TIME TO CHILDHOOD IMMUNIZATION UPTAKE IN KENYA: A SURVIVAL MODEL

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DECLARATION

I declare that this research Thesis is my original work and has not been presented in any other institution for any other award.

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DEDICATION

To Shammah, with love.

ACKNOWLEDGEMENT

Sincere gratitude to my supervisors.

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LIST OF ABBREVIATIONS

BCG	Baccile Calmette Guerin
CDC	Center for Disease Control
CMC	Century Month Code
DPT	Diphtheria Pertussis Tetanus
EPI	Expanded Program on Immunization
GAVI	Global Alliance for Vaccines and Immunization
GOK	Government of Kenya
GVAP	Global Vaccines Action Plan
KDHS	Kenya Demographic Health Survey
KEPI	Kenya Expanded Program on Immunization
MCV	Measles Containing Vaccine
OPV	Oral Polio Vaccine
PCV	Pneumococcal Conjugate Vaccine
REC	Reach Every Child
UNICEF	United Nations Children's Education Fund
VPDs	Vaccine Preventable Diseases
WHO	World Health Organization

ABSTRACT

Background: Childhood immunization is an important intervention aimed at reducing morbidity and mortality among under-fives. Immunization coverage is the most common indicator used to evaluate the performance of this intervention. To achieve maximum benefits in controlling vaccine preventable diseases, measuring the timeliness of vaccine uptake should be considered. A vaccine is considered untimely if it is administered outside the suitable age range based on the schedule. Children who are immunized outside the appropriate age range are susceptible to vaccine preventable diseases.

Objective: To examine time to childhood immunization uptake among children aged 12 to 23 months in Kenya.

Methodology: This study used Kenya Demographic Health Survey data for the year 2014. This data provides information on child details, immunization records including date of vaccine administration. The target population was of children between 12 and 23 months of age required vaccines. Categorical variables were summarized using percentages. Timeliness of vaccination was assessed using the date of vaccine administration and date of birth of child. Nonparametric Kaplan Meir method was used to estimate the cumulative vaccination coverage. The event of interest (failure) is untimely vaccine uptake and the survival time is time in months until vaccination receipt. Censored observations were those of children receiving a specific vaccine on time. Multilevel Cox regression was used to model the predictors of time to immunization uptake.

Results: Full immunization coverage was estimated at 54.3%. The coverage was highest for BCG (95.8%), OPV1 (96.6%) and Pentavalent1 (96.5%). Overall, the coverage reduced over time for the three doses of OPV, Pentavalent and PCV. 28.3% of the children received vaccines on time, 47.5% received early while 24.1% had delayed vaccines. Education level, place of delivery, birth order, religion and maternal age predicted time-to-immunization uptake but differ between vaccines.

Conclusion: Timeliness of vaccines was low despite the high coverage reported for the vaccines. This shows a gap in the implementation and monitoring of vaccine programs, which calls for focused efforts and strategies towards improving immunization timeliness as an indicator for effectiveness and immunization performance globally.

CHAPTER ONE: INTRODUCTION

1.1 Background

Globally, approximately 5.3 million children aged below five died in 2018, with greater than a half of these deaths resulting from preventable diseases (1). Vaccine preventable diseases(VPDs) like diarrhea and pneumonia are among the major causes of mortality accounting for 15% and 8% respectively (2). In addition, Measles which is a vaccine preventable disease, killed more than 140,000 in the United States in 2018 (3).

Childhood immunization is one of the important interventions aimed at lowering morbidity and mortality in children below five. It is a beneficial intervention preventing about 2–3 million deaths globally (2). The World Health Organization(WHO) and United Nations Children's Education Fund (UNICEF), through the Global Vaccines Action Plan (GVAP), targets 90% immunization coverage by 2020 (4).

Immunization coverage, the main immunization indicator, is defined as the proportion of children 12 to 23 months old who have received all the required vaccines (5). Specifically, Diphtheria, Pertussis and Tetanus (DPT3) vaccine, which given at 14 weeks, is considered a good indicator for immunization coverage (2). Globally, the immunization coverage rates for most of the basic vaccines are above 80% (6). The rates have increased more than four-folds from 20% in 1980 to 72% in 2000 and 86% in 2018 (2). However, the rates are still slightly below the GVAP target of 90% coverage by 2020 (4).

In Africa, there was a steady rise in immunization coverage rates from 57% in 2000 to 76% in 2015 (7). The global focus on the Millennium Development Goals (MDGs), increased vaccine availability, financial support and collaboration through the Global Alliance for Vaccines and

Immunization (GAVI) (8) and health systems strengthening have contributed to the increased immunization coverage in low resourced countries (9). Despite this increase, six of the 52 African countries had less than 50% coverage (10).

While the immunization coverage seems to increase, concerns exist on when the children receive the vaccines. The WHO immunization schedule guides on the age intervals at which a child ought to receive a vaccine to obtain adequate protection from vaccine preventable diseases (11). Delays in vaccination receipt interferes with the protective effect of the vaccine at that age and alters the sequence of vaccination (12). Interestingly, evidence shows delayed vaccination in areas with relatively high coverage (13–16)**.** In Nigeria, a cross-sectional study found that despite the coverage of 76.3% observed in the study, only a third of the vaccines were received on time and the remaining two thirds were received later than the appropriate time (17). Children remain unprotected for some period during a delay in vaccination (13). Accordingly, without considering the timeliness of vaccine administration, full immunization status could give a false implication of disease protection.

1.2 Problem Statement

Delay in age-appropriate-vaccination reflects on the adequacy of protection of a vaccine and the quality of the effect of the immunization intervention. Timeliness of vaccine receipt is key especially for severe infections like pertussis, *Streptococcus pneumoniae* and *Haemophilus influenza.* (18). Delays in vaccine uptake compromises herd immunity that may stem in outbreaks of these VPDs. A tremendous achievement has been made towards improving immunization coverage. Despite this achievement, VPDs still cause over 1.5 million deaths annually (19). Some of these diseases may be due to timeliness of the vaccines.

Kenya, just like other countries is focusing on reaching the highest possible vaccination coverage. This kind of focus overlooks delays in vaccination that may be existing in the population. This focus would be more beneficial if vaccine timeliness is also considered as an important public health goal. Several studies have confirmed delays in countries with high coverage. This study aims to assess the timeliness of vaccination and predictors of with the untimely vaccination.

1.3 Study Justification

Kenya has achieved great milestones in childhood immunization such as the introduction of PCV 10 and Rotavirus vaccines and being declared a Polio free nation. Going forward, efforts to improve immunization should consider age-appropriate-vaccinations. The Government is currently making preparation for the transition from GAVI funding in 2026. While these preparations are still underway, it is important to consider vaccination timeliness as an indicator for evaluating immunization outcomes. This will mean immunization monitoring data will include information on whether the vaccine was given on time or delayed. The transition planning should consider efforts to substation an immunization timeliness monitoring. To ensure that under five mortality is kept under check, there is need to strengthen immunization as one of the major interventions against child mortality. The study findings may help to identify the intervention gaps in immunization for possible health and policy action.

1.4 Study Objectives

1.4.1 Broad Objective

To examine time-to-childhood immunization uptake among children aged 12 to 23 months in Kenya

1.4.2 Specific Objectives

- To assess timeliness of immunization uptake among children aged 12 to 23 months in Kenya
- To estimate vaccination coverage among children aged 12 to 23 months in Kenya
- To model predictors of time-to-immunization uptake among children aged 12 to 23 months in Kenya

1.5 Research Questions

- What is the proportion of timely and untimely vaccines in Kenya?
- What is the coverage rate of the Expanded Programme on Immunization scheduled vaccines in Kenya?
- What are the predictors of time-to-childhood immunization uptake in Kenya?

CHAPTER TWO: LITERATURE REVIEW

2.1 Childhood Immunization

Immunization is an efficient and helpful in controlling and eliminating severe infections among children globally(20). Diseases such as smallpox have been completely eradicated(21)while poliomyelitis has been eradicated in some countries including Kenya(22). The WHO estimates that immunization prevents over 2 million deaths annually (20). For example, deaths due to measles dropped from approximately 535,000 in 2000 to 139,000 in 2010 (23). This drop was attributed to mass vaccination campaigns and improved immunization coverage (24).

There has been a significant shift in immunization since 1974 when the Expanded Programme on Immunization (EPI) was established. The immunization coverage has gone up from below 5% of children receiving basic vaccines in 1974 (25) to more than 86% in 2010 (26). These improvements are partly due to EPI(27), new partnerships on immunization such as GAVI(9)and development of new and combined vaccines(9). Since 2000, the GAVI Alliance has supported more than 70 low income countries in strengthening immunization systems and improving their healthcare systems(28). Specifically, the alliance supported the launch of Pneumococcal Conjugate Vaccine into the schedule in low-income countries including Kenya (29).

Most African countries have adopted the EPI for decision making on immunization at national level(30). In sub-Saharan Africa, the case of immunization has also been on a steady improvement despite some challenges(31). The African region increased DPT3 coverage from 5% to 75% in 2013 due to initiatives such as the Global Vaccine Action Plan that was aimed increasing immunization access and services among other efforts at national level (32). The region also recorded zero cases of Polio for a year and a half since 11 August 2014, an indicator of efforts

towards universal access to vaccines (31). Despite these achievements, Africa is still host to most of the under-immunized children with one in five children still not receiving vaccines (33).

The WHO provides a summary table recommending the appropriate ages at which the vaccines should be administered to children. It provides information on routine immunization for children and the recommended interval between the required doses (34). This summary helps in planning for immunization at national level in different countries. Based on the WHO guidelines, Kenya Expanded Programme on Immunization (KEPI) developed a schedule of the recommended vaccines for Kenya. KEPI was established to monitor immunization interventions for all children in all parts of Kenya (35). KEPI was part of the global Expanded Programmes on Immunization. The Schedule is summarized in Table 1.

