develop and test interventions to improve the timely receipt of childhood vaccinations. As evidenced by the increase in facility deliveries after maternity care was provided for free, first in the NUHDSS communities and later more broadly throughout Kenya, researchers should prioritize policy interventions. Larger-scale policy interventions that have potential to fundamentally alter the healthcare environment to increase vaccination timeliness have the potential to reach a larger number of families compared to individual-level interventions that place the onus on families who have myriad pressures occupying their time, attention, and resources. Future research should also consider interventions such as urban maternity waiting homes to ensure women living in urban settlements can give birth in health facilities rather than at home or en route to a facility, even if labor begins precipitously or at night when it is not safe to travel to a facility. Equipped with a deeper, more nuanced understanding of the ways in which social factors, such as maternal migration, may influence maternal and child healthcare uptake, policies and interventions can be developed and deployed to promote health equity, increase healthcare utilization, and eliminate preventable causes of maternal and under-five mortality in Kenya and globally.

References

1. Awoh AB, Plugge E. Immunisation coverage in rural-urban migrant children in low and middle-income countries (LMICs): A systematic review and meta-analysis. *J Epidemiol Community Health*. 2016;70(3):305-311. doi:10.1136/jech-2015-205652
2. Kiros GE, White MJ. Migration, community context, and child immunization in Ethiopia. *Soc Sci Med*. 2004;59(12):2603-2616. doi:10.1016/j.socscimed.2004.04.009
3. Antai D. Migration and child immunization in Nigeria: Individual- and community-level contexts. *BMC Public Health*. 2010;10:116. doi:10.1186/1471-2458-10-116
4. Smith-Greenaway E, Madhavan S. Maternal migration and child health: An analysis of disruption and adaptation processes in Benin. *Soc Sci Res*. 2015;54:146-158. doi:10.1016/j.ssresearch.2015.06.005
5. Mutua MK, Mohamed SF, Porth JM, Faye CM. Inequities in On-Time Childhood Vaccination: Evidence From Sub-Saharan Africa. *Am J Prev Med*. 2020;60(1):S11-S23. doi:10.1016/j.amepre.2020.10.002
6. Mutua MK, Mohamed SF, Iddi S, Muyingo S, Mwangi B, Kadengye D. Do inequalities exist in the disadvantaged populations? Levels and trends of full and on-time vaccination coverage in two Nairobi urban informal settlements. *Glob Epidemiol*. 2020;2. doi:10.1016/j.gloepi.2020.100044
7. Mutua MK, Kimani-Murage E, Ngomi N, Ravn H, Mwaniki P, Echoka E. Fully immunized child: Coverage, timing and sequencing of routine immunization in an urban poor settlement in Nairobi, Kenya. *Trop Med Health*. 2016;44(1):1-12. doi:10.1186/s41182-016-0013-x
8. Moïsi JC, Kabuka J, Mitingi D, Levine OS, Scott JAG. Spatial and socio-demographic predictors of time-to-immunization in a rural area in Kenya: Is equity attainable? *Vaccine*. 2010;28(35):5725-5730. doi:10.1016/j.vaccine.2010.06.011
9. Mor Z, Aharon AA, Sheffer R, Nehama H. Growth, developmental achievements and vaccines timeliness of undocumented migrant children from Eritrea compared with Israelis. *PLoS One*. 2018;13(3):1-11. doi:10.1371/journal.pone.0193219
10. Atahigwa C, Kadengye DT, Iddi S, Abrams S, Van Rie A. Trends and determinants of health facility childbirth service utilization among mothers in urban slums of Nairobi, Kenya. *Glob Epidemiol*. 2020;2:100029. doi:10.1016/j.gloepi.2020.100029
11. The DHS Program. The DHS Program STATCompiler. https://www.statcompiler.com/en/#. Published 2020. Accessed March 23, 2021.
12. Ministry of Health Kenya. *Implementing Free Maternal Health Care in Kenya-Challenges, Strategies and Recommendations*.; 2013.
13. Razzaque A, Clair K, Chin B, et al. Association of Time since Migration from Rural to Urban Slums and Maternal and Child Outcomes: Dhaka (North and South) and Gazipur City Corporations. *J Urban Heal*. 2020;97(1):158-170. doi:10.1007/s11524-019-00395-9
14. Kusuma YS, Kumari R, Kaushal S. Migration and access to maternal healthcare: Determinants of adequate antenatal care and institutional delivery among socio-economically disadvantaged migrants in Delhi, India. *Trop Med Int Heal*. 2013;18(10):1202-1210. doi:10.1111/tmi.12166
15. Cotton C. Migration and young women’s access to maternal healthcare in sub-Saharan Africa. *Heal Place*. 2019;55(January):136-144. doi:10.1016/j.healthplace.2018.12.006
16. World Health Organization. Maternal Mortality. https://www.who.int/news-room/fact-

sheets/detail/maternal-mortality. Published 2018. Accessed February 22, 2021.
17. World Health Organization. Children: reducing mortality. https://www.who.int/en/news-room/fact-sheets/detail/children-reducing-mortality. Published 2018.
18. The United Nations Department of Social and Economic Affairs. The 17 Goals - History. https://sdgs.un.org/goals. Published 2021. Accessed March 24, 2021.
19. United Nations. Goal 3 Targets and Indicators. https://sdgs.un.org/goals/goal3. Published 2020. Accessed December 27, 2020.