In Kenya, KEPI monitors immunization interventions for all children in Kenya (35). KEPI has developed a schedule—vaccine, dosages and interval between the required doses—of the recommended vaccines for Kenya based on WHO immunization guidelines (Table 1) (34)(35). Based on the schedule, every child is supposed to have completed the vaccines by 23 months to be regarded as fully immunized.

Table 1. KEPI Schedule

KEPI Schedule	Description	Age
BCG	Bacille Calmette-Guérin vaccine	Birth
OPV	Oral Polio Vaccine	Birth, six, ten, fourteen weeks
Pentavalent	Diphtheria and Tetanus and Pertussis and Haemophilus influenzae and Hepatitis B Vaccine	Six, ten, fourteen weeks
PCV 10	Pneumococcal Conjugate Vaccine	Six, ten, fourteen weeks
Measles	Measles Vaccine	9, 18 months

(36)

2.2 Immunization Coverage

Due to the global initiatives towards immunization (27), the proportion of children completing all the required vaccines has gone up. The global focus on MDGs, increased vaccine availability, financial support and collaboration through GAVI (8) and health systems strengthening have contributed to increased immunization coverage in low resource countries (9). Importantly, in the past decade, the global coverage rate increased by only 5% followed by a plateauing (8). The African region, for instance, has seen a great increase in immunization coverage over a 20 year period (8). The number of countries attaining 80% DTP3 coverage increased from 2% in 1980 to 67% in 2010 (28). At global level, the coverage has remained constant at 86% since the year 2010 (26). This constant status is because more children are born in countries having low coverage and weak health systems, hence causing a strain on the efforts to improve global coverage (8).

Most countries in the world currently have a relatively higher vaccination coverage over the years. Based on the Global Routine Vaccination Coverage, 130 out of 194 (67%) countries achieved the

90% national DTP3 coverage target in 2016, up from 128 out of 194 (66%) in the previous year (37). A study based on a survey in Ballabgarh, India reported a vaccination coverage >90% for that particular area (12). Between 2012 and 2016, the United States maintained a DTP3 coverage of >90% among children aged 19–35 months (38)

Bangladesh Demographic Health Survey reported a 91% coverage for the Pentavalent vaccine which includes DPT3 with 83% of the children having attained full coverage (39). In the African Region, immunization coverage increased to 76% in 2015, up from 52% in 2000 (40). However, only 16 out of 47 African region countries attained the GVAP target of >90% for national DTP3 coverage (40). In a survey of 13 West African countries, none of the countries achieved the 90% target for DTP3 coverage (41). Nigeria, which is currently one of the countries with the most under-immunized children had a DPT3 coverage of 38% and the highest proportion of unimmunized children (41). Shingai et al reiterates that though Africa has made notable strides in immunization, there is still much work to be done since many children are still unvaccinated, under-vaccinated, unreached and therefore at risk of dying due to VPDs (42).

The Kenya case of immunization has not been any different from some other countries in Africa. Immunization coverage has been on a steady increase from 57% in 2003 to 77% in 2007 (43). According to the KDHS 2014 report, immunization coverage is at 79% (44). Based on WHO and UNICEF estimates, the immunization coverage in Kenya is currently at 89%and this is relatively high. Despite this high coverage, studies have shown disparities in coverage within counties and rural divide in Kenya. A study in East Pokot revealed a 23% immunization coverage for that particular area (43). Mutua et al. recommended strengthening of immunization services in the slum areas of Nairobi after discovering a coverage of 41.3% (45).

2.3 Immunization Timeliness

Immunization timeliness is an important indicator in evaluating the outcome of immunization activities. Most studies have shown evidence of untimely vaccination in places where the coverage is relatively high. Hull & McIntyre state that even though most children complete the vaccines by 24 months, the completion is not based on the recommended schedule (18). A study in Eastern China provided a coverage of over 90% for all the vaccines, but more 50% of the children were not vaccinated at the appropriate age (46). In addition, Waroux et al found in Tanzania that 34% to 67% of the children vaccinated received the vaccines four weeks after the required age. This shows that vaccination delays are still substantial even with high coverage estimates. In Malawi, most children in two study districts received the measles dose after 365 days despite a coverage of >80% (47).

In Ethiopia, less than 40% of the children received the vaccines on time for each of the vaccines in a study with 99.3% coverage for measles and Penta 1–3 (48). A downward trend in the number of age-appropriate-vaccinations received was noted from Penta 1 to 3 (48). Similar trend was also noted in a study where 30% of the children had delayed DPT1 which increased to 38% for DPT2 and 47% for DPT3 (49). This shows that greater proportion of the children immunized received the doses later than the required age. Specifically, it is evident that a greater portion of children receive the initial dose of a vaccine on time and the proportion reduces drastically for the third dose. Walton et al found out that 79% of the infants received the first dose of OPV at the scheduled age while only 59% received the dose on time for the third dose (49). Still on the same study, 79% of the children received DPT 1 which is given at 6 weeks on time compared to the 59.7% who received Measles Mumps Rubella (MMR) which is given at nine months on time (49). Another

study in Uganda also showed this variation based on age where timeliness ranged from 92% for BCG to 68% for measles vaccine (50). Later doses in a series were more likely to be delayed (14).

In a study in three regions of South Africa, the percentages of timely-vaccinations were lower than the estimate for coverage for each of the vaccines in the three regions. Immunization coverage for Pentavalent vaccine were 94%, 90% and 74% for Paarl, Umlazi and Rietvlei respectively while the estimates for timeliness were 92%, 86% and 70% respectively (51). The proportion of children who had delay in vaccination were lower compared to what other studies have shown(51). The fact that vaccination delays have been confirmed in places where immunization coverage is high like Ballabgarh in India where more than half of the 90% of the children immunized had delays, means that children are exposed to these diseases which can actually lead to outbreaks (12).

According to a study in Israel, severe delay occurred when a child was immunized more than six months later than the appropriate age for vaccination and was particularly high for multiple dose vaccines (16). In Australia, timeliness of the DPT3 remained constant between the year 1998 and 2001 based on a comparison of study cohorts in those years while at the same time, immunization coverage has increased from 88% to 92% (18).

2.4 Predictors of Time to Vaccination

There are several socio-demographic, socioeconomic and health service factors that predict untimely vaccinations. Place of delivery is one of such factors. A study conducted in three regions of South Africa found that children born at home and those with many siblings were at a higher risk of delay in receiving vaccines (13). According to a study in Kampala Uganda, untimely vaccination was common among those who were in the poorest wealth quintile and those who not delivered in hospital (50). Children born at home were more likely to be vaccinated late (11).

Odutola et al, inferred that there was an independent association between place of birth and delay in DTP3 vaccine receipt (52).

A study showed that DTP1 delay had a significant association with the size of the household with 11.5% having delays in a household with four of more children compared to 2.5% in a household with one child (49). Dombkowski and colleagues observed that there were increased odds of delay for all the doses with increase in family size. Children from families with four or more children had 3 times higher odds of delay than for children without siblings (53). A study in Uganda also found that a child with more than three sibling was 26% more likely to have delays in vaccine receipt (13).

According to Walton et al and Fadness et al, boys were more likely to experience delay in receiving the first dose of DPT compared to girls (13,49). Another study had a contrary observation to the above where boys had timely vaccines compared to girls for DPT1 (54). In addition, another study in Ethiopia observed that female children had twice higher odds of delay in age appropriate Penta1 and vaccination compared to male children (48). However, females were more likely to have timely vaccinations with Penta3, OPV3 and MCV (55).

Maternal education is also an important predictor of delay in age-appropriate-vaccinations. Walton and colleagues observed a notable association between maternal education and delay in age-appropriate-vaccination with children whose mothers were uneducated having delayed receipt of vaccines compared to those whose mothers had attained degrees (49). Compared to children whose mothers were uneducated, children whose mothers had more than seven years of education had fewer delays in receiving MCV1 (54). Children whose parent had beyond high school diploma had lower odds of vaccine delay (53). The number of untimely-vaccinations were decreasing with

increase in parental education (50). Children of mothers with secondary education and above were more likely to receive Penta3 vaccine on time compared with those of uneducated mothers (55).

Income is a major determinant for delay in age-appropriate-vaccination (11). In Tanzania, children from the poorest quintiles delayed in receiving all the four vaccines under study later than children from less poor quintile and there was a significant relationship between socioeconomic status and delayed receipt of MCV1 (54). Children from the richest quintiles in Malawi were highly likely to receive correctly timed BCG and OPV3 vaccine (55). Children from least poor households were 2% less likely to experience delay in vaccine receipt compared to those from the poorest quintile (13).

Parental employment had an association with delayed immunization where, children whose parents had jobs were more likely to delay in receiving vaccines (11). Based on a study in The Gambia, illiteracy and unemployment were found to be significantly associated with delay for BCG vaccine whereby children of civil workers were less likely to delay in receiving BCG compared to those of unemployed mothers (52). Distance of the health facility is a potential predictor of delay in vaccination. Children living more than five kilometres from the immunization facility was significantly associated with delay in DPT1 vaccine (11).

2.5 Application of Survival Analysis in Studying Timeliness of Childhood Immunization

Several studies have applied Kaplan Meier approach in conducting analysis related to timeliness of childhood immunization. Tang et al used the Kaplan Meier method to calculate the median vaccination delay time (56). In a study in Senegal, the Kaplan Meier method was used to estimate the cumulative timely-vaccination coverage which gave more information on the timeliness (55). Using the inverse Kaplan Meier Survival function, Hu and colleagues were able to calculate the

cumulative likelihood of being vaccinated at a given age for every vaccine (11). In another study that applied survival analysis to measure time-to-vaccine uptake by dose, the researchers constructed Kaplan Meier curves for the specific vaccines (57).

The Cox Proportional Hazards Regression model has been used in studies to examine determinants of delay in age-appropriate-vaccination. Babirye et al, entered factors that were found statistically significant in the univariate model into a multivariate model (58). Fadness et al in their study also used the adjusted cox regression analysis to investigate determinants of timely vaccination (13).

2.6 Conceptual Framework

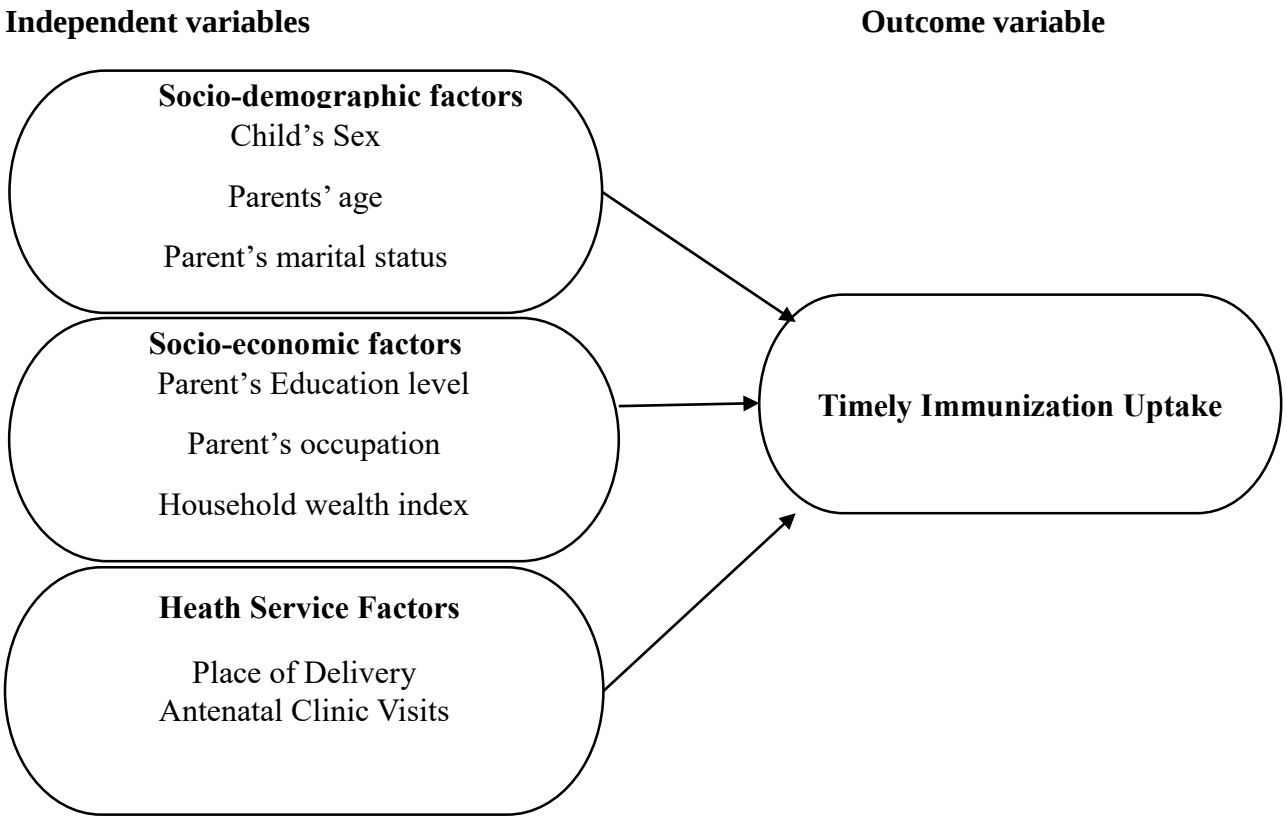

Figure 1 Conceptual framework

CHAPTER THREE: METHODOLOGY

3.1 Data Source

This study used Kenya Demographic Health Survey (KDHS) dataset for the year 2014. KDHS is a population based survey that is carried out in Kenya after every five years to help monitor the health status of the country and to generate indicators for health. A multistage cluster sampling technique was used for the survey with households as the primary sampling units. Woman's questionnaire, household questionnaire and man's questionnaire was used to collect data from preselected households. During the survey, child immunization status information was collected from the immunization card and recall on vaccination by the mother. Mothers' information on immunization was recorded as valid immunization status. KDHS data is available upon approval of request. More information on KDHS has been provided elsewhere (37).

3.2 Study Population

Participants were children of ages 12 to 23 months. Children aged between 12 and 23 months are expected to have completed the vaccines according to the KEPI schedule.

3.3 Description of Variables

Outcome variable: Time (in weeks) to vaccine uptake. This was calculated using the recorded date of vaccination and the date of birth of child.

In order to calculate timelines for each of the vaccines, three categories were generated from time to vaccine uptake as follows:

Early: The proportion of children who received a vaccine before the recommended range for timeliness(13)

Timely: The proportion of children who received a vaccine two weeks before or within one month from the recommended age

Delayed: The proportion of children who received a vaccine more than four weeks from the recommended age

Independent variables: From the literature review, variables associated with time to immunization uptake were identified. Maternal, child factors were included in the analysis. Child's sex (Male, Female), Place of delivery (Home, Health facility, Other), Birth order (1, 2-4, 5+), Place of residence(Urban, Rural), Maternal education(None, Primary, Secondary+), Marital status(In a union, Not in a union), Wealth index(Poorest, Poorer, Poor, Richer, Richest), Religion(Christian, Muslim, Other),Sex of the household head(Male, Female), ANC visits (0, 1=3, 4+), Maternal age (15-19, 20-29, 30-39, 40-49), Birth size (Small, Average, Large)

Table 2 Guideline for recommended age and delay for vaccines

Vaccine	**Early**	**Recommended age**	**Delay**
BCG	-	Birth	>4 weeks
OPV1	<4 weeks	6 Weeks	>10 Weeks
OPV2	<8 weeks	10 Weeks	>14 Weeks
OPV3	<12 weeks	14 Weeks	>18 Weeks
Penta1	<4 weeks	6 Weeks	>10 Weeks
Penta2	<8 weeks	10 Weeks	>14 Weeks
Penta3	<12 weeks	14 Weeks	>18 Weeks
Measles	<34 weeks	9 Months	>10 Months

Source: (59)

3.4 Statistical Analysis

Data wrangling and analysis was done using STATA 12. Categorical variables were summarized by providing frequencies and percentages. Timeliness of vaccination was calculated based on the date of vaccine administration and date of birth of child. Only complete cases with vaccination dates were included in the analysis for timeliness. Kaplan Meier, a non-parametric estimate, was used to estimate the cumulative vaccination coverage. Kaplan Meir curves were constructed for each of the vaccines.

Multilevel Cox proportional hazards regression was used to model the predictors of time-to-immunization uptake to account for county level characteristics. For the Cox model, delayed and early vaccinations were combined as untimely vaccinations. The event of interest (failure) was untimely vaccine uptake and the survival time was time in weeks until a child received a vaccine. Censored observations were of those children receiving a specific vaccine on time.

The fitted model was:

$$\boldsymbol{h(t) = h_0(t)\exp(\beta_i X_i + \alpha_j)}$$

Where: β_i – Regression coefficients

h (t) - the expected hazard at time t,

h_0 (t) - the baseline hazard and represents the hazard when all of the predictors X_i are equal to zero.

X_i – Independent/Predictor variables

α_j - Random effect associated with j^{th} cluster

All variables in the univariable were included in the multivariable model on the basis that they are important in informing policy decisions on immunization and have been shown to be associated with immunization from literature. The Cox PH test was used to check for the proportional hazards assumption in the univariable model. Hazard ratios and their confidence intervals were generated for the predictor variables and reported.

3.5 Ethical Statement

Since the data to be used for this study is secondary, there will be no direct interaction with human subjects. However, the data was handled with confidentiality and was used only for this study. Ethical approval to carry out the study will be sought from Moi University/Moi Teaching and Referral Hospital Institutional Review and Ethics Committee (IREC). Written approval to use the data was obtained from the DHS Program. The relevant approval letters are attached on the Appendix.

3.6 Dissemination

Research findings were written and presented to the University of Nairobi. The results will also be published in relevant journals to be accessed by other researchers and relevant stakeholders.

3.7 Study Timelines

Table 3 Study Timelines

Activity	Timelines
Proposal writing	January-March
Ethical Review	March-May
Data Analysis	June-September
Compilation of final report	October

3.8 Study budget

Table 4 Budget

Item	Cost(Kshs)
Proposal printing	2000
Ethical Approval	3000
Final Thesis Binding	3000
Total	8000

CHAPTER FOUR: RESULTS

4.1 Sample Characteristics

A total of 4,209 children aged 12–23 months were included in the analysis for coverage. Of the 4209, 1597 children who had vaccination dates were included in the analysis for timeliness. About half of the sampled children were males (51.8%), of birth order of two to four (50.3%) and were delivered in a health facility (50.7%). Majority of the children resided in urban areas (68.8%) and were Christians (79.9%). Majority of the children had their mothers attaining primary education (52.6%), were in a union (85.2%) and were aged 20-29 (57.5%) (Table 5).

4.2 Vaccination Coverage

Table 6 presents the vaccination coverage and timeliness. The proportion of full immunization coverage was 54.3%. The coverage was highest for BCG (95.8%), OPV1 (96.6%) and Pentavalent1 (96.5%). Overall, the coverage reduced over time for the three doses of OPV (1st dose 96.6% to 3rd dose 81.5%), Pentavalent (1st dose 96.5% to 3rd dose 89.2%) and Pneumococcal Conjugate vaccine (1st dose 92.6% to 3rd dose 84.7%). The vaccination coverage was lowest for OPV birth dose (73%). The national immunization coverage based on Pentavalent 3 estimates was 89.2%. The proportion of unimmunized children was higher for OPV0 (26.9%) and OPV3 (18.6%).

Cumulative vaccination coverage based on inverse Kaplan Meir curves is presented in Figure 2. It takes about 20 weeks for 50% of the children to complete Pentavalent, OPV and PCV vaccines. For measles, vaccine completion by 40 weeks of age was attained by about 10% of the children. 50% of the children had received BCG vaccination by week 8.

Table 5 Sample Characteristics

Characteristics of the study Sample		n	Proportion (%)
Education	No Education	894	21.24
	Primary	2,213	52.58
	Secondary and above	1,102	26.18
Marital Status	Not in a union	625	14.85
	In a union	3,584	85.15
No of ANC visits	0	227	5.76
	1–3	1,556	39.45
	≥4	2,161	54.79
Maternal age	40–49	249	5.92
	30–39	1,243	29.53
	20–29	2,419	57.47
	15–19	298	7.08
Child Sex	Male	2,181	51.82
	Female	2,028	48.18
Birth Order	One	971	23.07
	Two to Four	2,119	50.34
	Five and above	1,119	26.59
Birth Size	Large	486	24.06
	Average	1,175	58.17
	Small	359	17.77
Place of delivery	Home	1,834	43.70
	Health facility	2,127	50.68
	Other	236	5.62
Place of residence	Rural	1,314	31.22
	Urban	2,895	68.78
Religion	Christians	3,361	79.99
	Muslims	710	16.90
	Other	131	3.12
Sex of household head	Male	3,013	71.58
	Female	1,196	28.42
Wealth Index	Poorest	1,490	35.40
	Poorer	877	20.84
	Middle	683	16.23
	Richer	621	14.75
	Richest	538	12.78
Region	Nairobi	113	2.68
	Central	306	7.27
	Coast	550	13.07
	Eastern	597	14.18
	Nyanza	615	14.61
	Rift Valley	1,351	32.1
	Western	373	8.86
	North Eastern	304	7.22

4.4 Vaccination Timeliness

Overall, 28.3% of the children received vaccines on time, 47.5% received early while 24.1% had delayed vaccines. Majority of the children received BCG (87.1%) and OPV0 (96.1%) on time. Of the untimely vaccinations, the proportion of early vaccinations were higher than delayed vaccinations for all vaccines except measles (Early: 8.6% vs delayed: 16.9%). The proportion of early vaccination was highest for OPV1 (46.7%) and lowest for measles (8.6%) while that of delayed vaccination was highest for OPV3 (20.3) and lowest for PCV1 (9.5%) (Table 6).

Table 6 Vaccination Coverage and Timeliness

Vaccination Coverage and Timelines

	Coverage		Timeliness		
Vaccine	Vaccination coverage (%)	Unimmunized (%)	Early (%)	Timely (%)	Delayed (%)
All vaccines	**54.30%**	**1.95**	**47.5**	**28.4**	**24.1**
BCG	95.80	4.20		87.09	12.91
OPV0	73.03	26.97		96.06	3.94
OPV1	96.62	3.38	46.72	43.66	9.62
OPV 2	93.5	6.50	41.15	43.28	15.57
OPV 3	81.45	18.55	38.55	41.16	20.29
Pentavalent1	96.54	3.46	46.47	45.25	8.27
Pentavalent2	95.06	4.94	40.84	45.02	14.15
Pentavalent3	89.24	10.76	38.10	42.22	19.69
PCV1	92.62	7.38	45.41	45.09	9.50
PCV2	90.57	9.43	40.01	44.67	15.31
PCV3	84.65	15.35	37.53	42.28	20.20
Measles	84.83	15.17	8.57	74.44	16.99

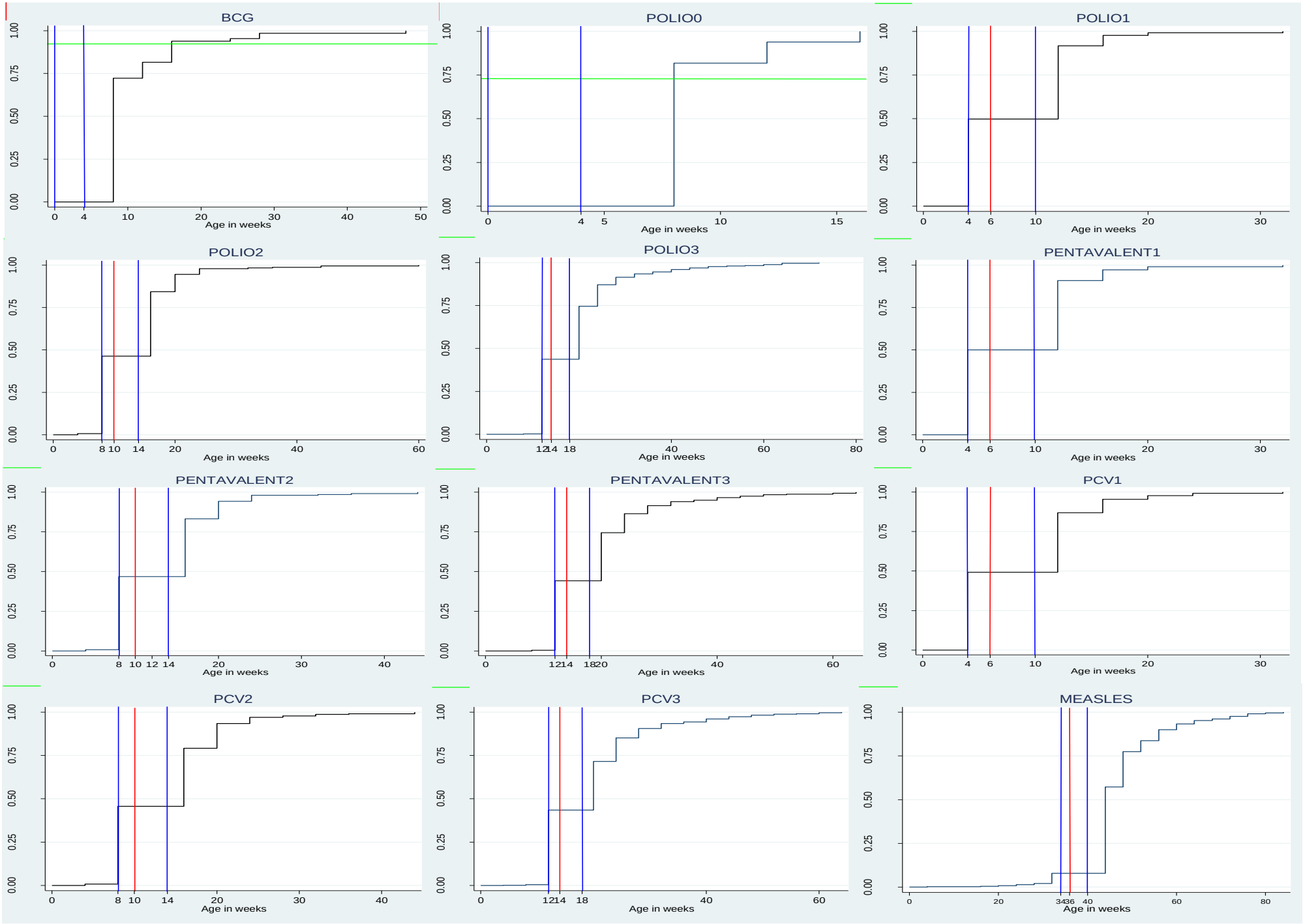

Figure 2. Inverse Kaplan Meir Plots for Vaccination Coverage

The blue lines indicate the time range for timeliness. The red line indicates the appropriate age for vaccine receipt. The green line indicates the coverage for the vaccine.

4.5 Predictors of Time-to-Vaccine Uptake

Predictors of untimely vaccination uptake (failure) were modelled for all the twelve vaccines. The models were adjusted for stratification based on the survey weights in the data. The hazards incorporate the variability in the random effects of county level characteristics. The independent variables included in the models differed in their association and prediction of untimely vaccinations as shown in Table 7-10.

Children from Muslim (HR: 3.19, 95% CI: 1.44–7.12), female headed (HR: 1.99, 95% CI: 1.23–3.24) and middle income (HR: 2.50, 95% CI: 1.2–5.22) households were more likely to have untimely BCG vaccinations compared to children from Christian, male headed and poorest respectively. Children of birth order of two to four (HR: 0.32, 95% CI: 0.16–0.61) and more than four (HR: 0.43, 95% CI: 0.19–0.98) had reduced hazards of untimely BCG vaccination. Children who were born in a health facility were 1% less likely to have untimely BCG vaccination compared to those born at home.

Female children had a 31% reduced hazards of untimely OPV dose at birth (OPV0). Birth size was associated with time to OPV1 uptake (HR: 0.77, 95% CI: 0.60–0.99), with children of small birth size being 23% less likely to have untimely OPV1 vaccine. Children whose mothers were in a marital union had 4% reduced hazards of untimely OPV3 uptake (HR: 0.96, 95% CI: 0.76–1.22) compared to those whose mothers were not in a union.

Birth order of five and above was associated with time to OPV2, OPV3, Pentavalent2 Pentavalent3 and PCV3 vaccinations while health facility delivery was associated with time uptake of the three doses of OPV, Pentavalent and Pneumococcal Conjugate vaccine. Secondary education and above

was associated with time to uptake of the three doses of Pneumococcal Conjugate Vaccine, OPV2 and OPV3 while primary education level was associated with time to OPV3 vaccine uptake.

Children whose mothers had ANC 4+ visits were 55% more likely to have untimely measles vaccination (HR: 1.55, 95% CI: 0.77–3.10) compared to those mothers had no ANC visit.

Table 7 Predictors of time to immunization uptake (BCG, OPV0, and Measles)

Predictors of time to immunization uptake (BCG, OPV0, Measles)							
	Vaccine	**BCG**		**OPV0**		**Measles**	
Variables	**Categories**	**HR (95% CI)**	**P-value**	**HR (95% CI)**	**P-value**	**HR (95% CI)**	**P-value**
Education	No Education	1		1		1	
	Primary	1.07(0.70-1.76)	0.794	3.64(0.66-19.99)	0.137	1.16(0.80-1.69)	0.408
	Secondary +	1.76(0.76-4.04)	0.184	2.85(0.20`-39.95)	0.436	1.12(0.69-1.82)	0.632
Marital Status	Not in union	1		1		1	
	In a union	1.32(0.65-2.66)	0.441	0.61(0.08-4.84)	0.638	0.89(0.59-1.34)	0.593
No of ANC visits	0	1		1		1	
	1=3	1.27(0.64-2.50)	0.492	0.08(0.003-1.71)	0.106	1.27(0.64-2.52)	0.493
	>=4	0.96(0.48-1.89)	0.898	0.07(0.003-1.34)	0.077	1.55(0.77-3.1)	0.212
Maternal age	40-49	1		1		1	
	30-39	0.58(0.28-1.16)	0.124	4.27(0.29-61.09)	0.285	0.81(0.48-1.39)	0.463
	20-29	0.75(0.34-1.65)	0.469	3.61(0.16-81.67)	0.420	0.71(0.40-1.27)	0.261
	15-19	0.40(0.12-1.31)	0.132	1.81(0.02-137.13)	0.789	0.59(0.26-1.35)	0.214
Child Sex	Male	1		1		1	
	Female	1.02(0.70-1.50)	0.890	1.08(0.31-3.77)	0.902	0.99(0.78-1.28)	0.978
Birth Order	1	1		1		1	
	2 to 4	**0.32(0.16-.61)**	**0.001**	0.59(0.07-4.63)	0.613	1.09(0.74-1.62)	0.646
	5+	**0.43(0.19-.98)**	**0.045**	0.81(0.05-12.9)	0.879	0.86(0.51-1.45)	0.561
Birth Size	Large	1		1		1	
	Average	0.86(0.54-1.38)	0.550	1.68(0.42-6.78)	0.461	1.23(0.89-1.68)	0.198
	Small	0.79(0.44-1.42)	0.444	1.19(0.19-7.3)	0.847	1.18(0.79-1.75)	0.399
Place of delivery	Home	1		1		1	
	Health facility	0.99(0.59-1.67)	0.992	1.45(0.38-5.56)	0.585	0.79(0.59-1.07)	0.137
	Other	1.01(0.27-3.74)	0.986	0	1	0.99(0.56-1.76)	0.973
Place of residence	Rural	1		1		1	
	Urban	1.09(0.61-1.97)	0.772	1.91(0.35-10.5)	0.455	1.04(0.73-1.47)	0.831
Religion	Christians	1		1		1	
	Muslims	**3.19(1.44-7.12)**	**0.004**	1.97(0.18-21.6)	0.579	**2.09(1.40-3.14)**	**0.000**
	Other	1.22(0.5-2.96)	0.665	4.73(0.09-241.7)	0.439	**2.66(1.39-5.07)**	**0.003**
Sex of household head	Male	1		1		1	
	Female	**1.99(1.23-3.24)**	**0.005**	0.69(0.17-2.92)	0.621	1.24(0.93-1.65)	0.144
Wealth Index	Poorest	1		1		1	
	Poorer	1.23(0.66-2.28)	0.513	0.68(0.10-4.67)	0.694	1.27(0.89-1.82)	0.174
	Middle	**2.50(1.2-5.22)**	**0.014**	0.93(0.10-8.21)	0.945	0.77(0.48-1.26)	0.312
	Richer	1.43(0.57-3.54)	0.441	0.71(0.05-10.25)	0.799	0.96(0.59-1.54)	0.865
	Richest	0.47(0.09-2.46)	0.378	1.05(0.04-29.82)	0.975	0.98(0.52-1.84)	0.947

Table 8 Predictors of time to immunization uptake (OPV1, OPV2, and OPV3)

Predictors of time to immunization uptake(OPV1, OPV2, OPV3)							
	Vaccine	**OPV1**		**OPV2**		**OPV3**	
Variables	**Categories**	**HR (95% CI)**	**P-value**	**HR (95% CI)**	**P-value**	**HR (95% CI)**	**P-value**
Education	No Education	1		1		1	
	Primary	1.22(0.95-1.58)	0.120	1.24(0.97-1.59)	0.082	**1.32(1.02-1.69)**	**0.032**
	Secondary +	**1.46(1.06-2.0)**	**0.018**	**1.39(1.03-1.89)**	**0.033**	1.27(0.94-1.72)	0.118
Marital Status	Not in a union	1		1		1	
	In a union	0.87(0.69-1.11)	0.266	0.91(0.73-1.16)	0.467	0.96(0.76-1.22)	0.765
No of ANC visits	0	1		1		1	
	1=3	1.12(0.74-1.69)	0.591	1.27(0.85-1.89)	0.237	1.17(0.76-1.84)	0.471
	>=4	1.19(0.78-1.80)	0.415	1.25(0.84-1.87)	0.255	1.09(0.70-1.71)	0.691
Maternal age	40-49	1		1		1	
	30-39	1.08(0.76-1.56)	0.660	0.95(0.67-1.36)	0.793	1.02(0.71-1.45)	0.909
	20-29	1.18(0.81-1.75)	0.376	0.94(0.65-1.37)	0.764	1.09(0.75-1.58)	0.661
	15-19	1.05(0.62-1.77)	0.862	0.83(0.50-1.38)	0.475	0.92(0.55-1.55)	0.758
Child Sex	Male	1		1		1	
	Female	1.06(0.91-1.23)	0.452	1.07(0.92-1.24)	0.405	1.03(0.89-1.19)	0.670
Birth Order	1	1		1		1	
	2 to 4	0.88(0.72-1.09)	0.259	0.84(0.68-1.04)	0.103	0.81(0.65-1.004)	0.054
	5+	**0.76(0.56-1.03)**	**0.080**	**0.72(0.54-0.97)**	**0.03**	**0.73(0.54-.99)**	**0.044**
Birth Size	Large	1		1		1	
	Average	0.92(0.77-1.11)	0.391	0.87(0.72-1.05)	0.142	1.01(0.84-1.22)	0.898
	Small	**0.77(0.60-0.99)**	**0.043**	0.84(0.66-1.07)	0.152	0.88(0.69-1.13)	0.318
Place of delivery	Home	1		1		1	
	Health facility	**1.35(1.13-1.64)**	**0.001**	**1.28(1.06-1.54)**	**0.011**	**1.42(1.18-1.72)**	**0.000**
	Other	1.11(.76-1.64)	0.581	0.95(0.64-1.39)	0.784	1.14(0.76-1.72)	0.517
Place of residence	Rural	1		1		1	
	Urban	0.99(0.82-1.22)	0.997	0.89(0.74-1.09)	0.302	.91(0.75-1.13)	0.419
Religion	Christians	1		1		1	
	Muslims	1.27(0.97-1.66)	0.083	1.29(0.98- 1.68)	0.063	1.23(0.95-1.59)	0.121
	Other	0.98(0.62-1.54)	0.914	0.83(0.52-1.30)	0.412	0.82(0.51-1.31)	0.410
Sex of household head	Male	1		1		1	
	Female	0.94(0.79-1.12)	0.508	1.01(0.85-1.19)	0.938	1.002(0.84-1.19)	0.984
Wealth Index	Poorest	1		1		1	
	Poorer	**1.31(1.03-1.67)**	**0.026**	**1.37(1.08-1.74)**	**0.009**	1.25(0.98-1.59)	0.070
	Middle	1.09(0.84-1.45)	0.499	1.16(0.88-1.53)	0.269	1.27(0.97-1.67)	0.077
	Richer	1.03(0.76-1.37)	0.859	1.05(0 .78-1.40)	0.732	1.12(0.85-1.50)	0.409
	Richest	1.01(0.71-1.44)	0.954	1.08(0.76-1.54)	0.672	1.23(0.85-1.76)	0.269

Table 9 Predictors of time to immunization uptake (Penta1, Penta2, and Penta3)

Predictors of time to immunization uptake(Penta1, Penta2, Penta3)							
	Vaccine	**Pentavalent1**		**Pentavalent2**		**Pentavalent3**	
Variables	**Categories**	**HR (95% CI)**	**P-value**	**HR (95% CI)**	**P-value**	**HR (95% CI)**	**P-value**
Education	No Education	1		1		1	
	Primary	1.19(0.92-1.54)	0.196	1.21(0.94-1.55)	0.123	1.19(0.93-1.54)	0.155
	Secondary +	**1.43(1.04-1.97)**	**0.029**	**1.47(1.08-2.00)**	**0.014**	1.21(0.89-1.66)	0.221
Marital Status	Not in a union	1		1		1	
	In a union	0.84(0.66-1.06)	0.143	0.86(0.68-1.08)	0.185	1.08(0.85-1.38)	0.509
No of ANC visits	0	1		1		1	
	1=3	1.27(0.83-1.97)	0.265	1.37(0.91-2.07)	0.133	1.45(0.89-2.36)	0.131
	>=4	1.32(0.85-2.03)	0.205	1.41(0.93-2.13)	0.108	1.31(0.81-2.13)	0.276
Maternal age	40-49	1		1		1	
	30-39	1.09(0.77-1.57)	0.613	0.98(0.69-1.39)	0.914	1.01(0.72-1.44)	0.936
	20-29	1.21(0.83-1.77)	0.317	1.01(0.70-1.46)	0.945	1.1(0.76-1.59)	0.609
	15-19	1.06(0.63-1.78)	0.831	0.86(0.52-1.43)	0.575	1.04(0.62-1.74)	0.879
Child Sex	Male	1		1		1	
	Female	1.08(0.92-1.25)	0.348	1.1(0.95-1.28)	0.210	1.11(0.95-1.29)	0.156
Birth Order	1	1		1		1	
	2 to 4	0.89(0.71-1.09)	0.271	0.89(0.72-1.09)	0.254	0.88(0.71-1.09)	0.249
	5+	0.79(0.58-1.07)	**0.133**	**0.74(0.55- 0.99)**	**0.050**	**0.71(.52-.97)**	**0.029**
Birth Size	Large	1		1		1	
	Average	0.94(0.78-1.13)	0.521	0.93(.77-1.12)	0.471	1.02(0.84-1.23)	0.825
	Small	0.81(0.62-1.03)	0.086	0.85(0.68-1.08)	0.208	0.79(0.62-1.03)	0.079
Place of delivery	Home	1		1		1	
	Health facility	**1.4(1.15-1.69)**	**0.001**	**1.41(1.16-1.71)**	**0.000**	**1.47(1.21-1.77)**	**0.000**
	Other	1.19(0.82-1.76)	0.354	1.09(0.74-1.6)	0.659	1.28(0.85-1.91)	0.237
Place of residence	Rural	1		1		1	
	Urban	1.03(0.85-1.26)	0.755	0.99(0.81-1.22)	0.934	0.95(0.77-1.18)	0.655
Religion	Christians	1		1		1	
	Muslims	1.29(0.97-1.71)	0.075	1.27(0.98-1.65)	0.075	1.11(0.86-1.44)	0.398
	Other	0.89(0.56-1.41)	0.610	0.89(0.55-1.42)	0.621	0.79(0.49-1.26)	0.329
Sex of household head	Male	1		1		1	
	Female	0.95(0.79-1.14)	0.574	0.99(0.83-1.18)	0.888	1.02(0 .86-1.22)	0.830
Wealth Index	Poorest	1		1		1	
	Poorer	**1.34(1.05-1.71)**	**0.017**	**1.39(1.09-1.78)**	**0.006**	1.22(0.96-1.54)	0.108
	Middle	1.11(0.84-1.47)	0.446	1.25(0.95-1.64)	0.114	1.14(0.86-1.50)	0.355
	Richer	1.03(0.77-1.38)	0.830	1.01(0.76-1.35)	0.954	1.06(0.79-1.43)	0.660
	Richest	1.09(0.76-1.55)	0.628	1.14(0.81-1.64)	0.444	1.26(0.88-1.81)	0.207

Table 10 Predictors of time to immunization uptake (PCV1, PCV2, and PCV3)

Predictors of time to immunization uptake(PCV1, PCV2, PCV3)							
	Vaccine	**PCV1**		**PCV2**		**PCV3**	
Variables	**Categories**	**HR (95% CI)**	**P-value**	**HR (95% CI)**	**P-value**	**HR (95% CI)**	**P-value**
Education	No Education	1		1		1	
	Primary	1.15(0.88-1.50)	0.293	1.12(0.88-1.45)	0.347	1.19(0.93-1.53)	0.174
	Secondary +	**1.43(1.03-1.98)**	**0.033**	**1.42(1.04-1.93)**	**0.028**	**1.44(1.06-1.95)**	**0.021**
Marital Status	Not in a union	1		1		1	
	In a union	0.85(0.67-1.08)	0.194	0.89(0.71-1.14)	0.382	0.86(0.68-1.09)	0.235
No of ANC visits	0	1		1		1	
	1=3	1.39(0.89-2.18)	0.137	1.42(0.93-2.15)	0.104	1.49(0.94-2.38)	0.088
	>=4	1.36(0.88-2.12)	0.169	1.44(0.95-2.19)	0.088	1.28(0.81-2.05)	0.284
Maternal age	40-49	1		1		1	
	30-39	1.09(0.76-1.58)	0.619	1.03(0.71-1.48)	0.864	1.02(0.70-1.48)	0.917
	20-29	1.25(0.85-1.85)	0.247	0.98(0.67-1.44)	0.934	1.07(0.73-1.59)	0.715
	15-19	1.24(0.74-2.12)	0.412	0.92(0.55-1.55)	0.764	0.91(0.54-1.56)	0.744
Child Sex	Male	1		1		1	
	Female	1.11(0.95-1.29)	0.183	1.09(0.93-1.27)	0.288	1.02(0.87-1.19)	0.771
Birth Order	1	1		1		1	
	2 to 4	1.05(0.85-1.31)	0.637	0.98(0.79-1.22)	0.863	0.84(0.68-1.05)	0.124
	5+	1.06(0.78-1.44)	0.712	0.79(0.58-1.07)	0.134	**0.67(0.49-.93)**	**0.015**
Birth Size	Large	1		1		1	
	Average	0.88(0.72-1.06)	0.177	0.92(0.76-1.11)	0.387	1.002(0.83-1.21)	0.984
	Small	0.82(0.63-1.04)	0.113	0.95(0.75-1.21)	0.679	0.81(0.63-1.05)	0.112
Place of delivery	Home	1		1		1	
	Health facility	**1.36(1.12-1.65)**	**0.002**	**1.32(1.09-1.62)**	**0.004**	**1.36(1.13-1.65)**	**0.001**
	Other	1.07(0.74-1.56)	0.712	0.86(0.58-1.29)	0.481	1.1(0.73-1.68)	0.64
Place of residence	Rural	1		1		1	
	Urban	1.07(0.87-1.32)	0.521	1.04(0.85-1.28)	0.685	0.98(0.79-1.21)	0.866
Religion	Christians	1		1		1	
	Muslims	1.26(0.94-1.69)	0.117	1.26(0.96-1.64)	0.093	1.09(0.85-1.39)	0.487
	Other	0.94(0.59-1.52)	0.809	0.9(0.57-1.43)	0.664	0.79(0.48-1.29)	0.346
Sex of household head	Male	1		1		1	
	Female	**0.82(0.68-.98)**	**0.033**	0.93(0.78-1.12)	0.491	0.84(0.71-1.03)	0.082
Wealth Index	Poorest	1		1		1	
	Poorer	1.31(1.02-1.66)	0.032	1.39(1.09-1.78)	0.008	1.06(0.83-1.35)	0.62
	Middle	1.16(0.88-1.53)	0.314	1.24(0.94-1.65)	0.131	1.29(0.98-1.71)	0.07
	Richer	1.17(0.87-1.58)	0.285	1.10(0.81-1.49)	0.52	1.01(0.76-1.37)	0.895
	Richest	1.1(0.76-1.59)	0.606	1.24(0.86-1.79)	0.247	1.23(0.86-1.77)	0.248

CHAPTER FIVE: DISCUSSION

This study shows a relatively high coverage for all the vaccines while the proportion of children receiving the vaccines on time was lower with more than half of the vaccines given outside the timeliness range. The factors included in the analysis predicted time to vaccination uptake differently for each vaccine.

Coverage was highest for BCG and Pentavalent2 while the proportion of timely vaccines were highest for BCG and OPV0. The high proportion of timely BCG and OPV0 could be related to the high proportion of children born in health facilities where the vaccines accessible at birth. These findings agree with those of previous studies (13–16) which have also shown that despite a high vaccination coverage, timeliness of vaccines is very low.

The proportion of children who had received all the vaccines according to the KEPI schedule was only 54.3%. This is consistent with a study in West Africa (41) and Malawi (47) which reported low prevalence of fully immunized child (FIC) despite high individual vaccination coverage. This shows that there is still challenge in the completeness and timeliness despite the selfless efforts towards improving immunization in general. The low FIC estimate could also be explained by the fact that DHS-type surveys underestimate full immunization coverage (60). The estimate for national immunization coverage based on the third dose of Pentavalent vaccine is 89% which is consistent with the KDHS estimates (61). This study reported high timely measles vaccinations confirming previous studies (14,46,58).

This study, unlike most studies on vaccination timeliness, assessed not just delays but also early vaccinations. Surprisingly, the proportion of early vaccinations were higher than delayed vaccination for all the vaccines except measles. One study that included early vaccination as part

of untimely vaccination reported lower proportion of early vaccination (13.4%) compared to delayed vaccination (63.3%) (52). Evaluation of early vaccinations provides valuable insight and gives a new focus in studying timeliness. Previous studies have suggested that early Measles vaccinations are advantageous but booster vaccines are still required to maintain the elicited immune responses (62) Many other studies (63,64) have suggested the benefits and drawbacks of untimely vaccinations (both early and late) but further research on this is necessary before any conclusions can be made.

There was decrease in the proportion of timely vaccinations from BCG to OPV3, Pentavalent3 and PCV3 a finding consistent with a study in the Gambia (52) but contrary to a study in Nigeria (63). Some studies have found reasons for delay in age appropriate vaccination to be forgetting (52), long waiting time (52), pain and fever on injection site (52), long distance to the health facility (54).

This study identified various predictors of time to vaccine uptake which were different for the vaccines and the vaccine doses. There was a significant association between health facility delivery and time to Pentavalent3 uptake, a finding consistent with a study by Odutola et al that found a significant association between health facility delivery and DPT3 uptake. In addition, this study found a statistically significant association between health facility delivery and time to uptake of all the three doses of OPV, Pentavalent and PCV. This could be due to the fact these vaccines are usually given together at same intervals. This finding mirrors a better health service delivery where immunization services are properly used. Health services utilization is improving with increased Reach Every Child strategies for immunization in marginalized communities(65) and better knowledge of the benefits of Health facility delivery and preventative effects of vaccination(66).

Children whose mothers had secondary+ level of education were more likely to have untimely vaccination for OPV3 contrary to a study that found that children whose mothers had attained high school+ level were less likely to have delayed OPV3 vaccination (53) and Penta3 vaccination (55). In Kenya, maternal education has been shown be positively associated with immunization coverage with educated women more likely to have their children vaccinated compared to the uneducated (67). Educated women have better knowledge of the importance of immunization(65) but have poor health seeking behavior (68) due to increased responsibilities including employment and household chores (66)

Birth order of more than one negatively predicted untimely vaccinations for all the vaccines except PCV1. This is contrary to a study in Uganda (58) and South Africa (13) that found that children with siblings were more likely to have untimely vaccination compared to those who had none. Female children were more likely to have untimely vaccinations for all the vaccines for all the vaccines compared to their male counterparts, a finding that has been established by a previous study (54). Other predictors identified by this study include wealth status, religion which associated with untimely measles vaccination, urban residence which negatively predicts untimely vaccination for most of the vaccines. These predictors reflect the importance of individual, socioeconomic, and contextual factors towards improving immunization services.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study reports high vaccination coverage with significant proportions of untimely vaccination with early vaccination being higher than delayed vaccinations. Time to immunization uptake was associated with wealth status, education level, place of delivery, birth order and place of residence among other factors. While it is important to monitor vaccination coverage as an indicator for effective immunization programs, this effectiveness is greatly influenced by the timeliness of vaccine receipt. In addition to the efforts already in place to improve immunization in Kenya, timeliness of the vaccines should be a focus while considering individual and contextual factors.

6.2 Strength and Limitations

This is study used a nationally representative data which makes the results generalizable to the entire population of Kenya. This is one of the first studies to assess timeliness of all the vaccines in the KEPI schedule. Some of the limitations of this study include the lack of a standard definition of timeliness and the definition used is based on those of previous studies(50,60). The vaccination dates included in the analysis included both date on health cards and as recalled by mothers which may introduce a recall bias. KDHS dataset has missing observations for very vital variables and the dates are recorded in Century Month Codes (CMC) which limits the accuracy of time estimates.

6.3 Recommendations

Based on the findings of this studies,

- Health departments and immunization planning teams should consider timeliness of vaccine uptake as a performance indicator for immunization service, taking into account both delayed and early vaccination.
- Future studies should explore extensively early vaccinations and its implications on immunization programs and child health as whole.
- The DHS program should consider recoding the exact vaccination date for future surveys instead of the CMC to better estimate time.

REFERENCES

1. WHO. Reducing mortality rates [Internet]. Vol. 9, Burns. 2019 [cited 2020 Feb 19]. Available from: https://www.who.int/news-room/fact-sheets/detail/children-reducing-mortality

2. UNICEF. Vaccination and Immunisation Statistics- UNICEF data [Internet]. Vol. 28, Vaccine. 2018 [cited 2020 Feb 20]. p. 1. Available from: https://data.unicef.org/topic/child-health/immunization/%0Ahttps://data.unicef.org/topic/child-health/immunization/%0Ahttps://data.unicef.org/topic/child-health/immunization

3. WHO. More than 140,000 Die From Measles as Cases Surge Worldwide [Internet]. Newsroom. 2019 [cited 2020 Mar 20]. p. 1. Available from: https://www.who.int/news-room/detail/05-12-2019-more-than-140-000-die-from-measles-as-cases-surge-worldwide

4. WHO. Title of Section (TK) Global Vaccine Action Plan. In 2013 [cited 2020 Feb 20]. Available from: www.who.int

5. World Health Organization. Immunization coverage [Internet]. Fact sheet. 2019 [cited 2020 Mar 20]. p. 1. Available from: https://www.who.int/news-room/fact-sheets/detail/immunization-coverage

6. Vanderslott, S & Roser M. Vaccination - Our World in Data [Internet]. 2019 [cited 2020 Feb 20]. Available from: https://ourworldindata.org/vaccination

7. Mihigo R, Okeibunor J, Anya B, Mkanda P, Zawaira F. Challenges of immunization in the African Region. Pan Afr Med J. 2017;27.

8. WHO. Progress and Challenges with Achieving Universal Immunization [Internet]. 2019 [cited 2020 Feb 20]. Available from: https://ourworldindata.org/vaccination

9. Mihigo R, Okeibunor J, Masresha B, Mkanda P, Zawaira F, Cabore J. IMMUNIZATION AND VACCINE DEVELOPMENT: Progress towards High and Equitable Immunization Coverage in the Africa Region from 2012 to 2016. J Immunol Sci. 2018 Sep 1;2(SI1):1–9.

10. Otieno S. African nations miss vaccines coverage target - SciDev.Net Sub-Saharan Africa [Internet]. [cited 2020 Feb 20]. Available from: https://www.scidev.net/sub-saharan-africa/medicine/news/african-nations-miss-vaccines-coverage-target.html?__cf_chl_jschl_tk__=8fc44df8806cea85c5f1dbaa4c48277621e5ac3e-1582203118-0-AcpVrfD6ZvntNNJIHG4ECP6WckJ_rLjWEiKyJD4Rfz1z7k54yFeSmbSKJsB6lExX8hu4rhFmPE

11. Hu Y, Li Q, Chen Y. Timeliness of Childhood Primary Immunization and Risk Factors Related with Delays: Evidence from the 2014 Zhejiang Provincial Vaccination Coverage Survey. Int J Environ Res Public Health. 2017;14(9).

12. Yadav K, Srivastava R, Kumar R, Chinnakal P, Rai SK, Krishnan A. Significant vaccination delay can occur even in a community with very high vaccination coverage: Evidence from Ballabgarh, India. J Trop Pediatr. 2012;58(2):133–8.

13. Fadnes LT, Nankabirwa V, Sommerfelt H, Tylleskär T, Tumwine JK, Engebretsen IMS. Is vaccination coverage a good indicator of age-appropriate vaccination? A prospective study from Uganda. Vaccine. 2011;

14. Mansour Z, Said R, Brandt L, Khachan J, Rady A, Fahmy K, et al. Factors affecting age-

appropriate timeliness of vaccination coverage among children in Lebanon. Gates Open Res. 2018;2(0):1–13.

15. Miyahara R, Jasseh M, Gomez P, Shimakawa Y, Greenwood B, Keita K, et al. Barriers to timely administration of birth dose vaccines in The Gambia, West Africa. Vaccine [Internet]. 2016;34(29):3335–41. Available from: http://dx.doi.org/10.1016/j.vaccine.2016.05.017

16. Stein-Zamir C, Israeli A. Timeliness and completeness of routine childhood vaccinations in young children residing in a district with recurrent vaccine-preventable disease outbreaks, Jerusalem, Israel. Eurosurveillance. 2019;

17. Jc N, Maduka O. Completeness and timeliness of immunization among children aged 12 to 23 months in South-South Nigeria. J Community Med Prim Heal Care. 2019;31(1):22–31.

18. Hull BP, McIntyre PB. Timeliness of childhood immunisation in Australia. Vaccine. 2006;24(20):4403–8.

19. Offit P. Global Immunization: Worldwide Disease Incidence | Children's Hospital of Philadelphia [Internet]. Children's hospital of Philadelphia. 2018 [cited 2020 Feb 24]. Available from: https://www.chop.edu/centers-programs/vaccine-education-center/global-immunization/diseases-and-vaccines-world-view

20. WHO. WHO | Immunization. 2018;

21. WHO. Smallpox [Internet]. 2020 [cited 2020 Nov 17]. Available from: https://www.who.int/health-topics/smallpox#tab=tab_1

22. GPEI. GPEI – Global Polio Eradication Initiative [Internet]. 2018 [cited 2020 Nov 17]. Available from: https://Polioeradication.org/

23. CDC. CDC Global Health - Global Immunization - Why CDC is Commited to Global Immunization [Internet]. 2011 [cited 2020 Feb 25]. Available from: https://www.cdc.gov/globalhealth/immunization/why/

24. Philippe D, Jean-Marie O-B, Marta G-D, Thomas C. Global immunization: status, progress, challenges and future. BMC Int Health Hum Rights. 2009 Oct 14;9(Suppl 1):S2.

25. Tiande L. Expanded programme on immunization. Vol. 19, International Journal of Epidemiology. 1990. p. 219–20.

26. Jonna L. Global Vaccination Coverage Remains Unchanged at 86% Since 2010 [Internet]. 2019 [cited 2020 Feb 26]. Available from: https://www.contagionlive.com/news/global-vaccination-coverage-remains-unchanged-at-86-since-2010

27. Richard Mihigo, Nadia AbdelAziz Teleb Badr HO and IC. Global Vaccine Action Plan. Vol. 31, Vaccine. 2013.

28. Clemens J, Holmgren J, Kaufmann SHE, Mantovani A. Ten years of the global Alliance for vaccines and immunization: Challenges and progress. Nat Immunol [Internet]. 2010;11(12):1069–72. Available from: http://dx.doi.org/10.1038/ni1210-1069

29. Wang SA, Mantel CF, Gacic MD, Dumolard L, Cherian T, Flannery B, et al. Progress in introduction of pneumococcal conjugate vaccine - Worldwide, 2000-2012. Morb Mortal Wkly Rep. 2013 Apr 26;62(16):308–11.

30. Burchett HED, Mounier-Jack S, Griffiths UK, Biellik R, Ongolo-Zogo P, Chavez E, et al.

New vaccine adoption: Qualitative study of national decision-making processes in seven low- and middle-income countries. Health Policy Plan [Internet]. 2012 May 1 [cited 2020 Nov 17];27(SUPPL.2):5–16. Available from: https://academic.oup.com/heapol/article/27/suppl_2/ii5/594662

31. Mihigo R, Okeibunor J, Anya B, Mkanda P, Zawaira F. Challenges of immunization in the African Region. Pan Afr Med J. 2017;27(Suppl 3):12.

32. Richard Mihigoi, Blanche Anyai, Joseph Okeibunori, Alain Poyi, Shingai Machingaidzeii, Charles S Wiysongeii, Gregory D Husseyii DN. Routine immunization in the WHO African Region : Progress ,. 2015;(July).

33. Olayinka F. Immunization in Africa: A story of hope and progress, but also challenges [Internet]. World Economic Forum. 2016 [cited 2020 Feb 25]. Available from: https://www.weforum.org/agenda/2016/05/immunization-in-africa-a-story-of-hope-and-progress-but-also-challenges

34. WHO. WHO | WHO recommendations for routine immunization - summary tables [Internet]. Who. 2016 [cited 2020 Feb 19]. Available from: https://www.who.int/immunization/policy/immunization_tables/en/

35. GoK. Ministry of Health National Policy Guidelines on Immunization. 2013;74. Available from: http://e-cavi.com/wp-content/uploads/2014/11/KENYA-NATIONAL-POLICY-ON-IMMUNIZATION-2013.pdf

36. KenyaPharmTech. Kenya Expanded Programme on Immunization Schedule 2019 [Internet]. 2019 [cited 2020 Feb 19]. Available from: https://www.kenyapharmtech.com/kenya-expanded-programme-immunization-schedule/

37. Feldstein LR, Mariat S, Gacic-Dobo M, Diallo MS, Conklin LM, Wallace AS. Global routine vaccination coverage, 2016. Morb Mortal Wkly Rep. 2017 Nov 17;66(45):1252–5.

38. Hill HA, Elam-Evans LD, Yankey D, Singleton JA, Kang Y. Vaccination coverage among children aged 19–35 months — United States, 2016. Morb Mortal Wkly Rep. 2017 Nov 3;66(43):1171–7.

39. Boulton ML, Carlson BF, Power LE, Wagner AL. Socioeconomic factors associated with full childhood vaccination in Bangladesh, 2014. Int J Infect Dis. 2018 Apr 1;69:35–40.

40. Casey RM, Hampton LMC, Anya BPM, Gacic-Dobo M, Diallo MS, Wallace AS. State of equity: childhood immunization in the World Health Organization African Region. Pan Afr Med J. 2017;27(Suppl 3):5.

41. Kazungu JS, Adetifa IMO. Crude childhood vaccination coverage in West Africa: Trends and predictors of completeness [version 1; Referees: 1 approved, 3 approved with reservations]. Wellcome Open Res. 2017;2.

42. Machingaidze S, Wiysonge CS, Hussey GD. Strengthening the Expanded Programme on Immunization in Africa: Looking beyond 2015. PLoS Med. 2013 Mar;10(3).

43. Kiptoo E. Factors Influencing Low Immunization Coverage Among Children Between 12-23 Months in East Pokot, Baringo Country, Kenya International Journal of Vaccines and Vaccination Factors Influencing Low Immunization Coverage Among Children Between 12-23 Months in East Pokot, Baringo Country, Kenya. 2016 [cited 2020 Feb 28]; Available from: http://medcraveonline.com

44. National Bureau of Statistics Nairobi K. Republic of Kenya Kenya Demographic and

Health Survey 2014 [Internet]. 2015 Dec [cited 2020 Feb 28]. Available from: www.DHSprogram.com.

45. 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).

46. Hu Y, Chen Y, Guo J, Tang X, Shen L. Completeness and timeliness of vaccination and determinants for low and late uptake among young children in eastern China. Hum Vaccines Immunother. 2014;10(5):1408–15.

47. Tsega A, Hausi H, Chriwa G, Steinglass R, Smith D, Valle M. Vaccination coverage and timely vaccination with valid doses in Malawi. Vaccine Reports [Internet]. 2016;6:8–12. Available from: http://dx.doi.org/10.1016/j.vacrep.2016.06.001

48. Marefiaw TA, Yenesew MA, Mihirete KM. Age-appropriate vaccination coverage and its associated factors for pentavalent 1-3 and measles vaccine doses, in northeast Ethiopia: A community-based cross-sectional study. PLoS One. 2019;14(8):1–19.

49. Walton S, Cortina-Borja M, Dezateux C, Griffiths LJ, Tingay K, Akbari A, et al. Measuring the timeliness of childhood vaccinations: Using cohort data and routine health records to evaluate quality of immunisation services. Vaccine [Internet]. 2017;35(51):7166–73. Available from: https://doi.org/10.1016/j.vaccine.2017.10.085

50. Babirye JN, Engebretsen IMS, Makumbi F, Fadnes LT, Wamani H, Tylleskar T, et al. Timeliness of childhood vaccinations in kampala uganda: A community-based cross-sectional study. PLoS One. 2012;7(4):1–6.

51. Fadnes LT, Jackson D, Engebretsen IM, Zembe W, Sanders D, Sommerfelt H, et al. Vaccination coverage and timeliness in three South African areas: a prospective study. BMC Public Health. 2011;11(1).

52. Odutola A, Afolabi MO, Ogundare EO, Lowe-Jallow YN, Worwui A, Okebe J, et al. Risk factors for delay in age-appropriate vaccinations among Gambian children. BMC Health Serv Res. 2015;

53. Dombkowski KJ, Lantz PM, Freed GL. Risk factors for delay in age-appropriate vaccination. Public Health Rep. 2004;119(2):144–55.

54. Le Polain de Waroux O, Schellenberg JRA, Manzi F, Mrisho M, Shirima K, Mshinda H, et al. Timeliness and completeness of vaccination and risk factors for low and late vaccine uptake in young children living in rural southern Tanzania. Int Health. 2013;5(2):139–47.

55. Mbengue MAS, Mboup A, Ly ID, Faye A, Camara FBN, Thiam M, et al. Vaccination coverage and immunization timeliness among children aged 12-23 months in Senegal: a Kaplan-Meier and Cox regression analysis approach. Pan Afr Med J. 2017;27(Supp 3):8.

56. Tang X, Geater A, McNeil E, Zhou H, Deng Q, Dong A. Timeliness and completeness of measles vaccination among children in rural areas of Guangxi, China: A stratified three-stage cluster survey. J Epidemiol [Internet]. 2017;27(7):317–24. Available from: http://dx.doi.org/10.1016/j.je.2016.08.006

57. Hughes MM, Katz J, Englund JA, Khatry SK, Shrestha L, LeClerq SC, et al. Infant vaccination timing: Beyond traditional coverage metrics for maximizing impact of vaccine programs, an example from southern Nepal. Vaccine [Internet]. 2016;34(7):933–41. Available from: http://dx.doi.org/10.1016/j.vaccine.2015.12.061

58. J.N. B, I.M.S. E, F. M, L.T. F, H. W, T. T. Timeliness of childhood vaccinations in kampala uganda: A community-based cross-sectional study. PLoS ONE. 2012.

59. Adetifa IMO, Karia B, Mutuku A, Bwanaali T, Makumi A, Wafula J, et al. Coverage and timeliness of vaccination and the validity of routine estimates: Insights from a Vaccine Registry in Kenya. bioRxiv. 2018;427773.

60. Adetifa IMO, Karia B, Mutuku A, Bwanaali T, Makumi A, Wafula J, et al. Coverage and timeliness of vaccination and the validity of routine estimates: Insights from a vaccine registry in Kenya. Vaccine. 2018;36(52).

61. National Bureau of Statistics-Kenya and ICF International. Kdhs 2014. Shikai Tenbo. 2014;58(1):125–32.

62. Stittelaar KJ, De Swart RL, Osterhaus ADME. Vaccination against measles: A neverending story. Vol. 1, Expert Review of Vaccines. 2002. p. 151–9.

63. Sadoh AE, Eregie CO. Timeliness and completion rate of immunization among Nigerian children attending a clinic-based immunization service. J Heal Popul Nutr. 2009;27(3):391–5.

64. Mupere E, Karamagi C, Zirembuzi G, Grabowsky M, de Swart RL, Nanyunja M, et al. Measles vaccination effectiveness among children under 5 years of age in Kampala, Uganda. Vaccine. 2006 May 8;24(19):4111–5.

65. Shikuku DN, Muganda M, Amunga SO, Obwanda EO, Muga A, Matete T, et al. Door - To - door immunization strategy for improving access and utilization of immunization Services in Hard-to-Reach Areas: A case of Migori County, Kenya. BMC Public Health

[Internet]. 2019 Aug 7 [cited 2020 Nov 18];19(1):1064. Available from: https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-019-7415-8

66. CDC. CDC Global Health - Kenya - Kenya joins the world in 'Closing the Immunization Gap' [Internet]. 2015 [cited 2020 Nov 18]. Available from: https://www.cdc.gov/globalhealth/countries/kenya/blog/closing_immunization-_gap.htm

67. Onsomu EO, Abuya BA, Okech IN, Moore DK, Collins-McNeil J. Maternal Education and Immunization Status Among Children in Kenya. Matern Child Health J [Internet]. 2015 Aug 24 [cited 2020 Nov 18];19(8):1724–33. Available from: https://pubmed.ncbi.nlm.nih.gov/25636652/

68. Li AJ, Tabu C, Shendale S, Okoth PO, Sergon K, Maree E, et al. Qualitative insights into reasons for missed opportunities for vaccination in Kenyan health facilities. Seale H, editor. PLoS One [Internet]. 2020 Mar 30 [cited 2020 Nov 18];15(3):e0230783. Available from: https://dx.plos.org/10.1371/journal.pone.0230783

APPENDIX

INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE (IREC)

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Reference: IREC/2020/61
***Approval Number:* 0003597**

3rd August, 2020

INSTITUTIONAL RESEARCH & ETHICS COMMITTEE
03 AUG 2020
RECEIVED
P. O. Box 4606-30100 ELDORET

Ms. Catherine Akoth,
University of Nairobi,
P.O. Box 30197-GPO,
NAIROBI-KENYA.

Dear Ms. Akoth,

RE: RATIFICATION OF THE DECISION TO GRANT FORMAL APPROVAL

Please note that in the IREC meeting of 25th May, 2020 the Full Committee did not ratify your Formal Approval for study ***"Time to Immunization Uptake in Kenya: A Survival Model"*** However, after addressing the concerns raised by the Committee your Formal Approval is now ratified. You may continue with your study.

Sincerely,

MS. CATHERINE OKWIRI
HUMAN PARTICIPANT ADMINISTRATOR
INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE