# The Timeliness of Childhood Vaccinations in Tanzania: A Literature Review and Analysis of Demographic Health Surveys Data

by

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Thesis submitted in partial fulfillment of
the requirements for the degree of
Master of Science in the Duke Global Health Institute
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ABSTRACT

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## Abstract

Background: Routine immunization is the most effective way to prevent mortality from vaccine preventable diseases. Though vaccination coverage rates have improved over the past decade, vaccinations still fail to be delivered and received within a proper timeframe. Across low and middle income countries the median vaccination delay falls between 2.3 to 6.2 weeks for birth through third dose vaccinations [1]. Countries in the African region have 5 to 6 percent lower coverage and face lower timeliness than LMICs overall, and in Tanzania, vaccination delays reach up to 70 percent [1, 2]. This study seeks to investigate the determinants of timely vaccination delivery using two approaches. First, a review is conducted to assess the causes of delayed vaccination in Sub-Saharan Africa (SSA) and, second, an analysis of the Tanzania Demographic and Health Surveys (DHS) data provides evidence of the timeliness factors of concern.

Methods: Peer-reviewed literature on vaccination coverage and timeliness in SSA was searched on several databases and was subsequently selected if it pertained to the determinants of vaccination coverage or vaccination timeliness for humans. Pharmacological interventions and vaccine efficacy research was excluded. The literature is rigorously reviewed by classification of determinants into four framework clusters (family characteristics, immunization systems, parental knowledge/ attitudes,

and communication and information). The 2015 Tanzania DHS data is used to measure timely immunization. Determinants of fully timely immunization are analyzed through logistic regression. Results: The results of the literature review provided 36 papers on vaccination timeliness and 15 papers on vaccination timeliness. Family characteristics are found to be the major determinants of both vaccination coverage and timeliness appearing 29 and 6 times, respectively. The immunizations system was also found to impact vaccination coverage and vaccination timeliness with 24 and 3 appearances. Our DHS analysis supports these findings, showing statistically significant links between complete timeliness and family characteristics (maternal age, wealth quintile, maternal education, and region) and the immunization system (antenatal care visits and tetanus toxoid vaccine). Conclusions: This investigation finds several family characteristics and the immunization system as determinants of delayed vaccination delivery. Escalating the number of vaccination facilities or health facilities in underserved regions could alleviate disparities found amongst families, as these characteristics are often clustered regionally. Further, action must be taken to improve the immunization system by ensuring availability of vaccines everywhere, good vaccine management, and adequate staff. Understanding the causes of poor vaccination timeliness is crucial in efforts to improve problems and provide timely vaccination to prevent child mortality.

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# List of Abbreviations

| Abbreviation | Definition |
|---|---|
| AFRO | African Regional Office |
| ANC | Antenatal Care |
| BCG | Bacillus Calmette–Guérin Vaccine |
| BCS | Binary Coverage Score |
| BTS | Binary Timeliness Score |
| CMC | Century Month Code |
| CRT | Cluster Randomized Trial |
| DHS | Demographic Heath Surveys |
| DTP1 | Diphtheria-Tetanus-Pertussis Vaccine Dose 1 |
| DTP2 | Diphtheria-Tetanus-Pertussis Vaccine Dose 2 |
| DTP3 | Diphtheria-Tetanus-Pertussis Vaccine Dose 3 |
| EPI | Expanded Program on Immunization |
| FGD | Focus Group Discussion |
| HCW | Health Care Worker |
| HepB2 | Hepatitis B Vaccine Dose 2 |
| HepB3 | Hepatitis B Vaccine Dose 3 |
| HF | Health Facility |
| LCS | Linear Coverage Score |
| LRT | Likelihood Ratio Test |
| LTS | Linear Timeliness Score |

| | |
|---|---|
| LR | Linear Regression |
| MCH | Maternal and Child Health |
| MCV1 | Measles Containing Vaccine Dose 1 |
| MLR | Multiple Logistic Regression |
| MRR | Mortality Rate Ratio |
| MV | Measles Vaccination |
| OPV | Oral Polio Vaccine |
| OPV0 | Oral Polio Vaccine Dose 0 (birth dose) |
| OPV1 | Oral Polio Vaccine Dose 1 |
| OPV3 | Oral Polio Vaccine Dose 3 |
| OR | Odds Ratio |
| Penta 1 | Pentavalent Vaccine Dose 1 |
| Penta 2 | Pentavalent Vaccine Dose 2 |
| Penta 3 | Pentavalent Vaccine Dose 3 |
| PCV | Pneumococcal Conjugate Vaccine |
| RCT | Randomized Control Trial |
| RR | Risk Ratio |
| SAGE | Strategic Advisory Group of Experts |
| SSA | Sub-Saharan Africa |
| TR | Time Ratio |
| WHO | World Health Organization |

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# 1. Introduction

The use of vaccinations is estimated to prevent 2.5 million deaths every year [3]. Polio, measles[1], tuberculosis, and tetanus are examples among the many vaccine preventable diseases, and all have decreased in incidence over the past few decades, and, in fact, polio has nearly been eradicated [4, 5]. Further, between 2000 and 2010, deaths due to diphtheria, pertussis, tetanus, measles, and polio decreased from 0.9 million to 0.4 million globally following increased vaccine uptake [3]. According to the World Health Organization, the measles vaccine alone is estimated to have prevented 20.3 million deaths globally and measles deaths have been reduced by 75 percent in the WHO defined AFRO Region since 2000 [6, 7].

The Expanded Program on Immunizations (EPI) was founded in the 1970s by the WHO, and has since addressed many issues on global vaccination from cold chain issues to vaccine quality to the implementation of routine immunization. Routine immunization services have helped to improve coverage and decrease child mortality due to vaccine preventable diseases [8]. Near the start of the program in the 1980s, vaccination coverage for the third dose of diphtheria-tetanus-pertussis vaccine (DTP3) was a mere 20 percent and by 2012, coverage was up to 83 percent [8]. There is no denying the benefits of vaccine usage given the overwhelming scientific evidence;

[1] Though recent measles outbreaks have been noted, these have occurred in unvaccinated communities.

however, it is important to ensure that these vaccines are received within the proper time window to "induce adequate protective immunity", maximize vaccine efficacy, and prevent mortality [9-11]. The WHO prescribes a vaccination schedule for children from birth through one year of age comprised of BCG, polio, DPT or pentavalent, rotavirus, PCV, and measles vaccines [12]. Additional doses are scheduled between one to five years of age to boost immunity [12]. Delayed vaccination delivery (as well as incomplete vaccination) has been shown to correlate with lower survival rates and greater mortality, as is the case for BCG and DTP [13-15]. Vaccines given earlier in life may induce a broad spectrum immune response, which would allow for protection against a greater range of pathogens and lead to a non-specific beneficial effect against infections besides those expected of the vaccine thereby decreasing mortality [13, 14]. In SSA, delayed vaccination coverage and timeliness is associated with variations in family wealth, region, and rural vs. urban living [16]. Common barriers to vaccination include distance from vaccination centers, access to media and education, and illiteracy [16].

Analysis of DHS data by Clark and Sanderson between 1996 and 2005 shows that many vaccinations are very late, and often doses are entirely skipped [1]. In the past decade, Tanzania has made significant improvements to vaccination coverage, but this does not address the regional variation in coverage rates or lack of vaccine timeliness, which disproportionately affects disadvantaged groups [17-19]. These results are supported by other studies, which also show issues of delayed commencement of

vaccination and failure to follow the vaccination schedule [15, 20-22]. Tanzania, like many sub-Saharan African countries still faces a high child mortality rate of 67 deaths per 1000 live births (compared to 43 per 1000 globally) due to diseases that are vaccine preventable [23, 24]. Targeting vaccination timeliness could greatly impact these mortality rates as it would allow children to achieve better immune response and prevent windows of time when they are unprotected. Thus, it is necessary to explore the timeliness of vaccination in Tanzania.

Exploring the causes of poor vaccination coverage and vaccination delay throughout SSA provides a foundational insight to the expected barriers and facilitators of timely vaccination in Tanzania. Because improvements to coverage mask issues caused by poor vaccination timeliness, it can be challenging to recognize the presence of vaccination delays and then determine where and why they occur. Understanding the prevalence of and reasons for vaccination delays is crucial for designing contextually specific and appropriate interventions that improve timeliness.

## *1.1 Study Aims*

Given the challenges facing timely provision and uptake of vaccinations, this study aims to investigate the current state of vaccination delivery in SSA and the specific barriers to success of vaccination timeliness within Tanzania accounting for its cultural and infrastructure.

The specific aims are:

1. To develop a literature review regarding the determinants of coverage, the timeliness, and the determinants of timeliness of childhood vaccinations in SSA.
2. To utilize the 2015 - 2016 DHS Data for Tanzania to determine vaccine coverage and timeliness and to assess determinants of vaccination delay throughout the regions of Tanzania.

## *1.2 Study Conspectus*

Chapters 2 to 4 describe results of a literature review exploring the determinants of poor vaccination coverage and delayed vaccinations throughout SSA. Published literature develops an argument for the causes of delayed vaccinations in SSA and defines a need for intervention. This is done by researching qualitative and quantitative data specific to SSA and by extrapolating vaccination delay and coverage information from other east African countries. Chapters 5 through 7 describe the analysis of 2016 Tanzania DHS data. These chapters define vaccination timeliness based on the WHO prescribed schedules to determine the state of timeliness in Tanzania. Additional preliminary analyses break down vaccination timeliness by region and type of vaccination. Further analyses, make use of appropriate statistical tools such as regression analyses to define relevant barriers and facilitators of vaccination. The determinants that are explored in Chapters 2 through 4 are statistically analyzed to

determine relevance in defining timely delivery and uptake of vaccination in Tanzania. Finally, Chapter 8 describes next steps research and for addressing the factors that impact timeliness.

# 2. Review of the Timeliness Literature: Methods

This study aims to develop a literature review regarding the timeliness of childhood vaccinations in SSA and to determine the reasons for lack of coverage and delays in childhood vaccination. PRISMA reporting guidelines were used to instruct reporting.

## *2.1 Setting*

All research is set in SSA. Countries represented include Ethiopia, Kenya, Nigeria, Guinea-Bissau, Ghana, South Africa, Guinea, Mozambique, Malawi, Senegal, Uganda, Zambia, and Tanzania. Both urban and rural environments were investigated. The surveys conducted and/or utilized in the published articles collected data from households and healthcare settings.

## *2.2 Participants*

Participants primarily include children and parents of children who are eligible for vaccination as well as care providers, community leaders, and HCWs, living in various regions of sub-Saharan Africa.

## 2.3 Procedures

A literature review on the coverage rates and timeliness of childhood vaccination was conducted to establish determinants of poor vaccination coverage and vaccination delays. The review was inclusive of all study designs regarding vaccination timeliness as well as barriers and facilitators to vaccination timeliness and coverage. The search was restricted to published literature written in English. After compiling search terms, the search was run on PubMed, Cochrane, Web of Science, and Scopus. The search was performed between November and December 2015. Search terms for "vaccination", "timeliness", "sub-Saharan Africa", and "barriers and facilitators" were combined in variation with "vaccination" serving as a root term. Details on the search terms can be found in Appendix A. Combinations included "vaccination" and "timeliness", "vaccination" and "sub-Saharan Africa", "vaccination" and "barriers and facilitators", "vaccination" and "timeliness" and "sub-Saharan Africa", and "vaccination" and "timeliness" and "sub-Saharan Africa" and "barriers and facilitators". The search combining search terms for "vaccination", "timeliness", and "sub-Saharan Africa" provided an optimal search strategy for obtaining results that were specific to vaccination coverage and timeliness in SSA.

Results from PubMed were used as the final search, which was conducted on December 2, 2015. The search results were downloaded to Endnote X7. Duplicate articles were removed using an automated feature in endnote and articles published before 1990

were manually excluded to avoid using outdated data. The remaining abstracts were subject to title and abstract screening for a full text review. Inclusion criteria were journal published articles regarding vaccination coverage and its determinants, vaccination timeliness, vaccination timeliness determinants. Articles not pertaining to humans, not located in SSA, pharmacological interventions, vaccine efficacy research, protocols, and theses or dissertations were excluded. After selecting studies, the full text was first searched for and downloaded through the EndNote X7 digital full text search. Articles that were not found through open access were obtained through the Duke University institutional access. Remaining articles that could not be accessed were requested through Research Gate or through author contact.

## *2.4 Analysis*

Each selected article was first reviewed and written into narrative summaries. Patterns which emerged from the summaries were used to determine themes universally relevant to the studies based on the research question. After broadly defining themes found to encompass the determinants of poor immunization coverage and the determinants of vaccination delays, an existing framework was investigated. One report, the "Epidemiology of the Unimmunized Child", completes a comprehensive search into the grey literature on the reasons for non-immunization across Africa, Asia, Latin-America, the Middle East, and Europe [25]. The multi-country investigation

thoroughly reports all documented factors of non-immunization and then builds on four main clusters of vaccination factors defined in the *Vaccines* article "Classification of Factors Affecting Receipt of Vaccines" [25]. These categories include family characteristics, the immunization system, parental attitudes/ knowledge, and communication and information and are shown below in Figure 1.

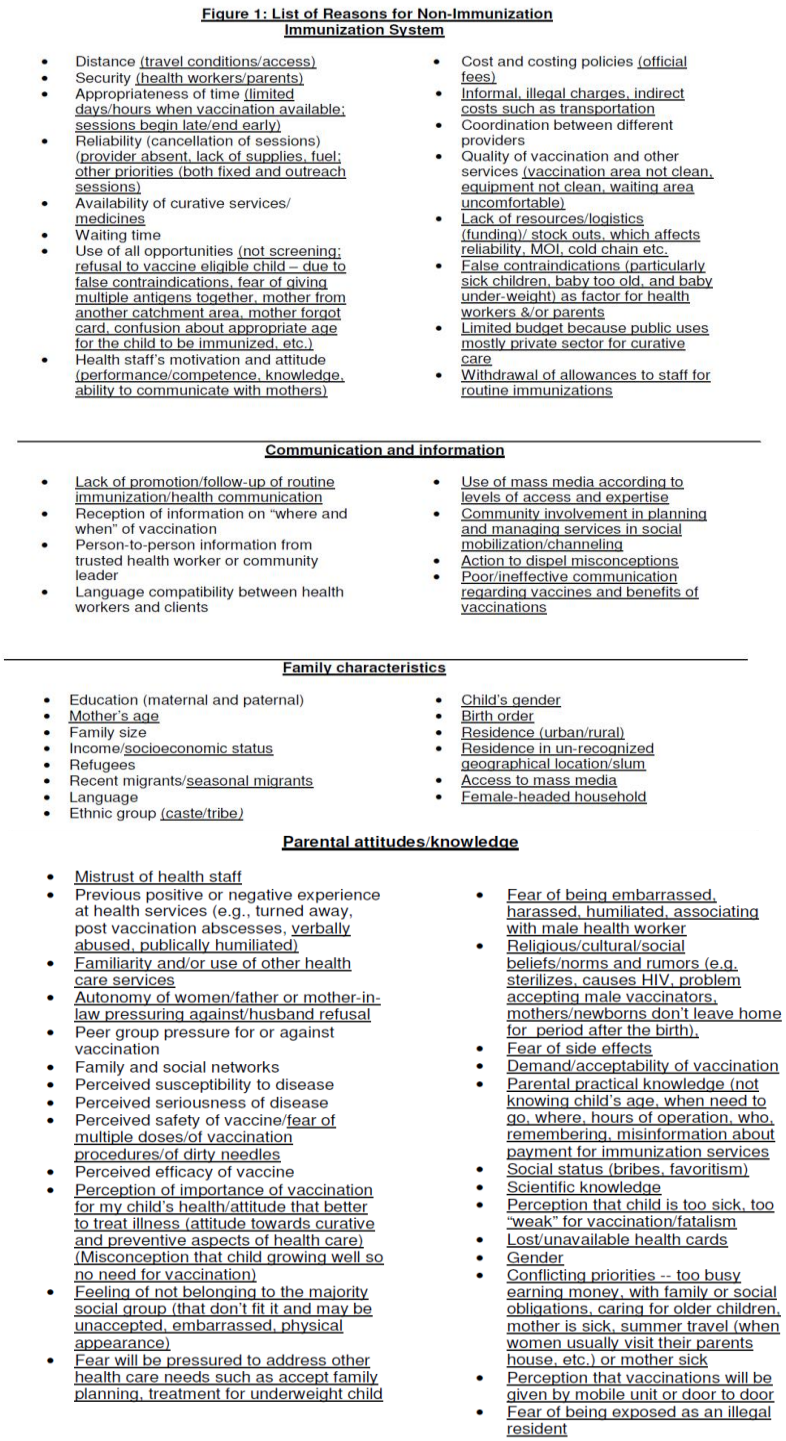


**Figure 1:** ***Epidemiology of the Unimmunized Child*** **framework with specific reasons for non-immunization.**

The broad themes defined in our study paralleled the clusters established in the unimmunized child report. The four clusters from the *Epidemiology of the Unimmunized Child* framework were used to classify both determinants of vaccination coverage and of vaccination timeliness. Data were extracted from each study and structured into the developed template as suited to the developed categories. Thus, these four clusters are used to analyze the variables reported in the literature assessed in this study. For the purpose of these analyses, the immunization system category has been expanded to include the antenatal care system as antenatal care is often found to correlate with issues of vaccination [26, 27]. It is within reason to believe that the causes of non-immunization may also be the causes of non-timely immunization [10]. Summary measures and their corresponding classifications are reported in the terms of individual articles in Table 1 and Table 2. Data extraction was completed independently by one researcher

## 3. Review of the Timeliness Literature: Results

The literature selection process is summarized in the PRISMA Flow Diagram below.

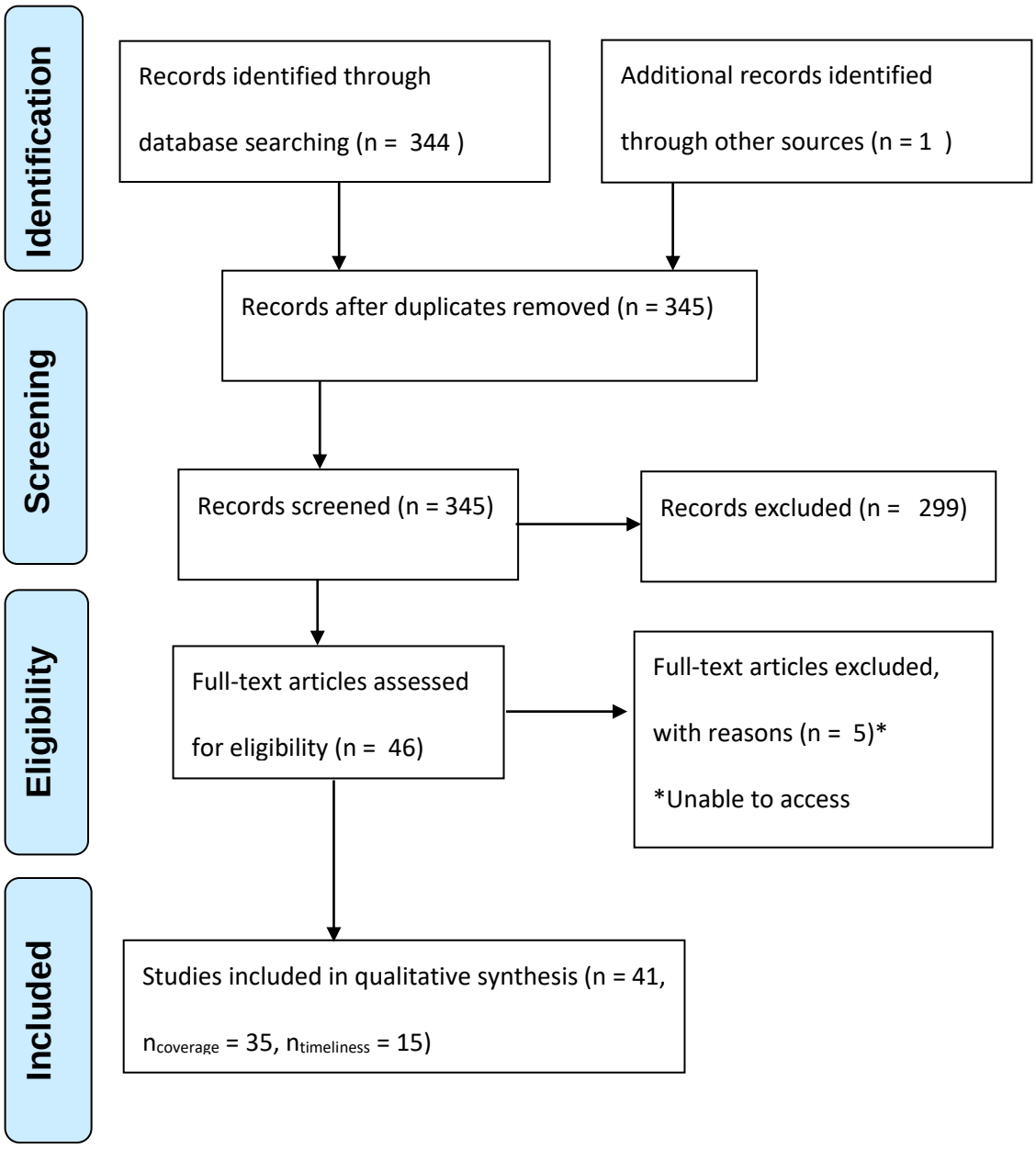


**Figure 2: PRISMA Flow Diagram**

After conducting the search on all listed databases, it was determined that PubMed returned the most relevant results and that the results were sufficient in number. Other databases duplicated the results from PubMed, provided many extraneous results from other topics (e.g. economics), or were too few in number of search results. As such, the final results represented are obtained from PubMed.

Thirty-five articles examined vaccination coverage and determinants of coverage and fifteen examined vaccination timeliness and determinants of timeliness. Table 1 and Table 2 below highlight the study characteristics and key outcomes for each paper. The articles consisted primarily of quantitative analysis, with only three qualitative assessments of the determinants of vaccination coverage and timeliness. Majority of study used cross-sectional study designs.

## *3.1 Determinants of Vaccination Coverage*

Based on the SAGE report, *Epidemiology of the Unimmunized Child*, we utilize the four pre-defined categories in our analysis of vaccination coverage and timeliness determinants.

Family characteristics appear frequently and are cited as determinants of vaccination coverage in thirty-two studies and appear eighty-five time. The family characteristic issues presented include maternal education, family wealth, household size, ethnicity, urban vs. rural residence, language, child gender, and other SES

indicators. The impact of these determinants on vaccination coverage vary significantly. A determinant that is found to be a barrier of vaccination completion in one case is also found to be a facilitator of vaccination completion in another setting. Further, in yet another study, the determinants is found to have no impact. Such is the case with maternal education. Animaw finds primary school education of a mother to be the greatest facilitator of full immunization while Fatiregun finds that completion of post-secondary education is the best facilitator [28, 29]. Not only are family characteristics found to be inconsistent with regard to whether they hinder or aid with vaccination coverage, but the degree to which a barrier or facilitator impedes or boosts vaccination coverage also varies. The inconsistency among family characteristics as determinants of vaccination coverage also exists among the degree of impact of the same level of characteristic.

Issues of the immunization system also appear frequently (cited in twenty-seven papers with fifty-one appearances) as both barriers and facilitators of vaccination coverage. Distance to a HF, whether a child was born in a clinic or at home, antenatal care, and attitude of service providers, and clinic environment are the most commonly observed determinants.

Parental attitudes/knowledge are often investigated in the literature included for analysis and when found to have an impact on vaccination coverage are generally greatly significant in degree of impact. This cluster appears impactful in thriteen of

thirty-five papers with thirty-five appearances. Parental attitudes and knowledge include awareness of immunization schedule and immunization timing, knowledge about vaccinating a child when sick and reactions to vaccinations, understanding of vaccination benefits, and perception of vaccinations having value, all of which are positively associated with vaccination coverage.

Communication and information appear least frequently in our analyses with only seven citations and seven appearances. Communication occurs though educational campaigns, provision of vaccination information by healthcare providers, and community involvement in vaccination services. Though communication and information may influence parental attitudes/ knowledge, the cluster is distinguished by its inclusion of action and mobilization efforts. The literature regarding this largely provides qualitative information.

Few papers explore the impact of non-vaccination. Benn examines the result of non-vaccination for the measles vaccination and finds higher risk of mortality. Biai finds the risk of hospitalization increases when is child is not immunized. Such studies also determine that vaccinations are generally more protective for females than males, though they are not harmful for males [15, 30].

## Table 1: Studies on Vaccination Coverage Determinants

| Author | Year | Country | Study Type/ Analysis Type | Outcome Measured | Barrier to Outcome | Facilitators of Outcome |
|---|---|---|---|---|---|---|
| | | | | | N/A or neither/both | |
| Abebe[31] | 2012 | Malawi | Cross-sectional/ multilevel LR | Full vaccination coverage[2] | Region[a] (districts varied 2 – 74%), | |
| | | | | | Illiteracy[a] (OR = 0.88), child's age, lack of toilet facility[a] (OR = 0.74), unsafe water source[a] (OR = 0.81) | Midwife delivery[b] (OR = 1.31), birth at hospital/ clinic[b] (OR = 1.0), wealthiest quintile[a] (OR = 1.13) |
| Animaw[28] | 2014 | Ethiopia | Cross-section[a]l community based/ LR | Full immunization[2] | Unaware of immunization schedule[c] (OR = 0.43, home delivery[b] (OR = 0.41), living area: high land[a] (OR = 0.48) | Mother's education: primary school[a] (OR = 2.22), perceived vaccines accessible[c] (OR = 4.54) |
| Antai[32] | 2009 | Nigeria | Cross-sectional/ multilevel LR | Full immunization[2] | Mother's occupation: clerical, sales, services, skilled manual employee[a] (OR = 0.56), poorest wealth quintile[a] (OR = 0.35) | Igbo ethnicity[a] (OR = 2.47), high level of hospital delivery in community[b] (OR = 1.12) |

[2] Child received all doses of each country recommended vaccine
[a] Family Characteristics
[b] Immunization System
[c] Parental attitudes/ knowledge

| Author | Year | Country | Study Type/ Analysis Type | Outcome Measured | Barrier to Outcome | Facilitators of Outcome |
|---|---|---|---|---|---|---|
| | | | | | N/A or neither/both | |
| Benn[15] | 2012 | Guinea-Bissau | Longitudinal cohort/ Cox proportional hazards | Mortality before 18 months<br><br>Mortality before 36 months<br><br>Mortality before 18 months<br><br>Mortality before 36 months | | Female missing 1 or more DTP doses at 9 months[a] ($MRR_{18}$ = 11.16)<br>Female missing 1 or more DTP doses at 9 months[a] ($MRR_{36}$ = 3.55) |
| | | | | | Male missing 1 or more DTP doses at 9 months[a] (no mortality at 18 months)<br><br>Male missing 1 or more DTP doses at 9 months[a] (no mortality difference at 36 months) | |
| Berry[33] | 1991 | South Africa | Cross-sectional cluster/ chi-squared | Vaccination coverage | Place of birth not Cape Town[a] ($p < 0.01$) | Educational campaign[d] (increased coverage after campaign), HF birth[b] (OR = 3.21), <6 month stay in Capetown for children born elsewhere[a] (OR = 2.22) |
| *Biai[20] | 2011 | Guinea-Bissau | Cross-sectional / binary regression | Hospitalization | | No BCG (RR = 1.99) |

[d] Communication and information

| Author | Year | Country | Study Type/ Analysis Type | Outcome Measured | Barrier to Outcome | Facilitators of Outcome |
|---|---|---|---|---|---|---|
| | | | | | N/A or neither/both | |
| Bosu[34] | 1997 | Ghana | Qualitative/ qualitative | Attendance to immunization sessions | Inadequate knowledge about immunization[c] (70% regular attendance vs. 85%), financial difficulties[a] (38% non-attendance), transportation difficulties[b], teenage or single mothers[a], poor appreciation of importance of immunization[c], service charges[b], lack of suitable venues[b], insufficient venue furniture and privacy[b], poorly motivated service providers[b], weak intersection collaboration between MOH and community leaders[b] | Attitude of service providers[b], perceived benefits of immunization on disease prevention and socio-economic development[c] |
| | | | | | Side effects of immunization[c] (non-deterrent) | |
| Brugha [35] | 1996 | Ghana | Cluster control trial/ t-test and MLR | Vaccination coverage<br><br>Completion of immunization schedule[2] | | Home visits by nurse[b] ($p<0.0001$)<br><br>Father participation in immunization decision[a] (RR = 1.85) |

| Author | Year | Country | Study Type/ Analysis Type | Outcome Measured | Barrier to Outcome | Facilitators of Outcome |
|---|---|---|---|---|---|---|
| | | | | | N/A or neither/both | |
| Cutts[36] | 1990 | Guinea | Cross-sectional and qualitative/ OR model[3] and qualitative | Received DTP1/OPV<br><br>Received DTP3/OPV | HCWs not screening vaccination status[b], mother's not provided information about vaccine reactions[d], parental knowledge about vaccinating sick children or number of vaccinations needed[c]<br><br>Not turned away from vaccination[b] (OR = 4.4), short waiting time[b] (OR = 3.1), does not know child with post vaccination abscess[c] (OR = 2.2) | Adequate vaccination supplies and support from MOH[b], parents knowledge about vaccine preventable diseases[c], importance of vaccination card and need for newborn vaccination[c]<br><br>Owning a television[a], speaking French[a], considers vaccination affordable[a] |
| Desgrees[37] | 1994 | Senegal | Cross-sectional/ univariate analysis and MLR | Vaccinated at least three times | Distance to health center[b] (OR = 0.88) | Village locations: plains vs. hills[a] (RR = 36.4, number of inhabitants in compounds[a] (RR = 1.4), |

[3] Study does not provide details about model but results presented indicate a multivariate logistic regression.

| Author | Year | Country | Study Type/ Analysis Type | Outcome Measured | Barrier to Outcome | Facilitators of Outcome |
|---|---|---|---|---|---|---|
| | | | | | **N/A or neither/both** | |
| | | | | | Ethnic group[a] (no variation)<br>Mother's age[a] (not significant) | |
| Etana[27] | 2012 | Ethiopia | Cross-sectional/ multivariate LR | Child fully vaccinated[2] | | Mother's education: literate[a] (OR = 2.8), child's birth at health institution[b] (OR = 4.4), urban residence[a] (OR = 2.99), ANC follow-up[b] (OR = 6.8), 3+ doses of TT[b] (OR = 4.9), mother's knowledge: vaccine used to prevent disease[c] (OR = 4.5), age to begin child immunization[c] (OR = 5.9), age child immunizations complete[c] (OR = 10), number of immunization sessions needed[c] (OR = 1.7) |
| Fadnes[10] | 2011 | South Africa | Community based CRT/ Cox regression | Incomplete vaccination | Geographical site[a] (HR = 7.2) | Breast feeding peer-counseling[b] (HR = 0.64), intention to formula feed[b4] (HR = 0.39) |

[4] Mother's with intention to breastfeed likely have HIV+ children and attend more health care sessions, which may explain greater vaccination completion 10. Fadnes, L.T., et al., *Vaccination coverage and timeliness in three South African areas: a prospective study.* BMC Public Health, 2011. **11**: p. 404..

| Author | Year | Country | Study Type/ Analysis Type | Outcome Measured | Barrier to Outcome | Facilitators of Outcome |
|---|---|---|---|---|---|---|
| | | | | | N/A or neither/both | |
| Fatiregun[29] | 2012 | Nigeria | Cross-sectional/ chi-squared and multivariate LR | Completion of immunization | | Both parents decide to immunize[a] ($p < 0.001$), awareness of vaccination benefit[c] ($p < 0.05$), awareness of side effects[c] ($p < 0.05$), perception of vaccine safety[c] ($p < 0.05$), maternal age < 30[a] (OR = 2.26), immunization card at first contact[b] (OR = 7.72), < 3 offspring (OR = 2.2), completion of post secondary education[a] (OR = 2.34), maternal unemployment[a] (1.71) |
| Fisker[30] | 2014 | Guinea-Bissau | Observational cohort/ binomial regression | Measles vaccinated<br><br>DTP3 coverage 2009 vs 2007 (RR = 1.10)<br><br>Mortality | Measles vaccinated (MRR = 0.72), measles vaccinated girls[a] (MRR = 0.59), measles vaccinated boys[a] (MRR = 0.87) | Fula and Mandinga ethnic group[a]<br>DTP series initiation (increase), dropout (decrease) |

| Author | Year | Country | Study Type/ Analysis Type | Outcome Measured | Barrier to Outcome | Facilitators of Outcome |
|---|---|---|---|---|---|---|
| | | | | | N/A or neither/both | |
| Gram[38] | 2014 | Ghana | Cross-sectional/ chi-squared and Cox regression | Polio 0, polio 3, measles, and yellow fever coverage at one year<br><br>Polio 0 coverage at one year | | Socioeconomic status[a] ($p < 0.001$), educational level[a] ($p < 0.001$)<br><br>Urban vs. rural residence[a] ($p < 0.001$) |
| Gidado[39] | 2014 | Nigeria | Cross-sectional/ bivariate analysis and LR | Reasons for non-vaccination<br><br>Complete immunization | | Lack of knowledge[c], no permission from husband[a]<br>Satisfactory vaccination knowledge[c] (OR = 18.4)<br>Mother's education: secondary[a] (OR = 3.6) |
| Jani[40] | 2008 | Mozambique | Cross-sectional/ chi-squared and LR | Missed vaccination opportunity<br><br>Incomplete vaccination | Child born outside Mozambique[a] (OR = 0.26), | HF delivery[b] (OR = 2.29), single, divorced, and widow mother[a] (OR = 1.68)<br>Administrative post outside of village[b] (OR = 2.89), time to HF[b] (OR = 3.64), no mother's schooling[a] (OR = 2.24), no EPI information[c] (OR = 2.02), child born outside Mozambique[a] (OR = 5.20), home delivery[b] (OR = 1.78) |

| Author | Year | Country | Study Type/ Analysis Type | Outcome Measured | Barrier to Outcome | Facilitators of Outcome |
|---|---|---|---|---|---|---|
| | | | | | N/A or neither/both | |
| Lakew[41] | 2015 | Ethiopia | Cross-sectional/ multivariable LR | Full immunization coverage | Regions[a]: Afar, Amhara, Oromiya, Somali, and Southern Nation and Nationalities People (OR = {0.07 - 0.35}) | Rich wealth index[a] (OR = 1.4), mother with vaccination card[b] (OR = 7.7), postnatal check-up within 2 months of birth[b] (OR = 1.8), mother's aware of community conversation program[c] (OR = 1.9) |
| Le Polain de Waroux[2] | 2013 | Tanzania | Cross-sectional/ cluster | Not vaccinated with BCG, DTP3, and MCV1<br><br>Not vaccinated with MCV1 | <br><br>Maternal education 7 + years (RR = 0.49)[a] | ≥ 5 km from health facility (RR = {1.48 – 2.96})[b] |

| Author | Year | Country | Study Type/ Analysis Type | Outcome Measured | Barrier to Outcome | Facilitators of Outcome |
|---|---|---|---|---|---|---|
| | | | | | N/A or neither/both | |
| Legesse[42] | 2015 | Ethiopia | Cross-sectional/ bivariate analysis and multivariate LR | Full immunization | | Mother's occupation: farmer[a] (OR = 1.7), father's education: secondary or above[a] (OR = 1.8), family income >1000 Ethiopian Birr[a] (OR = 3.0), distance to health facility 30 – 60 minutes[b] (OR = 3.0), ever discussed immunization with health extension workers[d] (OR = 2.1), good knowledge of immunization[c] (OR = 2.3), ANC visit[b] (OR = 3.7) |
| Maina[43] | 2013 | Kenya | Cross-sectional/ multivariate LR | Full immunization coverage | | 1 - 3 children in family[a] (OR = 2.67), HF birth[b] (OR = 2.26), advice on next date for growth monitoring[d] (OR = 2.94), very good opinion on immunization services in the area[c] (OR = 2.21) |

| Author | Year | Country | Study Type/ Analysis Type | Outcome Measured | Barrier to Outcome | Facilitators of Outcome |
|---|---|---|---|---|---|---|
| | | | | | N/A or neither/both | |
| Mohamud[26] | 2014 | Ehtiopia | Cross-sectional/ multiple LR | Full immunization | | Maternal age[a]: 20 – 24 (OR = 2.19), ≥ 30 (OR = 3.79), mother's education: literate[a] (OR = 3.06), urban residence[a] (OR = 2.04), TT vaccine[b] (OR = 2.43), health institution delivery[b] (OR = 2.02), household visit by health workers[d] (OR = 1.92) |
| Moisi[44] | 2010 | Kenya | Cross-sectional/ Kaplan–Meier and Cox proportional hazards | Coverage of OPV0, Penta 3, OPV3, and MV<br><br>Coverage of BCG, OPV0, OPV1<br><br>Received OPV0 | Geographic location[a] (27.2% - 73% for OPV0),<br><br>Month of birth[a] (35.5% - 58.8% for OPV0)<br><br>Ethnicity[a] ($p < 0.01$), education[a] ($p < 0.01$), migration[a] ($p < 0.01$) | |
| | | | | Immunization rate | Rainy season[b] (HR = 0.86) | |
| Ndiritu[45] | 2006 | Kenya | Cross-sectional/ Kaplan-Meier and proportional hazards | Immunization rate for DTP | Rainy season[b] (RR = 0.73), distance to clinic[b] (RR = 0.95), number of children in family[a] (RR = {0.55 – 0.74}) | |
| Okwaraji[46] | 2012 | Ethiopia | Cross-sectional/Poisson regression model | Vaccination coverage (BCG, Penta 1, Penta 2, Penta 3, measles) | Travel time to clinic[b]: 30 – 60 min (RR = {0.92 – 0.98}), ≥60 min (RR = {0.85 – 0.95}) | |

| Author | Year | Country | Study Type/ Analysis Type | Outcome Measured | Barrier to Outcome | Facilitators of Outcome |
|---|---|---|---|---|---|---|
| | | | | | N/A or neither/both | |
| | | | | | Household wealth[a] | |
| Owino[47] | 2009 | Kenya | Qualitative and cross-sectional/ logistic regression and qualitative | Reasons for failure to immunize | | Fear of adverse events[d], refusal to vaccinate children born at home[b], refusal to vaccinate children of parents with no ANC visits[b], negative attitudes and abusive language by health workers[b] |
| | | | | Reasons for failure to immunize | | Ignorance[c] (34.6%), obstacles such as busy mother or waiting times too long[ab] (43.4%), lack of motivation[c] (12.5%), missed opportunity[b] (9.5%) |
| | | | | Immunization status at 23 months | | Maternal age[a] ($p < 0.05$), child welfare card[b] ($p < 0.001$), SES[a] (OR = 4.97), knowledge of immunization schedule[c] ($p < 0.05$), immunization information source[c] ($p < 0.05$), birth order[a] ($p < 0.05$) |
| | | | | | Ethnicity[a] ($p < 0.01$) | |

| Author | Year | Country | Study Type/ Analysis Type | Outcome Measured | Barrier to Outcome | Facilitators of Outcome |
|---|---|---|---|---|---|---|
| | | | | | N/A or neither/both | |
| Semali[19] | 2009 | Tanzania | Longitudinal/ LR | Completion of immunization | Female head of household[a] (OR = 0.6), long distance to community market[a] (OR = 0.96) | >3 children under 5[a] (OR = 1.3), mother's education >7 years[a] (OR = 14.9), increasing wealth[a], access to all weather passable roads[b] (OR = 1.9), urban residence[a] (OR = 2.9), HF within 1 km[b] (OR = 1.9) |
| Semali [18] | 2010 | Tanzania | Cross-sectional/ univariate analysis | 2005 Complete immunization | Household head not educated[a] (OR = 0.4) | Urban residence[a] (OR = 1.4), >2 children under 5[a] (OR = 1.4), increasing wealth[a] ($p < 0.05$) |
| Setse[48] | 2006 | Zambia | Nested case-control/ LR | Incomplete DTP and OPV immunization | | HIV-1 infection[b] (OR = 1.9), no measles vaccination[b] (OR = 8.8), maternal education <7 years[a] (OR = 3.7), 3+ children in home[a] (OR = {2.1 – 2.9}) |

| Author | Year | Country | Study Type/ Analysis Type | Outcome Measured | Barrier to Outcome | Facilitators of Outcome |
|---|---|---|---|---|---|---|
| | | | | | N/A or neither/both | |
| Tadesse[49] | 2009 | Ethiopia | Unmatched case-control | Default from complete immunization | Did not postpone vaccination schedule[b] (OR = 0.02), high monthly family income[a] (OR = 0.32) | No postnatal care[b] (OR = 5.8), negative perceptions towards health institutions support[c] (OR = 2.71), no knowledge of vaccine schedule[c] (OR = 3.01), no knowledge on benefit of vaccine[c] (OR = 6.36), no knowledge about measles[c] (OR = 84.89) |
| Ushie[50] | 2014 | Nigeria | Longitudinal / LR | Complete immunization | Islam or other Christian religion[a] (OR = {0.687 - 0.694}) | Increasing maternal education[a] (OR = {1.613 – 2.944}), urban residence[a] (OR = 1.606), hospital or other delivery[b] (OR = {1.471 – 2.092}), child age >0[a] (OR = {5.782 – 7.187}) |
| | | | | | Geopolitical zone[a]: north-west (OR = 0.671), south-east (OR = 0.576), south-south (OR = 1.192) | |
| Van Malderen[51] | 2013 | Kenya | Cross-sectional/ multivariate logistic regression | Measles coverage | Birth order >4[a] | |
| Verguet[52] | 2012 | South Africa | Cross-sectional/ regression model | Full immunization | Supplemental immunization activities[b] (-3.8%) | |

| Author | Year | Country | Study Type/ Analysis Type | Outcome Measured | Barrier to Outcome | Facilitators of Outcome |
|---|---|---|---|---|---|---|
| | | | | | N/A or neither/both | |
| Wiysonge[16] | 2012 | SSA (24 countries) | Cross-sectional/ logistic regression | Unimmunized for DTP3 | Childs age[a] (OR = 0.97), media access[d] (OR = 0.94), health seeking behavior[c] (OR = 0.56) | Polygamous family[a] (OR = 1.08), mother's age 15 to 24[a] (OR = 1.18), mother's education[a]: no educaton (OR = 1.35), primary (OR = 1.26), father's education[a]: no education (OR = 1.13), urban[a] (OR = 1.12), illiteracy rate (OR = 1.13), high country fertility rate[b] (OR = 4.43), increasing wealth relative to richest[a] (OR = {1.15 – 1.36}) |

## *3.2 Vaccination Timeliness*

Studies on vaccination timeliness and determinants of vaccination timeliness are reviewed with the same four cluster classifications as studies on vaccination coverage, and include the adjustment to the immunization system category (i.e. inclusion of antenatal care).

Several papers do not investigate the reasons for delays in receipt of vaccination, but rather only the degree of the delays and the results of the delays. One such example, Clark and Sanderson, describes the length of delay for various vaccination doses and illustrates that later vaccination doses have greater delays[1]. Studies by both Benn and Biai only examine the results of delayed vaccination in terms of mortality and risk of hospitalization [15, 20]. The results extracted from Benn are the same for both coverage and timeliness, but this results from the ambiguity in definition of the cause mortality. Because the explanatory variable is defined as non-vaccination of DTP3 at 9 months, the potential for later vaccination makes it unclear whether this is non-vaccination or delayed vaccination.

## Table 2: Studies on Vaccination Timeliness

| Author | Year | Country | Study Type/ Analysis Type | Outcome | Barrier to Outcome | Facilitator of Outcome |
|---|---|---|---|---|---|---|
| Benn[15] | 2012 | Guinea-Bissau | Longitudinal cohort/ Cox proportional hazards | Mortality before 18 months<br><br>Mortality before 36 months | | Female missing 1 or more DTP doses at 9 months[a] ($MRR_{18}$ = 11.16)<br>Female missing 1 or more DTP doses at 9 months[a] ($MRR_{36}$ = 3.55) |
| | | | | Mortality before 18 months<br><br>Mortality before 36 months | Male missing 1 or more DTP doses at 9 months[a] (no mortality at 18 months)<br><br>Male missing 1 or more DTP doses at 9 months[a] (no mortality difference at 36 months) | |
| Biai[20] | 2011 | Guinea-Bissau | Cross-sectional / Hazard risk ratio | Risk of hospitalization | | Delayed BCG: received with DTP 2 or 3 (RR = 4.18)<br><br>Delayed DTP: after MV (RR = 1.60)<br><br>Delayed DTP: with MV (RR = 1.51) |
| Clark[1] | 2009 | Multi-Country | Cross-sectional | Median BCG delay (2.3 weeks)<br><br>Median DTP1 delay (2.4 weeks)<br><br>Median MCV1 delay (2.7 weeks)<br><br>Median DTP3 delay (6.2 weeks) | | |

| Author | Year | Country | Study Type/ Analysis Type | Outcome | Barrier to Outcome | Facilitator of Outcome |
|---|---|---|---|---|---|---|
| Fisker[30] | 2014 | Guinea-Bissau | Observational cohort/ Binomial regression | DTP3 median decrease ($p < 0.01$)<br><br>MV median age increase ($p < 0.01$) | | |
| Ndiritu[45] | 2006 | Kenya | Cross-sectional/ Kaplan-Meier, proportional hazards | DTP1 by 6 weeks (22%), DTP2 by 10 weeks (15%), DTP3 by 14 weeks (9%) | | |
| Sadoh[9] | 2009 | Nigeria | Cross-sectional | On time vaccination: OPV1 (51.7%), DPT1 (61.5%), HepB2 (21.8%), OPV2 (43.8%), DPT3 (51.8%), OPV3 (38.7%), DPT3 (46.7%), HepB3 (18.7%) | | |

## *3.3 Determinants of Vaccination Timeliness*

Studies that conduct research on timeliness and barriers and facilitators to vaccination timeliness, find family characteristics as the most prevalent cluster (appear sixteen times and found in seven studies). The immunization system is second most common with four appearances in four papers. Family characteristics include region, maternal education, urban versus rural residence, and wealth. Immunization system characteristics include distance from a HF, missed vaccination opportunities, and HF delivery. Parental knowledge/ attitudes appear only twice in two studies, and communication and information appear once in one paper.

**Table 3: Studies on Vaccination Timeliness Determinants**

| Author | Year | Country | Study Type/ Analysis Type | Outcome | Barrier to Outcome | Facilitator of Outcome |
|---|---|---|---|---|---|---|
| Cutts[21] | 1991 | Mozambique and Guinea | Cross-sectional | Inappropriately timed vaccination (Mozambique = 9%, Conakry = 11%) | Missed vaccination opportunity[b] (19% in Conakry)<br><br>Would not accept vaccination for child with fever[c] (Mozambique = 24%) | |
| Fadnes[10] | 2011 | South Africa | Community based CRT/ Cox regression | Untimely vaccination | Health facility delivery[b] (HR = 0.37) | Geographical site[a] (HR = 3.3) |
| Fadnes[53] | 2011 | Uganda | CRT/ Kaplan-Meier and Cox regression | Untimely vaccination | Mother's education: higher education[a] (HR = 0.53), secondary education[a] (HR = 0.76), primary education[a] (HR = 0.87) | |
| Gram[38] | 2014 | Ghana | Cross-sectional/ chi-squared and Cox regression | 8+ week delay in OPV3/ Penta 3 vaccination | Urban vs. rural residence[a] ($p < 0.0001$), most vs. least educated[a] ($p < 0.001$), wealthiest vs. poorest quintile[a] ($P<0.001$) | |

| Author | Year | Country | Study Type/ Analysis Type | Outcome | Barrier to Outcome | Facilitator of Outcome |
|---|---|---|---|---|---|---|
| Le Polain de Waroux[2] | 2013 | Tanzania | Cross-sectional/ cluster | Delayed BCG (33%), delayed DTP1 (34%), delayed DTP3 (69%)<br><br>Delayed BCG, DTP1, DTP3, and MCV1<br><br>Delayed MCV1<br><br>Delayed DTP1 | Mothers education: 1 – 6 years (RR = 0.77), 7+ years (RR = 0.72)<br>Male (RR = 0.84) | Wealthiest quintile (RR = {{0.69 - 0.81}), |
| Moisi[44] | 2010 | Kenya | Cross-sectional/ Kaplan–Meier and Cox proportional hazards | Time-to-immunization with Penta 3 | Pedestrian travel time[b] (HR = 1.00), vehicular travel time[b] (HR = 1.01) | |
| Mutua[17] | 2015 | Kenya | Observational cohort/ lognormal model | Time to BCG (days) | Public HF[b] (TR = 0.48) | Low birthweight[a]: <2000 g (TR = 8.97), 2000 – 2499 g (TR = 1.44), ethnic group[a] (TR = {1.16 – 1.31}) |

| Author | Year | Country | Study Type/ Analysis Type | Outcome | Barrier to Outcome | Facilitator of Outcome |
|---|---|---|---|---|---|---|
| Sadoh [22] | 2013 | Nigeria | Cross-sectional/ Chi-squared and Fisher's exact test | Age at presentation for first immunization < 7 days | | Mother knows immunization should commence at birth[c] ($p < 0.01$), SES[a] ( $p < 0.01$), HF delivery[b] ($p < 0.01$), female sex[a] ($p < 0.05$), maternal education > 12 years[a] ($p > 0.001$) |
| | | | | | Source of information on immunization commencement[c] | |
| Wakadha[54] | 2013 | Kenya | Pilot intervention | Decision to vaccinate children on time | SMS reminder[d] (47%), conditional cash transfer (4%), both SMS reminder and conditional cash transfer[d] (4%), neither SMS reminder and conditional cash transfer (16%) | |

## *3.4 Literature by Country*

Because there is such variation in the relevance and association of the determinants of both vaccination coverage and vaccination timeliness, it is essential to consider the specific context where vaccination is taking place. While Ethiopia, Kenya, and Nigeria have several studies documenting issues concerning vaccination coverage and vaccination coverage, such information for other countries remains sparse. In the case of Tanzania, we see only two studies regarding vaccination coverage and none on the timeliness of vaccinations.

**Table 4: Number of Studies based on Country[5]**

| Country | Number of Coverage Studies | Number of Timeliness Studies |
|---|---|---|
| Ethiopia | 7 | 0 |
| Kenya | 7 | 4 |
| Nigeria | 6 | 2 |
| Guinea-Bissau | 3 | 3 |
| Ghana | 3 | 1 |
| South Africa | 3 | 1 |
| Guinea | 2 | 1 |
| Mozambique | 2 | 1 |
| **Tanzania** | **3** | **1** |
| Malawi | 1 | 0 |
| Senegal | 1 | 0 |
| Uganda | 1 | 1 |
| Zambia | 1 | 0 |
| Multi-Country | 1 | 1 |

[5] Studies may be represented in both coverage and timeliness columns.

# 4. Review of the Timeliness Literature: Discussion

*The Epidemiology of the Unimmunized Child* conducts an investigation of the grey literature on immunization. After identifying and analyzing the literature, authors categorized several determinants of non-immunization into four aforementioned classifications. Using this classification, our study categorizes the vaccination determinants in our own review into the same classifications. The determinants encompassed by these classifications are nearly, but not entirely comprised by all the determinants revealed in this literature review. Primarily, no category included antenatal care or non-immunization health care, and as such, the "immunization system" classification was expanded to include maternal and child healthcare system determinants.

Review of the literature on coverage shows that two categories, family characteristics and the immunization system are dominant in SSA. Analyses reveal that these clusters explain the majority of barriers and facilitators of immunization coverage. The communication and information cluster is observed least often in the coverage literature. It is important to consider that family characteristics, the immunization system, and parental attitudes/ knowledge are researched far more frequently than communication and information thus resulting in greater reporting.

Among family characteristics, geographic variation in vaccination coverage is cited frequently. One possible interpretation of the regional variation in vaccination

coverage is that it results from regional variation in health systems and health care resources [10, 28, 31]. Alternatively, regional clustering of ethnic groups, religious and political situations, levels of development, and the varying inclination of different populations (due to knowledge and conceptions about health) may also result in variation in vaccination coverage [31, 32].

Other family characteristics, mother's age, parent's education, parent's occupation, and ethnicity, appear often as either barriers or facilitators or do not affect vaccination coverage. The observed inconsistency among determinants such as mother's education may be explained by the fact that education correlates with other inter-cluster determinants (e.g. maternal occupation and/or wealth). A positive correlation between maternal education and wealth could explain why education is a facilitator of vaccination coverage, while a correlation between maternal education and occupation may explain why education is a barrier to vaccination coverage (i.e. a high education occupation may decrease the availability of mothers to attend vaccination sessions) [10]. These inconsistencies also emphasize the value of contextual research. With such variation throughout SSA, it's essential to understand the vaccination situation in each country and within geographic regions of each country.

Greater SES and urban residence are both facilitators of vaccination coverage which likely results from better access to healthcare due to both personal resources and

availability [26]. There seems to be little effect on vaccination coverage due to child sex in SSA, despite a significant sex differential throughout Asia [55].

The immunization system/ MCH system is also found to have significant impact on vaccination coverage. Distance from vaccination clinic was the most commonly cited factor affecting vaccination coverage, with greater distance correlating with decreased coverage. Greater distance to a vaccination clinic or HF is possibly a deterrent of attendance to immunization sessions because difficulty of travel, lost income due to time spent travelling, and lack of availability of child care for other children.

Mothers who have received any doses of TT vaccine, have been to ANC visits, or have had a midwife or HF delivery result in higher vaccination coverage, which is supported by results observed in Bangladesh [56, 57]. Those that delivered in a HF or received ANC may have greater access to healthcare or HCWs, or they may live closer to a clinic, which would lead to greater vaccination coverage [27]. Farther, mother's that have received vaccinations themselves or attended ANC sessions could have greater knowledge of vaccinations or more positive perceptions of vaccinations. The availability and presence of health professional, such as nurses can help to improve vaccination coverage [31]. The provision of new educational opportunities such as vocational training programs and incentives for HCWs could aid in improving access to healthcare thereby leading to improved vaccination coverage.

Parental knowledge and attitudes also had noticeable impact on vaccination coverage. Factors primarily include awareness of vaccination schedule, perceived benefits of vaccination, and knowledge of vaccination side effects. Parental attitudes and knowledge are expected to correlate with determinants of other classifications. Possible correlation was noted with regard to ANC, but also likely exists for family income, maternal and paternal education, and distance from a HF.

Communication and information appeared least frequently as an explanatory classification for immunization coverage. Educational campaigns were seen to improve vaccination coverage as was good communication from HCWs. However, there are limited results from which to conclude the collective impact of communication and information on vaccination coverage.

Vaccination timeliness presented in fifteen studies, only nine of which examine the determinants of vaccination delay rather than just the presence of vaccination delays. Most recurrent classifications are family characteristics and the immunization system, which include mother's education, SES, HF birth of child, distance to a HF, and geographical site. The reasoning behind these few factors presumably mirrors those of vaccination coverage. Parental knowledge/ attitudes, while present, is infrequent and thus provides no conclusion. This may again result from limited research on the classification topic in addition to the few papers available for the overall study. No issues of communication and information were present, one intervention suggests that

providing vaccination communication through mobile phones may increase the uptake of vaccinations [54]. This reflects a need for future research on communication needs and potential interventions.

A majority of the research was conducted in Guinea-Bissau, Ethiopia, Nigeria, and Kenya with little research in Tanzania. Only one study is on vaccination timeliness is presented for Tanzania. Though the documented barriers and facilitators of timely vaccination are few, this should not limit our study. In his 2011, South African study Fadnes writes, "[i]n general the factors associated with good vaccination coverage were the factors that were associated with timely vaccination [10]." This is the observed result for the few determinants established throughout the vaccination timeliness literature, and other factors impacting vaccination timeliness are likely encompassed by the reported determinants of vaccination coverage. The results presented here are all valuable in helping to define areas of concern, which should be addressed to impact change. While this study does establish the relative importance of several different vaccination coverage and vaccination timeliness determinants, it is essential to keep in mind the contextual relevance of these factors, such as ethnic and cultural differences and variations in infrastructure both within and across countries. It is important to investigate the determinants specific to vaccination timeliness in Tanzania, and we expect to see some overlap in trends from the complete literature review.

# 5. Analysis of the Demographic Health Surveys Data: Methods

This study utilizes the 2015 - 2016 DHS Data for Tanzania to determine coverage and timeliness of vaccines at the regional level in Tanzania and investigates the delays and reasons for delays in childhood vaccination across households Tanzania in 2016. Quantitative analyses are conducted on the Tanzania Demographic Health Survey conducted by USAID. The results of these analyses are important for understanding the current state of childhood vaccinations and how to prevent any delays.

## *5.1 Setting*

Demographic Health Surveys are collected globally every 5 years. The 2015 - 2016 DHS data was collected across 608 sample points in Tanzania for a total of 12,563 households between August 2015 to February 2016 [24]. The survey data were collected in both urban and rural settings, and data were collected on child health, education, HIV prevalence, malaria, nutrition, etc. This study is a secondary analysis of the data collected by the National Bureau of Statistics in Tanzania, USAID, and many other collaborators [24].

## *5.2 Participants*

Within the households surveyed, 3,514 participants were males between the ages of 15 and 49 and 13,266 participants were females, also between ages 15 to 49 [24].

Questions about child health were obtained from mothers and from data available on child health cards [24].

## *5.3 Procedures*

DHS uses a representative probability sample of 12,536 households selected through a two-stage cluster sampling process. In the first stage, clusters were selected, each consisting of enumeration areas defined by the 2012 Tanzania Population and Housing Census. In the second stage, 22 households were selected from each of the 608 clusters.

The data collected from this survey were used in our assessment of the status of childhood vaccination timeliness in the country and established determinants of vaccination delay. Measures of timeliness were defined based on the 2015 WHO guidelines for routine immunization and are outlined in Table 5 below. In addition to vaccination timeliness and vaccination coverage, several additional measures including mother's age, birth order of child, urban vs. rural residence, mother's education, wealth quintile, region of Tanzania, child's sex, low birth weight, distance from clinic, maternal tetanus vaccinations, and antenatal care were defined for exploratory analyses. All of these determinants were observed as impacting factors in the literature review.

## 5.4 Measures

Measures of vaccination coverage, vaccination timeliness, and factors that may explain vaccination timeliness are defined here. Immunization data is collected for children between 12 to 23 months of age. If a child has received a particular dose of a vaccination at any point in time until the date of measure or up to one year of age, he or she is defined as being covered for that vaccination dose. Vaccination timeliness, is more variable and complex. After 2010, there were changes in the recommended vaccination schedule, varying dates of adoption of the new schedule in different areas of Tanzania, and general uncertainty about how to manage cases that deviate from the schedule [58]. Table 5 below presents a summary of the current Immunization and Vaccination Development (IVD) Program schedule for immunization which follows the 2015 WHO recommendations for vaccination [12]. The information presented shows the recommended vaccination timeline.

**Table 5: Summary of IVD and WHO Reccomendations for Routine Immunization**

| | **Age** | | | |
|---|---|---|---|---|
| **Vaccine** | *Dose 0* | *Dose 1* | *Dose 2* | *Dose 3* |
| *BCG* | | 0 days | | |
| *Polio* | 0 days | 6 weeks | 10 weeks | 14 weeks |
| *Pentavalent* | | 6 weeks | 10 weeks | 14 weeks |
| *Pneumococcal* | | 6 weeks | 10 weeks | 14 weeks |
| *Rotavirus* | | 6 weeks | 10 weeks | |

These target vaccination ages comprise what could be considered most effective vaccination, however proper spacing between vaccinations is also necessary for an effective immune response, and the WHO generally recommends a four week minimum and an eight week maximum waiting period between doses [9, 10, 12]. Based on these recommendations we derive Table 6 below, which is used in our analyses to measure timely vaccination.

**Table 6: Timely Vaccination Schedule**

| | Age Time Window | | | |
|---|---|---|---|---|
| **Vaccine** | *Dose 0* | *Dose 1* | *Dose 2* | *Dose 3* |
| *BCG* | | 0 -28 days | | |
| *Polio* | 0 - 28 days | 6 -10 weeks | Dose 1 + 4 – 8 weeks | Dose 2 + 4 – 8 weeks |
| *Pentavalent* | | 6 -10 weeks | Dose 1 + 4 – 8 weeks | Dose 2 + 4 – 8 weeks |
| *Pneumococcal* | | 6 -10 weeks | Dose 1 + 4 – 8 weeks | Dose 2 + 4 – 8 weeks |
| *Rotavirus* | | 6 -10 weeks | Dose 1 + 4 – 8 weeks | |
| *Measles* | | 9 months | | |

### 5.4.1 Vaccination Coverage

Vaccination coverage is defined both as a linear variable and a binary variable. A linear coverage score (LCS) is calculated as a discrete continuous variable, for which each vaccination dose received by one year of age adds one point to the score. The minimum score is zero and the maximum score is fourteen. The binary coverage score (BCS) is calculated as a binary variable, for which coverage for all fourteen vaccination doses is defined as one, and if at least one vaccination dose is not covered, the score is zero.

### 5.4.2 Vaccination Timeliness

Vaccination timeliness is defined both as a linear variable and a binary variable, as well. Timeliness is calculated for the first fourteen weeks of recommended vaccines, and thus, the measles vaccine is excluded from the scoring calculation, though individual measles timeliness is still calculated. A linear timeliness score (LTS) is calculated as a discrete continuous variable, for which each on time vaccination dose adds one point to the score. The minimum score is zero and the maximum score is thirteen. The binary timeliness score (BTS) is calculated as a binary variable, for which timeliness of all thirteen vaccination doses is defined as one, and if at least one vaccination dose is not on time, the score is zero.

### 5.4.3 Region

Region is a categorical variable with 30 categories. These align with the administrative regions, called *mikoa,* in Tanzania.


**Figure 3: Map of Tanzania divided by mikoa**

### 5.4.4 Mother's Age

Mother's age is a continuous measure of the mother's age in years at the time of interview. This is calculated from a century month code (CMC)[6] using the mothers date of birth and the date of interview.

### 5.4.5 Birth Order

Birth order is a discrete continuous variable corresponding to the numerical order in which the child of interest was born.

[6] The (CMC) is the number of the month since the start of the century and allows for comparison between dates.

### 5.4.6 Residence

The variable residence is a binary variable that defines place of residence as either urban or rural.

### 5.4.7 Mother's Education

Mother's education is an ordinal categorical variable defining the mother's highest level of education. Categories include: no education, primary, secondary, and higher as defined by the DHS.

### 5.4.8 Wealth Quintile

Wealth quintile is presented as five ordinal categories. According to the DHS, wealth is calculated as "a composite measure of a household's cumulative living standard" based on ownership of selected assets, including "televisions and bicycles; materials used for housing construction; and types of water access and sanitation facilities." This data is used to determine a wealth index score, which is then broken into quintiles and presented in a separate variable [24].

### 5.4.9 Child's Sex

Child's sex is a binary variable, either male or female, defined by the biological sex of the child.

### 5.4.10 Low Birthweight

The World Health Organization defines low birth weight as a birthweight below 2499 grams. Low birthweight is a binary variable (one for birthweight below 2499 g and

zero for birthweight equivalent to or above 2499 g) defined from the continuous birthweight variable provided by the DHS.

### 5.4.11 Distance to Clinic

Distance to clinic is a binary variable in which mothers are asked about getting medical care for themselves. The distance from a clinic can be defined as "not a problem" and "a big problem."

### 5.4.12 Maternal Tetanus Vaccination

Maternal tetanus is a discrete continuous variable with values zero through five. The value represents the number of tetanus toxoid injections a mother received during pregnancy. Each value is treated as a disjoint indicator for the regression analyses due to the small possible range of the variable

### 5.4.13 Antenatal Care

Antenatal care is an ordinal categorical variable that represents the number of antenatal care visits a mother made during her pregnancy. Categories include zero visits, one to three visits, four or five visits, and six or more visits.

## 5.5 Analysis

After defining all variables and preparing the data for analysis through data cleansing and proper coding, descriptive data were depicted and calculated. Data are weighted using the DHS sampling weights to account for samples that are selected with unequal probability. A chi-squared test of homogeneity is conducted to test for regional variation of timely Penta 3 vaccination.

Several regression models were run to determine the correlation between vaccination coverage and vaccination timeliness with the demographic and health variables. Variables were first individually regressed on the outcomes to determine any correlation. Linear coverage and linear timeliness are correlated with the determinants using linear regression. Binary coverage and binary timeliness are correlated with the determinants using logistic regression. After initial bivariate relationships correlations between outcomes and exposures were determined, the exposure was included in the initial full model if a bivariate analysis was found to show significance. For the outcome LTS, this was a multiple linear regression and for the outcome BTS, this was a logistic regression. Backwards model selection is used to determine the best models because there are several determinants expected to be relevant based on the literature and the descriptive data. Beginning with all the determinants allows us to determine the relative significance of each factor. Because the residence variable was found to have such strong impact on the BTS model, and because of the health system disparities of which we are

already aware in urban versus rural settings, the model was separated by this variable into two models. This allows for a clearer picture of the impact of the other determinants is each residence setting. The final models are used to present the correlation between predicted determinants and outcome. All data analysis was conducted on Stata 14.

# 6. Analysis of the Demographic Health Surveys Data: Results

## *6.1 Descriptive Data*

The analyses indicate that the extent of delays is often quite severe, though many of those getting vaccinated are being vaccinated within a reasonable time. Figure 4 provides the entire distribution of a few vaccination doses up to one year (eighteen months for measles). Plots for polio, BCG, penta, pneumo, rota, and measles depict a range of about 40 to 75 percent of children being vaccinated on time, but all vaccination doses face extreme delays past one year. The vaccination birth doses have delays of up to 400 to 500 days, penta, pneumo, and rota doses are delayed up to approximately 60 to 80 weeks, and measles is delayed as much as 23 months.

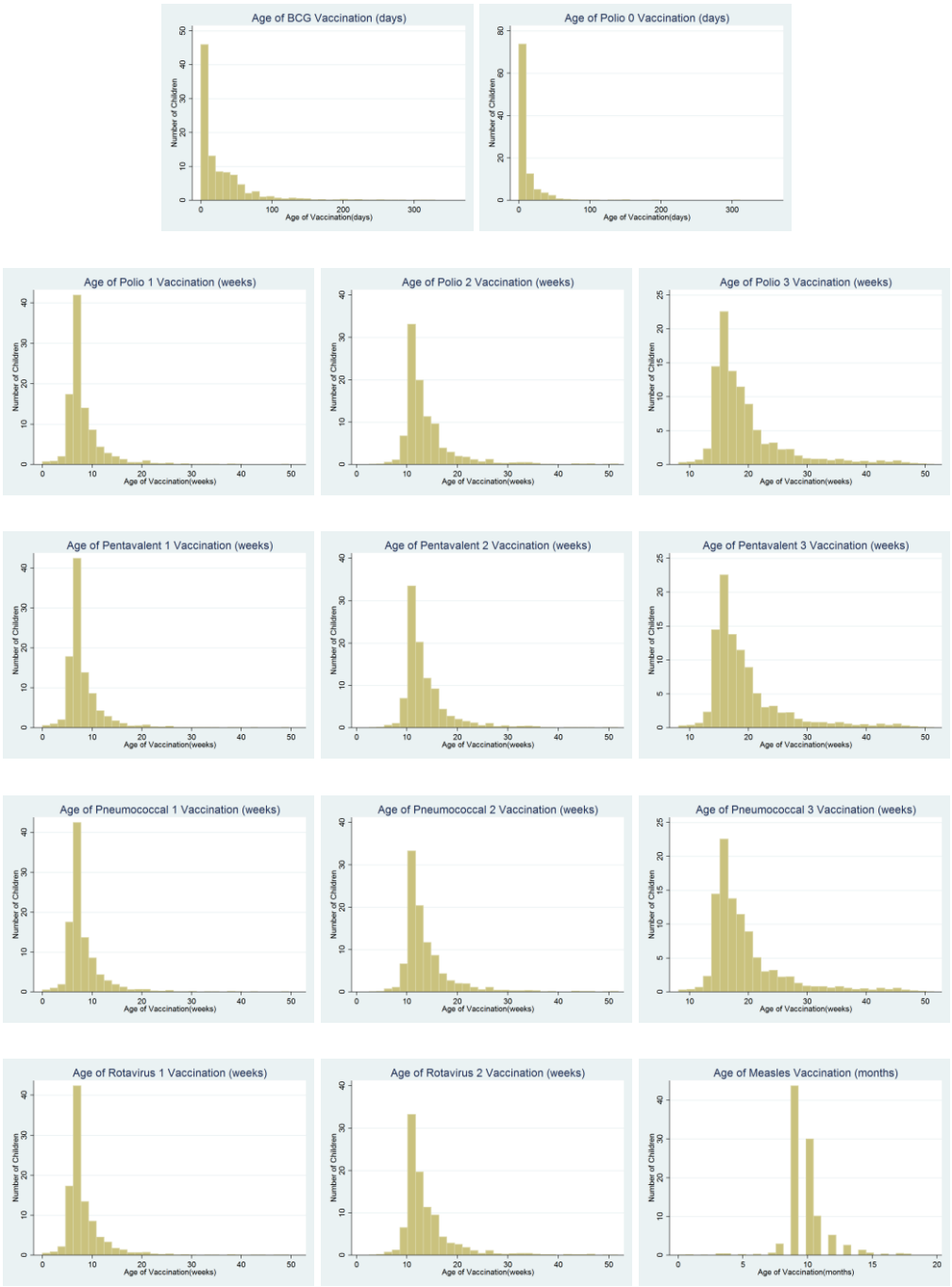


**Figure 4: Distribution of vaccination age for all required vaccination doses for children between 12 – 23 months of age**

Regional variation of coverage and timeliness was found to be quite noticeable given differences above 40 percent comparing region with the highest and lowest timeliness. Timeliness for Penta 3 varied from 44 to 88 percent and is depicted in the map in Figure 5. Regional clustering is evident as well. A test of homogeneity confirms significant difference ($p < 0.0001$) for odds of timely Penta 3 vaccination across regions.

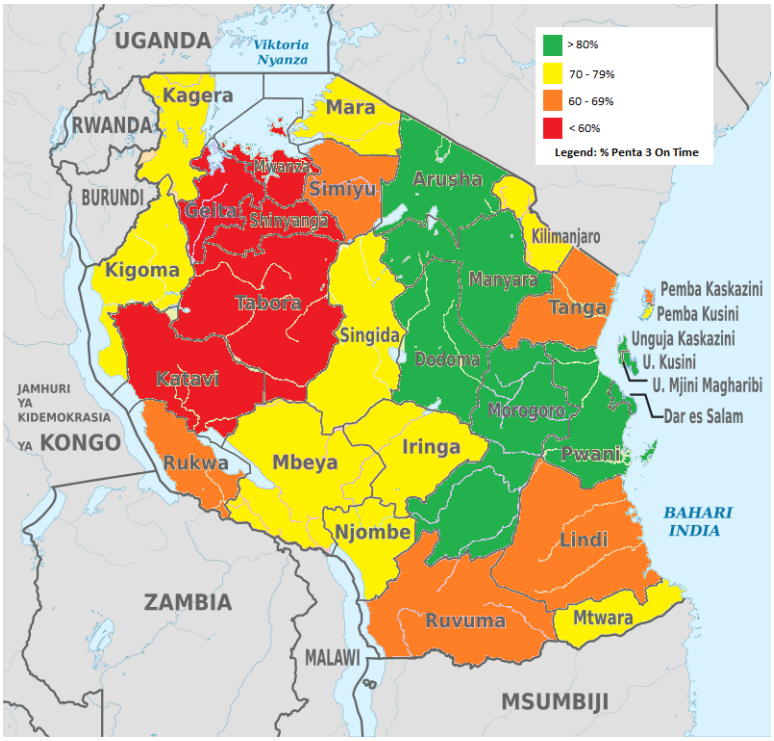


**Figure 5: Regional Variation of Vaccination Timeliness for Pentavalent 3 Dose**

The vaccination coverage, timeliness, and quartile and range is reported for each vaccination dose in Table 7. Timeliness is always lower than coverage, often as much as 40 percent. Measles and polio 0 have the worst vaccination timeliness at 55 percent and 41 percent, respectively. Noticeably, first and third doses of vaccination have lower timeliness than second doses of about 8 to 12 percent.

**Table 7: Vaccination Age Distribution Summary**

| Vaccination Dose | Vaccination Window | Minimum | 25th %ile | 50th %ile | 75th %ile | Maximum | % Coverage | % on Time |
|---|---|---|---|---|---|---|---|---|
| *BCG (days)* | 0 – 28 days | 0 | 3 | 13 | 41 | 486 | 95.28 | 62.78 |
| *Polio 0 (days)* | 0 - 28 days | 0 | 1 | 4 | 11 | 366 | 62.61 | 54.52 |
| *Polio 1 (weeks)* | Polio 0 + 6 – 10 weeks | 0.00 | 6.29 | 7.00 | 9.00 | 59.14 | 94.79 | 67.43 |
| *Polio 2 (weeks)* | Polio 1 + 4 – 8 weeks | 2.43 | 11.00 | 12.14 | 15.14 | 74.43 | 90.58 | 75.21 |
| *Polio 3 (weeks)* | Polio 2 + 4 – 8 weeks | 8.14 | 15.57 | 17.43 | 21.00 | 83.14 | 81.90 | 65.00 |
| *Penta 1 (weeks)* | 6 – 10 weeks | 0.00 | 6.29 | 7.00 | 8.86 | 59.14 | 96.28 | 67.62 |
| *Penta 2 (weeks)* | Penta 1 + 4 - 8 weeks | 2.43 | 11.00 | 12.14 | 15.00 | 74.43 | 92.85 | 77.88 |
| *Penta 3 (weeks)* | Penta 2 + 4 - 8 weeks | 8.14 | 15.57 | 17.43 | 21.00 | 83.14 | 87.86 | 67.43 |
| *Pneumo 1 (weeks)* | 6 – 10 weeks | 0.00 | 6.29 | 7.00 | 9.00 | 59.00 | 94.11 | 66.12 |
| *Pneumo 2 (weeks)* | Pneumo 1 + 4 weeks | 2.43 | 11.00 | 12.14 | 15.00 | 74.43 | 90.43 | 74.54 |
| *Pneumo 3 (weeks)* | Pneumo 2 + 4 – 8 weeks | 8.14 | 15.57 | 17.43 | 21.00 | 83.14 | 84.70 | 66.10 |
| *Rota 1 (weeks)* | 6 – 10 weeks | 0.00 | 6.29 | 7.00 | 9.14 | 61.57 | 92.92 | 64.60 |
| *Rota 2 (weeks)* | Rota 1 + 4 – 8 weeks | 2.43 | 11.00 | 12.14 | 15.14 | 77.71 | 88.63 | 71.51 |
| *Measles (months)* | 9 months | 0 | 9 | 10 | 10 | 23 | 83.31 | 41.47 |

## *6.2 Multivariable Analyses*

The proportion of children aged 12 – 23 months receiving full timely vaccination was very low at only 15.71% completion.

Table 8 below depicts the rates of timely vaccination completion against Residence has remarkable differences among completion with a greater than 50% difference in completion when comparing urban to rural settings. Birth order, mother's education, and antenatal care also have completion differences of over 40% across strata.

**Table 8: Proportion of Children with Full Timely Immunization**

| Variable | | Incomplete Timeliness | Complete Timeliness | Total |
|---|---|---|---|---|
| | *Levels* | N (%)<br>mean (sd) | N (%)<br>mean (sd) | N |
| *Low Birthweight* | No | 1640.02 (96.42%) | 301.78 (95.22%) | 1941.79 |
| | Yes | 60.82 (3.58%) | 15.13 (4.78%) | 75.96 |
| *Birth Order* | < 5 | 1198.44 (70.46%) | 252.26 (79.60%) | 1450.70 |
| | 5 + | 502.40 (29.54%) | 64.66 (20.40%) | 567.05 |
| *Mother's Education* | No Education | 381.56 (22.43%) | 25.53 (8.06%) | 407.08 |
| | Primary | 1061.75 (62.43%) | 212.68 (67.11%) | 1274.43 |
| | Secondary | 244.51 (14.38%) | 75.19 (23.73%) | 319.71 |
| | Higher | 13.02 (0.77%) | 3.52 (1.11%) | 16.54 |
| *Mother's Age* | | 28.23 (7.02) | 28.31 (6.61) | 2133.91 |

| | | | | |
|---|---|---|---|---|
| *Child Sex* | Male | 845.48 (49.71%) | 149.71 (47.24%) | 995.18 |
| | Female | 855.36 (50.29%) | 167.21 (52.76%) | 1022.57 |
| *Residence* | Rural | 1296.07 (76.20%) | 165.81 (52.32%) | 1461.88 |
| | Urban | 404.77 (23.80%) | 151.10 (47.68%) | 555.87 |
| *Region* | Dodoma | 67.79 (3.99%) | 12.88 (4.07%) | 80.67 |
| | Arusha | 53.93 (3.17%) | 7.38 (2.33%) | 61.31 |
| | Kilimanjaro | 27.06 (1.59%) | 7.66 (2.42%) | 34.72 |
| | Tanga | 68.03 (4.00%) | 16.72 (5.28%) | 84.75 |
| | Morogoro | 61.11 (3.59%) | 12.83 (4.05%) | 73.94 |
| | Pwani | 28.58 (1.68%) | 10.41 (3.29%) | 39.00 |
| | Dar Es Salaam | 128.22 (7.54%) | 51.44 (16.23%) | 179.66 |
| | Lindi | 28.76 (1.69%) | 6.13 (1.94%) | 34.90 |
| | Mtwara | 32.87 (1.93%) | 14.69 (4.63%) | 47.55 |
| | Ruvuma | 48.04 (2.82%) | 3.32 (1.05%) | 51.36 |
| | Iringa | 21.99 (1.29%) | 12.29 (3.88%) | 34.28 |
| | Mbeya | 77.70 (4.57%) | 21.96 (6.93%) | 99.66 |
| | Singida | 63.37 (3.73%) | 10.52 (3.32%) | 73.89 |
| | Tabora | 156.38 (9.19%) | 13.13 (4.14%) | 169.51 |
| | Rukwa | 53.26 (3.13%) | 10.63 (3.35%) | 63.89 |
| | Kigoma | 93.10 (5.47%) | 17.64 (5.57%) | 110.74 |
| | Shinyanga | 76.02 (4.47%) | 3.75 (1.18%) | 79.77 |
| | Kagera | 86.61 (5.09%) | 16.07 (5.07%) | 102.69 |
| | Mwanza | 111.57 (6.56%) | 18.61 (5.87%) | 130.18 |
| | Mara | 81.67 (4.80%) | 9.57 (3.02%) | 91.24 |
| | Manyara | 74.76 (4.40%) | 5.61 (1.77%) | 80.37 |
| | Njombe | 17.48 (1.03%) | 5.36 (1.69%) | 22.83 |
| | Katavi | 23.47 (1.38%) | 1.34 (0.42%) | 24.81 |
| | Simiyu | 84.86 (4.99%) | 10.31 (3.25%) | 95.16 |
| | Geita | 90.84 (5.34%) | 7.68 (2.42%) | 98.52 |
| | Kaskazini Unguja | 5.98 (0.35%) | 2.11 (0.66%) | 8.08 |
| | Kusini Unguja | 3.84 (0.23%) | 0.94 (0.30%) | 4.78 |
| | Mjini Magharibi | 17.85 (1.05%) | 3.25 (1.03%) | 21.11 |
| | Kaskazini Pemba | 8.66 (0.51%) | 1.29 (0.41%) | 9.96 |
| | Kusini Pemba | 7.03 (0.41%) | 1.40 (0.44%) | 8.42 |
| *Wealth Quintile* | 0 - 20th %ile | 451.28 (26.53%) | 29.30 (9.25%) | 480.58 |
| | 20-40th %ile | 389.47 (22.90%) | 41.49 (13.09%) | 430.96 |
| | 40-60th %ile | 318.40 (18.72%) | 63.28 (19.97%) | 381.68 |
| | 60-80th %ile | 305.24 (17.95%) | 84.27 (26.59%) | 389.51 |
| | 80-100th %ile | 236.45 (13.90%) | 98.57 (31.10%) | 335.02 |
| *Distance to* | No | 849.85 (49.97%) | 190.58 (60.14%) | 1040.43 |

| | | | | |
|---|---|---|---|---|
| *HF is a problem* | Yes | 850.99 (50.03%) | 126.33 (39.86%) | 977.32 |
| *Maternal Tetanus Vaccinations* | 0 | 393.46 (24.30%) | 77.60 (25.90%) | 471.06 |
| | 1 | 377.14 (23.29%) | 49.75 (16.61%) | 426.89 |
| | 2 | 660.90 (40.81%) | 118.01 (39.39%) | 778.91 |
| | 3 | 171.19 (10.57%) | 51.22 (17.10%) | 222.40 |
| | 4 | 14.04 (0.87%) | 1.21 (0.40%) | 15.26 |
| | 5 | 2.72 (0.17%) | 1.81 (0.60%) | 4.53 |
| *Antenatal Care Visits* | 0 | 43.96 (2.71%) | 4.97 (1.65%) | 48.93 |
| | 1 - 3 | 795.12 (49.10%) | 97.95 (32.60%) | 893.07 |
| | 4 - 5 | 627.12 (38.72%) | 146.03 (48.60%) | 773.15 |
| | 6+ | 153.25 (9.46%) | 51.49 (17.14%) | 204.75 |

The LTS model was dropped to due insufficient data points for many of the vaccination score values, while several data points were clustered at very high or very low values. The model did not provide meaningful results.

All variables found to have a bivariate relationship with BTS were included in a logistic regression model. Exposure variables child sex, child birth order, and low birthweight were removed as they had little influence on the outcome. The results of this analysis are presented in Table 9 and Table 10. Mother's education, mother's age, region, wealth, tetanus toxoid, and antenatal care all show significant association at the 5 percent significance level.

**Table 9: Rural BTS bivariate and logistic regression model**

| **Rural Model (n = 1,452)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Variables** | **Crude Associations** | | | **Full Model** | | **Final Model** | |
| | *Levels* | *OR (CI)* | *p* | *OR (CI)* | *p* | *OR (CI)* | *p* |
| *Low Birthweight* | No | 1.00 | | | | | |
| | Yes | 1.41 (0.58, 3.42) | 0.444 | | | | |

| Rural Model (n = 1,452) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Variables** | **Crude Associations** | | | **Full Model** | | **Final Model** | |
| | *Levels* | *OR (CI)* | *p* | *OR (CI)* | *p* | *OR (CI)* | *p* |
| *Birth Order* | < 5 | 1.00 | | 1.00 | | | |
| | 5 + | 0.76 (0.53, 1.08 | 0.127 | 0.78 (0.44, 1.37) | 0.386 | | |
| *Mother's Education* | No Education | 1.00 | | 1.00 | | 1.00 | |
| | Primary | 2.35 (1.45, 3.79) | 0.000 | 1.78 (1.06, 2.97) | 0.028 | 1.81 (1.08, 3.01) | 0.024 |
| | Secondary | 4.21 (2.31, 7.68) | 0.000 | 3.03 (1.49, 6.15) | 0.002 | 3.13 (1.54, 6.34) | 0.002 |
| | Higher | 1.00 | | 1.00 | | 1.00 | |
| *Mother's Age* | | 1.01 (0.98, 1.03) | 0.611 | 1.02 (0.98, 1.06) | 0.297 | 1.01 (0.98, 1.04) | 0.550 |
| *Child Sex* | Male | 1.00 | | 1.00 | | | |
| | Female | 1.31 (0.94, 1.81) | 0.106 | 1.27 (0.89, 1.81) | 0.189 | | |
| *Region* | Dodoma | 1.00 | | 1.00 | | 1.00 | |
| | Arusha | 0.71 (0.21, 2.38) | 0.581 | 0.90 (0.25, 3.24) | 0.869 | 0.92 (0.25, 3.30) | 0.893 |
| | Kilimanjaro | 1.07 (0.24, 4.75) | 0.931 | 0.49 (0.10, 2.45) | 0.388 | 0.51 (0.10, 2.53) | 0.411 |
| | Tanga | 0.77 (0.25, 2.40) | 0.652 | 0.61 (0.18, 2.01) | 0.413 | 0.61 (0.18, 2.02) | 0.417 |
| | Morogoro | 1.49 (0.54, 4.07) | 0.440 | 0.98 (0.32, 2.96) | 0.973 | 1.02 (0.34, 3.08) | 0.969 |
| | Pwani | 2.94 (0.94, 9.23) | 0.065 | 2.87 (0.86, 9.62) | 0.087 | 3.09 (0.93, 10.25) | 0.065 |
| | Lindi | 1.39 (0.34, 5.79) | 0.647 | 1.38 (0.30, 6.43) | 0.678 | 1.53 (0.33, 7.02) | 0.583 |
| | Mtwara | 2.95 (1.07, 8.15) ) | 0.037 | 3.16 (1.03, 9.73) | 0.045 | 3.40 (1.11, 10.43) | 0.032 |
| | Ruvuma | 0.35 (0.07, 1.79) | 0.207 | 0.30 (0.06, 1.59) | 0.156 | 0.31 (0.06, 1.63) | 0.164 |
| | Iringa | 3.87 (1.22, 12.32) | 0.022 | 3.72 (1.06, 13.02) | 0.040 | 3.83 (1.10, 13.37) | 0.035 |
| | Mbeya | 1.64 (0.66, 4.07) | 0.286 | 1.53 (0.59, 3.98) | 0.382 | 1.58 (0.61, 4.10) | 0.346 |
| | Singida | 1.11 (0.40, 3.07) | 0.837 | 1.22 (0.41, 3.63) | 0.721 | 1.23 (0.42, 3.65) | 0.706 |
| | Tabora | 0.41 (0.15, 1.13) | 0.085 | 0.59 (0.20, 1.68) | 0.322 | 0.58 (0.20, 1.65) | 0.306 |
| | Rukwa | 0.98 (0.31, 3.04) | 0.967 | 0.88 (0.25, 3.15) | 0.849 | 0.85 (0.24, 3.02) | 0.801 |
| | Kigoma | 1.19 (0.48, 2.98) | 0.707 | 1.24 (0.46, 3.36) | 0.675 | 1.27 (0.47, 3.43) | 0.637 |
| | Shinyanga | 0.40 (0.11, 1.43) | 0.160 | 0.54 (0.15, 1.99) | 0.351 | 0.52 (0.14, 1.92) | 0.330 |
| | Kagera | 1.00 (0.39, 2.59) | 0.997 | 1.05 (0.39, 2.85) | 0.926 | 1.06 (0.39, 2.86) | 0.915 |
| | Mwanza | 0.54 (0.17, 1.69) | 0.292 | 0.59 (0.18, 2.00) | 0.399 | 0.61 (0.18, 2.04) | 0.420 |
| | Mara | 0.80 (0.27, 2.38) | 0.685 | 0.92 (0.29, 2.91) | 0.893 | 0.93 (0.30, 2.91) | 0.899 |
| | Manyara | 0.58 (0.19, 1.78) | 0.343 | 0.60 (0.19, 1.94) | 0.396 | 0.65 (0.20, 2.06) | 0.460 |
| | Njombe | 2.14 (0.55, 8.32) | 0.270 | 1.78 (0.43, 7.41) | 0.427 | 1.83 (0.44, 7.57) | 0.403 |
| | Katavi | 0.24 (0.02, 3.08) | 0.274 | 0.30 (0.02, 4.04) | 0.366 | 0.31 (0.02, 4.11) | 0.374 |
| | Simiyu | 0.93 (0.35, 2.45) | 0.885 | 1.15 (0.41, 3.26) | 0.786 | 1.17 (0.42, 3.31) | 0.761 |
| | Geita | 0.27 (0.07, 1.07) | 0.063 | 0.32 (0.08, 1.33) | 0.117 | 0.32 (0.08, 1.33) | 0.117 |
| | Kaskazini Unguja | 2.52 (0.42, 14.96) | 0.309 | 1.12 (0.17, 7.36) | 0.907 | 1.17 (0.18, 7.67) | 0.871 |
| | Kusini Unguja | 1.90 (0.18, 20.64) | 0.597 | 0.46 (0.03, 6.97) | 0.573 | 0.48 (0.03, 7.20) | 0.594 |

| Rural Model (n = 1,452) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Variables** | **Crude Associations** | | | **Full Model** | | **Final Model** | |
| | *Levels* | *OR (CI)* | *p* | *OR (CI)* | *p* | *OR (CI)* | *p* |
| | Mjini Magharibi | 0.77 (0.08, 7.12) | 0.816 | 0.27 (0.02, 3.07) | 0.293 | 0.26 (0.02, 2.90) | 0.272 |
| | Kaskazini Pemba | 0.97 (0.12, 8.05) | 0.975 | 0.78 (0.08, 7.37) | 0.825 | 0.77 (0.08, 7.31) | 0.822 |
| | Kusini Pemba | 1.42 (0.16, 12.74) | 0.753 | 0.91 (0.09, 9.44) | 0.936 | 0.88 (0.09, 9.12) | 0.918 |
| *Wealth Quintile* | 0 - 20th %ile | 1.00 | | 1.00 | | 1.00 | |
| | 20-40th %ile | 1.60 (0.96, 2.67) | 0.072 | 1.37 (0.79, 2.38) | 0.262 | 1.37 (0.79, 2.38) | 0.261 |
| | 40-60th %ile | 2.93 (1.80, 4.76) | 0.000 | 2.24 (1.31, 3.82) | 0.003 | 2.27 (1.33, 3.88) | 0.003 |
| | 60-80th %ile | 4.07 (2.42, 6.86) | 0.000 | 2.84 (1.56, 5.18) | 0.001 | 2.88 (1.58, 5.24) | 0.001 |
| | 80-100th %ile | 4.41 (1.79, 10.82) | 0.001 | 3.48(1.15, 10.60) | 0.028 | 3.69 (1.21, 11.22) | 0.021 |
| *Distance to HF* | Not a Problem | 1.00 | | 1.00 | | 1.00 | |
| | Problem | 0.67 (0.48, 0.92) | 0.014 | 0.77 (0.53, 1.11) | 0.164 | 0.76 (0.53, 1.10) | 0.151 |
| *Maternal Tetanus Vaccinations* | 0 | 1.00 | | 1.00 | | 1.00 | |
| | 1 | 0.49 (0.30, 0.80) | 0.005 | 0.46 (0.26, 0.80) | 0.006 | 0.46 (0.26, 0.80) | 0.006 |
| | 2 | 0.71 (0.48, 1.06) | 0.091 | 0.58 (0.37, 0.93) | 0.022 | 0.59 (0.38, 0.94) | 0.026 |
| | 3 | 1.04 (0.59, 1.84) | 0.889 | 0.77 (0.39, 1.50) | 0.436 | 0.78 (0.40, 1.52) | 0.462 |
| | 4 | 0.49 (0.04, 5.56) | 0.566 | 0.70 (0.05, 9.00) | 0.786 | 0.78 (0.06, 9.90) | 0.848 |
| | 5 | 1.86 (0.08, 45.60) | 0.703 | 0.51 (0.02, 14.75) | 0.697 | 0.50 (0.02, 13.91) | 0.684 |
| *Antenatal Care Visits* | 0 | 1.00 | | 1.00 | | 1.00 | |
| | 1 - 3 | 0.62 (0.23, 1.65) | 0.335 | 0.49 (0.16, 1.52) | 0.215 | 0.49 (0.16, 1.55) | 0.226 |
| | 4 - 5 | 1.11 (0.42, 2.95) | 0.830 | 0.76 (0.24, 2.40) | 0.641 | 0.77 (0.24, 2.45) | 0.659 |
| | 6+ | 0.86 (0.28, 2.62) | 0.786 | 0.53 (0.15, 1.87) | 0.323 | 0.52 (0.15, 1.87) | 0.319 |
| *Model Intercept* | | | | 0.07 (0.01, 0.38) | 0.002 | 0.10 (0.02, 0.48) | 0.004 |

**Table 10: Urban BTS bivariate and logistic regression model**

| Urban Model (n = 420) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Variables** | **Crude Model** | | | **Full Model** | | **Final Model** | |
| | *Levels* | *OR (CI)* | *p* | *OR (CI)* | *p* | *OR (CI)* | *p* |
| *Low Birthweight* | No | 1.00 | | | | | |
| | Yes | 0.89 (0.41, 1.93) | 0.770 | | | | |
| *Birth Order* | < 5 | 1.00 | | 1.00 | | | |
| | 5 + | 0.85 (0.48, 1.53) | 0.593 | 0.75 (0.34, 1.64) | 0.474 | | |

| Urban Model (n = 420) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Variables** | **Crude Model** | | | **Full Model** | | **Final Model** | |
| | *Levels* | *OR (CI)* | *p* | *OR (CI)* | *p* | *OR (CI)* | *p* |
| *Mother's Education* | No Education | 1.00 | | 1.00 | | 1.00 | |
| | Primary | 2.57 (0.90, 7.32) | 0.077 | 2.40 (0.78, 7.40) | 0.127 | 2.46 (0.80, 7.57) | 0.117 |
| | Secondary | 2.22 (0.76, 6.48) | 0.145 | 1.52 (0.45, 5.09) | 0.500 | 1.59 (0.48, 5.30) | 0.453 |
| | Higher | 1.94 (0.40, 9.35) | 0.408 | 2.15 (0.34, 13.67) | 0.419 | 2.34 (0.38, 14.47) | 0.359 |
| *Mother's Age* | | 1.03 (1.00, 1.06) | 0.054 | 1.04 (1.00, 1.09) | 0.039 | 1.04 (1.00, 1.07) | 0.052 |
| *Child Sex* | Male | 1.00 | | 1.00 | | | |
| | Female | 0.90 (0.62, 1.30) | 0.570 | 0.98 (0.63, 1.53) | 0.934 | | |
| *Region* | Dodoma | 1.00 | | 1.00 | | 1.00 | |
| | Arusha | 0.45 (0.07, 2.79) | 0.390 | 0.87 (0.10, 7.48) | 0.901 | 0.87 (0.10, 7.51) | 0.901 |
| | Kilimanjaro | 0.68 (0.13, 3.57) | 0.652 | 1.58 (0.21, 12.13) | 0.660 | 1.55 (0.20, 11.99) | 0.674 |
| | Tanga | 0.89 (0.21, 3.87) | 0.880 | 0.72 (0.11, 4.61) | 0.727 | 0.75 (0.12, 4.81) | 0.761 |
| | Morogoro | 0.29 (0.05, 1.60) | 0.156 | 0.83 (0.11, 6.38) | 0.858 | 0.79 (0.10, 6.06) | 0.819 |
| | Pwani | 0.39 (0.07, 2.20) | 0.289 | 0.33 (0.04, 2.74) | 0.307 | 0.33 (0.04, 2.73) | 0.304 |
| | Dar Es Salaam | 0.51 (0.14, 1.86) | 0.308 | 0.55 (0.10, 2.93) | 0.480 | 0.56 (0.10, 3.01) | 0.500 |
| | Lindi | 0.31 (0.05, 1.78) | 0.188 | 0.28 (0.03, 2.23) | 0.228 | 0.29 (0.04, 2.31) | 0.242 |
| | Mtwara | 0.77 (0.14, 4.34) | 0.765 | 0.99 (0.13, 7.56) | 0.989 | 1.04 (0.14, 7.95) | 0.967 |
| | Ruvuma | 0.21 (0.02, 1.78) | 0.151 | 0.43 (0.04, 4.94) | 0.500 | 0.44 (0.04, 5.04) | 0.509 |
| | Iringa | 0.77 (0.15, 4.05) | 0.757 | 1.27 (0.17, 9.33) | 0.815 | 1.27 (0.17, 9.33) | 0.814 |
| | Mbeya | 0.82 (0.17, 3.96) | 0.806 | 1.17 (0.18, 7.72) | 0.868 | 1.13 (0.17, 7.47) | 0.896 |
| | Singida | 0.35 (0.05, 2.60) | 0.304 | 0.66 (0.06, 6.79) | 0.729 | 0.65 (0.06, 6.77) | 0.721 |
| | Tabora | 0.47 (0.09, 2.36) | 0.358 | 0.71 (0.09, 5.40) | 0.743 | 0.70 (0.09, 5.30) | 0.728 |
| | Rukwa | 0.57 (0.11, 2.92) | 0.498 | 0.92 (0.13, 6.47) | 0.934 | 0.91 (0.13, 6.46) | 0.928 |
| | Kigoma | 0.57 (0.10, 3.23) | 0.525 | 0.83 (0.10, 6.58) | 0.859 | 0.82 (0.10, 6.56) | 0.854 |
| | Shinyanga | | | | | | |
| | Kagera | 1.18 (0.20, 6.79) | 0.854 | 1.45 (0.18, 11.72) | 0.729 | 1.50 (0.18, 12.17) | 0.705 |
| | Mwanza | 0.42 (0.10, 1.68) | 0.218 | 0.62 (0.11, 3.71) | 0.605 | 0.63 (0.11, 3.76) | 0.613 |
| | Mara | 0.17 (0.03, 0.95) | 0.043 | 0.28 (0.04, 2.10) | 0.217 | 0.28 (0.04, 2.05) | 0.208 |
| | Manyara | | | | | | |
| | Njombe | 0.44 (0.05, 3.88) | 0.456 | 0.48 (0.04, 5.90) | 0.569 | 0.49 (0.04, 5.97) | 0.573 |
| | Katavi | 0.26 (0.01, 4.68) | 0.359 | 0.57 (0.02, 13.66) | 0.729 | 0.55 (0.02, 13.25) | 0.714 |
| | Simiyu | | | | | | |
| | Geita | 0.43 (0.09, 2.17) | 0.308 | 0.76 (0.11, 5.16) | 0.778 | 0.75 (0.11, 5.11) | 0.770 |
| | Kaskazini Unguja | 0.61 (0.00, 254.35) | 0.874 | 1.23 (0.00, 788.43) | 0.950 | 1.22 (0.00, 764.43) | 0.951 |
| | Kusini Unguja | | | | | | |

| Urban Model (n = 420) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Variables** | **Crude Model** | | | **Full Model** | | **Final Model** | |
| | *Levels* | *OR (CI)* | *p* | *OR (CI)* | *p* | *OR (CI)* | *p* |
| | Mjini Magharibi | 0.33 (0.05, 2.27) | 0.262 | 0.48 (0.05, 4.65) | 0.526 | 0.49 (0.05, 4.79) | 0.540 |
| | Kaskazini Pemba | 0.64 (0.00, 158.75) | 0.872 | 1.05 (0.00, 310.48) | 0.986 | 1.01 (0.00, 299.61) | 0.997 |
| | Kusini Pemba | 0.27 (0.01, 14.43) | 0.521 | | | | |
| *Wealth Quintile* | 0 - 20th %ile | 1.00 | | 1.00 | | 1.00 | |
| | 20-40th %ile | 3.81 (0.59, 24.39) | 0.158 | 3.78 (0.48, 29.88) | 0.208 | 3.90 (0.49, 30.86) | 0.197 |
| | 40-60th %ile | 3.04 (0.66, 14.04) | 0.154 | 2.27 (0.40, 13.01) | 0.356 | 2.38 (0.42, 13.54) | 0.329 |
| | 60-80th %ile | 2.24 (0.56, 8.87) | 0.252 | 1.56 (0.33, 7.44) | 0.578 | 1.64 (0.35, 7.76) | 0.535 |
| | 80-100th %ile | 3.23 (0.83, 12.58) | 0.091 | 2.19 (0.45, 10.76) | 0.333 | 2.33 (0.48, 11.33) | 0.294 |
| *Distance to HF* | Not a Problem | 1.00 | | 1.00 | | 1.00 | |
| | Problem | 0.97 (0.66, 1.44) | 0.884 | 1.04 (0.66, 1.65) | 0.858 | 1.04 (0.66, 1.65) | 0.857 |
| *Maternal Tetanus Vaccinations* | 0 | 1.00 | | 1.00 | | 1.00 | |
| | 1 | 0.87 (0.44, 1.72) | 0.697 | 0.97 (0.44, 2.13) | 0.937 | 1.00 (0.46, 2.19) | 0.999 |
| | 2 | 0.89 (0.50, 1.59) | 0.691 | 0.72 (0.35, 1.45) | 0.357 | 0.74 (0.37, 1.50) | 0.408 |
| | 3 | 1.30 (0.68, 2.51) | 0.428 | 1.14 (0.51, 2.54) | 0.756 | 1.18 (0.53, 2.60) | 0.689 |
| | 4 | 0.24 (0.01, 4.66) | 0.349 | 0.15 (0.01, 3.67) | 0.247 | 0.16 (0.01, 3.79) | 0.258 |
| | 5 | 3.07 (0.24, 40.05) | 0.392 | 2.17 (0.09, 49.86) | 0.628 | 2.30 (0.10, 52.55) | 0.601 |
| *Antenatal Care Visits* | 0 | 1.00 | | 1.00 | | 1.00 | |
| | 1 - 3 | 0.40 (0.23, 0.70) | 0.001 | 0.35 (0.18, 0.67) | 0.002 | 0.36 (0.19, 0.68) | 0.002 |
| | 4 - 5 | 0.61 (0.37, 0.99) | 0.045 | 0.54 (0.31, 0.93) | 0.028 | 0.54 (0.31, 0.93) | 0.028 |
| | 6+ | | | | | | |
| *Model Intercept* | | | | 0.11 (0.01, 1.81) | 0.122 | 0.11 (0.01, 1.81) | 0.122 |

The results of both LRTs show that the final models do not fit better than the full models. The AIC and BIC indicate that the final models are better fit than the full models for both the rural and urban models (Table 11).

**Table 11: Results of likelihood ratio test comparing full and final model**

| **Test/ Information Criteria** | **Rural Model** | | **Urban Model** | |
|---|---|---|---|---|
| *Model Iteration* | *Full Model* | *Final Model* | *Full Model* | *Final Model* |
| LRT | p = 0.290 | | p = 0.771 | |
| AIC | 966.34 | 964.27 | 635.92 | 632.44 |
| BIC | 12124.43 | 1202.35 | 7809.65 | 798.09 |

# 7. Analysis of the Demographic Health Surveys Data: Discussion

As observed in the results of the literature review, the location in which one lives greatly impacts the likeliness of both coverage and of timely vaccination delivery. Figure 5 depicts the regional variation in Penta 3 timeliness. There is significant regional variation in vaccination timeliness. There is notable clustering of vaccination timeliness rates indicating that differences in vaccination timeliness are zonal. Regional or zonal differences may be due to disparities in accessibility of healthcare as well as economic and cultural variations [10, 28, 31]. It is important to take action that addresses these regional inequities.

Final vaccination doses have lower timeliness than first vaccination doses. This trend likely occurs because mothers are less willing or able to return to clinics for follow up vaccinations leading to higher dropout [30]. Polio 0 has lower timeliness than all three remaining doses of polio vaccine. It also has lower timeliness than BCG, which should be administered at the same time (at birth). Farther, coverage of OPV0 is also lower than coverage for following polio doses and coverage of BCG. We would expected to see similar coverage and similar timeliness of BCG and OPV0 as they align on the vaccination schedule, so it is possible that the vaccine is not being administered due to a lack of availability. The higher BCG coverage than timeliness suggests that of those children being vaccinated at birth, many are not being vaccinated on time. Probable

cause is the immunization system, and in particular, management of vaccinations (e.g. stockouts, lack of available refrigeration, and insufficient energy sources to run refrigerators).

First and third doses of vaccines have lower timeliness than the second dose (Table 7). This results due to the definitions of vaccination timeliness. The first dose has a stricter definition than the following doses as it is based on the WHO vaccination schedule recommendation of six to ten weeks. Second and third doses follow four to eight weeks after the prior does and thus have a more lenient definition. This likely explains why timeliness tends to be higher for the second dose than the first. The third dose may be lower due to increased dropout due to poor parental knowledge about immunization schedule or poor follow-up from the immunization system [43, 47].

Because of the strong correlation between urban versus rural setting and vaccination timeliness, the LR model for BTS was run as two separate models. Between the two models there are many clear common variables that indicate likeliness for complete vaccination timeliness.

In rural settings increased education means increased odds of full vaccination coverage, yet in urban settings, primary education and higher education have the greatest odds of full vaccination while secondary education has the lowest odds. Only rural education results are statistically significant. We would expect increasing education status to correlate with increased vaccination timeliness because of greater

vaccination knowledge of mothers or increased health seeking tendencies [42]. Yet the inconsistent results from our LR model are comparable to the results obtained across and within countries in the literature review. Correlation among mother's education and occupation in urban area may define education as a barrier to vaccination timeliness, while correlation with mother's income and SES quartile may help to explains it's effect as a facilitator in urban areas [10]. Intersectoral collaboration between departments of health and education may be crucial in reducing disparities in vaccination timeliness due to education level [39].

Increasing maternal age is significantly associated with lower completion of timely vaccination in the urban model. Some literature suggests that older mothers may have more vaccination awareness, greater health seeking resources, or greater health seeking behaviors. Yet, others find results similar to ours [29]. It is possible that older mother are less target in awareness campaigns, are busier as they have more children, less help from other family members (e.g. their own mother's), or are employed [59, 60].

In rural settings the odds of full vaccination timeliness increases with increasing wealth. In urban settings, there is no correlation between full vaccination timeliness and wealth quintile. Wealth at or above 40 percent increased the odds of being fully vaccinated on time in rural setting. Being rural and poor leads to inaccessible timely vaccination, yet the same is not shown to occur in urban settings. It is plausible that greater density of HFs in urban areas and greater population density ability improve

access to vaccination and facilitate distribution of vaccination information such as vaccination dates and locations, and reasons for their need, which reduces the impact of the wealth disparity. Possibly, vaccination outreach to the lowest wealth quintiles is also greater reality in urban settings as these families maybe more geographically accessible.

In rural settings, maternal tetanus toxoid vaccine leads to an increase in odds of full timely vaccination. Those receiving two doses have a higher odds than those only receiving one vaccine, but neither one or two doses is protective for timely vaccination completion compared to no maternal TT. In urban model any antenatal care correlates with lower odds of complete timely vaccination. Generally, ANC and maternal vaccination have been found to facilitate vaccination coverage, and therefore would have been expected to facilitate vaccination timeliness [26, 42, 47, 51]. Possibly, mothers who receive ANC or TT vaccine had poor encounters with health personnel or at health facilities. This is also a sign of an inadequate immunization system and a lack of communication as mothers receiving care are not being directed about the vaccination needs of their children or are not provided the same opportunities to travel to HFs for vaccination needs as for postnatal care [27, 31].

Timely completion of vaccination varies quite significantly among many regions of Tanzania. Regions with a larger rural population generally have a greater odds of full vaccination timeliness in the rural model, and regions with larger urban populations have larger odds in the urban model. This occurs by design of the two models, as reginal

variation is associated with degree of urban versus rural settings. For example, Arusha is largely urban while Pwani is largely rural. Thus, the high odds on complete timely vaccination for Arusha in the urban model and Pwani in the rural model, is a result of the dominant residence type in each region.

## *7.1 Implications for policy and practice*

In the mid-nineties, the Tanzania Government and development partnership began reforming the healthcare sector, which included integration of EPI [18]. Tanzania EPI sought high level political commitment, commitment of the health system, and support for households in combination with a multi sectoral strategic approach to increase immunization coverage [18]. This increased access to immunization services as well as knowledge of the need for vaccinations, thus leading to the boom in vaccination coverage. During this time Semali also finds that there is little to no immunization disparity by wealth quintile [18]. However, Semali finds that there is significant wealth disparity for complete immunization by year 2004 and suggests the programs lost efficacy among the least advantaged [18]. Government action must be taken to address this disparity in vaccination coverage and must implement additional steps to improve timely vaccination. Improving vaccination timeliness first requires that vaccination is accessible so it is necessary to ensure a strong cold chain, good vaccination storage, no stock outs, and adequate HF staff [53]. Reimplementing previous EPI strategies,

including routine immunization services, with a greater emphasis on the importance of vaccination timeliness may also be effective. Sustainability of outreach programs is of large concern, and these programs must be prioritized. Good governance through alignment of stakeholder goals and commitment to achieving these goals in necessary for making progress towards more timely vaccination delivery.

Regional variation, which also resulted as significant, must be addressed in this multi-sector government strategy. Compositional explanations posit that geographical variation in vaccination coverage and timeliness occur due to clustering of households with low vaccination uptake [31]. Targeting equality of vaccination access among varying SES categories and ethnic groups should aid in alleviating the regional disparities.

Though funding remains an issues, childhood vaccination must be prioritized, which requires sustainable financing. Fund issues could be addressed by creating more efficient systems. National records, which are kept by paper, could be less costly if made entirely electronic. Because costs related to transportation of documents and payment of clinic staff for record keeping, funds could be reallocated to maintain adequate and safe supply of vaccinations, while staff time could be used more effectively. Maintaining an electronic system does present its own issues with regard to resources, but use of mobile health applications could make this system a reality and was proven successful in in Kenya [62].

## *7.2 Study strengths and limitations*

The Demographic and Health surveys are large, well conducted surveys. This provided the opportunity to examine many variables that may be associated with vaccination coverage and vaccination timeliness. However, with this data, we were not able to account for parents' perceptions despite evidence in the literature that this is a likely contributor to poor vaccination coverage and therefore, low vaccination timeliness. Further, we are limited by the data in that we were only able to explore demand-side issues of vaccination, though supply-side issues could significantly impact the receipt and delivery of vaccinations. We are unable to explore, through statistical analyses, whether vaccine stock outs, inadequate vaccination storage, or a lack of workers in vaccination facilities cause delays with timely vaccination delivery. Finally, we must acknowledge that in some assessments we are limited be our sample size. Though the sample size starts off very large, after apply age restrictions and then further examining specific variables categories, such as specific regions, the sample size does become much smaller. Thus we must interpret our results with caution.

# 8. Conclusion

There are several factors that are associated with poor vaccination coverage and timeliness throughout SSA. In the Tanzania data, we found many of the same factors, the most significant of which include location (both geographic region and urban or rural residence), socio-demographic factors, and antenatal care factors. Oddly, antenatal care was negatively associated with timely vaccination. This indicates serious issues with the maternal and child health care system, and further research must be conducted to understand the reason for this anomaly.

Higher coverage in some regions of the country mask the issues of poor vaccination coverage in other areas. Further, most vaccinations suffer serious delays and very few children (15%) complete the immunization schedule on time. It is essential to emphasize the importance of following vaccination schedules and report timeliness data according to these schedules (rather than, for example, reporting vaccination before one year of age as on time). Future research should also investigate the problems of vaccination in specific regions and design campaigns to address these particular issues, while collaborating at the government level to ensure sustainability.

# Appendix A: Literature Review Search Terms

| **Search Heading** | **Database** | | | |
|---|---|---|---|---|
| | *MEDLINE* | *Cochrane* | *Web of Science* | *Scopus* |
| Vaccine | "Diphtheria-Tetanus-acellular Pertussis Vaccines"[Majr] OR "Tuberculosis Vaccines"[Majr] OR "Poliovirus Vaccines"[Majr] OR "Measles Vaccine"[Majr] OR "Vaccines"[[Majr] And[All Fields]] OR "Immunization"[Majr] ] OR "Immunotherapy, Active"[Majr] OR "Vaccines/administration and dosage"[Majr] OR "Maternal-Child Health Centers"[Majr] | "Diphtheria-Tetanus-acellular Pertussis Vaccines" or "Tuberculosis Vaccines" or "Poliovirus Vaccines" or "Measles Vaccine" or "Vaccines" or "Immunization" or "Immunotherapy, Active" or "Vaccines/administration and dosage" or "Maternal-Child Health Centers" | TS=("Diphtheria-Tetanus-acellular Pertussis Vaccines"OR "Tuberculosis Vaccines" OR "Poliovirus Vaccines" OR "Measles Vaccine" OR "Vaccines" OR "Immunization" OR "Immunotherapy, Active" OR "Vaccines/administration and dosage" OR "Maternal-Child Health Centers") | ALL ( "Diphtheria-Tetanus-acellular Pertussis Vaccines" OR "Tuberculosis Vaccines" OR "Poliovirus Vaccines" OR "Measles Vaccine" OR "Vaccines" OR "Immunization" OR "Immunotherapy,Active" OR "Vaccines/administration and dosage" OR "Maternal-Child Health Centers" ) |
| Timeliness | "Immunization Schedule"[Majr] OR "Vaccine Timeliness"[tiab] OR "Immunization Timeliness"[tiab] OR "Vaccine Coverage"[tiab] OR "Immunization Coverage"[tiab] OR "Vaccination Catch-up"[All Fields] OR "Immunization Catch-up"[tiab] OR "Vaccination Campaign"[All Fields] OR "Immunization Campaign"[tiab] OR "Mass | "Immunization Schedule" or "Vaccine Timeliness" or "Immunization Timeliness" or "Vaccine Coverage" or "Immunization Coverage" or "Vaccination Catch-up" or "Immunization Catch-up" or "Vaccination | TS=("Immunization Schedule" OR "Vaccine Timeliness" OR "Immunization Timeliness" OR "Vaccine Coverage" OR "Immunization Coverage" OR "Vaccination Catch-up" OR "Immunization | TITLE-ABS-KEY ( "Diphtheria-Tetanus-acellular Pertussis Vaccines" OR "Tuberculosis Vaccines" OR "Poliovirus Vaccines" OR "Measles Vaccine" OR "Vaccines" OR "Immunization" OR |

| **Search Heading** | **Database** | | | |
|---|---|---|---|---|
| | *MEDLINE* | *Cochrane* | *Web of Science* | *Scopus* |
| | Vaccination"[Majr] | Campaign" or "Immunization Campaign" or "Mass Vaccination":ti,ab,kw | Catch-up" OR "Vaccination Campaign" OR "Immunization Campaign" OR "Mass Vaccination") | "Immunotherapy, Active" OR "Vaccines/administration and dosage" OR "Maternal-Child Health Centers" ) |
| Tanzania OR East Africa OR Sub-Saharan Africa | ("tanzania"[MeSH Terms] OR "tanzania"[All Fields]) OR ("africa south of the sahara"[MeSH Terms] OR ("africa"[All Fields] AND "south"[All Fields] AND "sahara"[All Fields]) OR "africa south of the sahara"[All Fields] OR ("sub"[All Fields] AND "saharan"[All Fields] AND "africa"[All Fields]) OR "sub saharan africa"[All Fields]) OR ("africa south of the sahara"[MeSH Terms] OR ("africa"[All Fields] AND "south"[All Fields] AND "sahara"[All Fields]) OR "africa south of the sahara"[All Fields] OR ("sub"[All Fields] AND "saharan"[All Fields] AND "africa"[All Fields]) OR "sub saharan africa"[All Fields]) OR ("africa, eastern"[MeSH Terms] OR ("africa"[All Fields] AND "eastern"[All Fields]) OR "eastern africa"[All Fields] OR ("east"[All Fields] AND "africa"[All Fields]) OR "east | “Tanzania” or “Sub-Saharan Africa” or “Sub Saharan Africa” or “East Africa” or “African Union” or “Benin” or “Botswana” or “Burkina Faso” or “Cameroon” or “Congo” and “Brazzaville” or “Congo” or “Democratic Republic of Congo” or “Ethiopia” or “Ghana” or “Guinea” or “Ivory Coast” or “Kenya” or “Lesotho” or “Madagascar” or “Malawi” or “Mauritius” or “Mozambique” or “Namibia” or “Niger” or “Nigeria” or “Rwanda” or “Senegal” or “Sierra | TS=(“Tanzania” OR “Sub-Saharan Africa” OR “Sub Saharan Africa” OR “East Africa” OR “African Union” OR “Benin” OR “Botswana” OR “Burkina Faso” OR “Cameroon” OR “Congo” AND “Brazzaville” OR “Congo” OR “Democratic Republic of Congo” OR “Ethiopia” OR “Ghana” OR “Guinea” OR “Ivory Coast” OR “Kenya” OR “Lesotho” OR “Madagascar” OR “Malawi” OR “Mauritius” OR “Mozambique” OR “Namibia” OR “Niger” OR “Nigeria” OR | ALL ( "Tanzania" OR "Sub-Saharan Africa" OR "Sub Saharan Africa" OR "East Africa" OR "African Union" OR "Benin" OR "Botswana" OR "Burkina Faso" OR "Cameroon" OR "Congo" AND "Brazzaville" OR "Congo" OR "Democratic Republic of Congo" OR "Ethiopia" OR "Ghana" OR "Guinea" OR "Ivory Coast" OR "Kenya" OR "Lesotho" OR "Madagascar" OR "Malawi" OR "Mauritius" OR "Mozambique" OR "Namibia" OR "Niger" OR "Nigeria" OR |

| Search Heading | Database | | | |
|---|---|---|---|---|
| | *MEDLINE* | *Cochrane* | *Web of Science* | *Scopus* |
| | africa"[All Fields]) OR (("african continental ancestry group"[MeSH Terms] OR ("african"[All Fields] AND "continental"[All Fields] AND "ancestry"[All Fields] AND "group"[All Fields]) OR "african continental ancestry group"[All Fields] OR "african"[All Fields]) AND Union[All Fields]) OR ("benin"[MeSH Terms] OR "benin"[All Fields]) OR ("botswana"[MeSH Terms] OR "botswana"[All Fields]) OR ("burkina faso"[MeSH Terms] OR ("burkina"[All Fields] AND "faso"[All Fields]) OR "burkina faso"[All Fields]) OR ("cameroon"[MeSH Terms] OR "cameroon"[All Fields]) OR ("congo"[MeSH Terms] OR "congo"[All Fields]) AND Brazzaville[All Fields] OR ("congo"[MeSH Terms] OR "congo"[All Fields]) OR (Democratic[All Fields] AND Republic[All Fields] AND ("congo"[MeSH Terms] OR "congo"[All Fields])) OR ("ethiopia"[MeSH Terms] OR "ethiopia"[All Fields]) OR ("ghana"[MeSH Terms] OR "ghana"[All Fields]) OR ("guinea"[MeSH Terms] OR "guinea"[All Fields]) OR ("cote d'ivoire"[MeSH Terms] OR ("cote"[All Fields] AND "d'ivoire"[All Fields]) OR "cote d'ivoire"[All Fields] OR ("ivory"[All Fields] | Leone" or "South Africa" or "Swaziland" or "Togo" or "Uganda" or "Zambia" | "Rwanda" OR "Senegal" OR "Sierra Leone" OR "South Africa" OR "Swaziland" OR "Togo" OR "Uganda" OR "Zambia") | "Rwanda" OR "Senegal" OR "Sierra Leone" OR "South Africa" OR "Swaziland" OR "Togo" OR "Uganda" OR "Zambia" ) |

| Search Heading | Database | | | |
|---|---|---|---|---|
| | *MEDLINE* | *Cochrane* | *Web of Science* | *Scopus* |
| | AND "coast"[All Fields]) OR "ivory coast"[All Fields]) OR ("kenya"[MeSH Terms] OR "kenya"[All Fields]) OR ("lesotho"[MeSH Terms] OR "lesotho"[All Fields]) OR ("madagascar"[MeSH Terms] OR "madagascar"[All Fields]) OR ("malawi"[MeSH Terms] OR "malawi"[All Fields]) OR ("mauritius"[MeSH Terms] OR "mauritius"[All Fields]) OR ("mozambique"[MeSH Terms] OR "mozambique"[All Fields]) OR ("namibia"[MeSH Terms] OR "namibia"[All Fields]) OR ("niger"[MeSH Terms] OR "niger"[All Fields]) OR ("nigeria"[MeSH Terms] OR "nigeria"[All Fields]) OR ("rwanda"[MeSH Terms] OR "rwanda"[All Fields]) OR ("senegal"[MeSH Terms] OR "senegal"[All Fields]) OR ("sierra leone"[MeSH Terms] OR ("sierra"[All Fields] AND "leone"[All Fields]) OR "sierra leone"[All Fields]) OR ("south africa"[MeSH Terms] OR ("south"[All Fields] AND "africa"[All Fields]) OR "south africa"[All Fields]) OR ("swaziland"[MeSH Terms] OR "swaziland"[All Fields]) OR ("togo"[MeSH Terms] OR "togo"[All Fields]) OR ("uganda"[MeSH Terms] OR "uganda"[All | | | |

| **Search Heading** | **Database** | | | |
|---|---|---|---|---|
| | *MEDLINE* | *Cochrane* | *Web of Science* | *Scopus* |
| | Fields]) OR ("zambia"[MeSH Terms] OR "zambia"[All Fields]) | | | |
| Barriers OR Facilitators | (Barriers[All Fields] OR ("Plan Parent Chall"[Journal] OR "challenges"[All Fields]) OR Difficulties[All Fields] OR Obstacles[All Fields] OR Determinants[All Fields] OR Access[All Fields] OR Disparity[All Fields]) OR (Facilitators[All Fields] OR Interventions[All Fields] OR Program[All Fields] OR Campaign[All Fields] OR ("supply and distribution"[Subheading] OR ("supply"[All Fields] AND "distribution"[All Fields]) OR "supply and distribution"[All Fields] OR "distribution"[All Fields])) | (“Barriers” or “Challenges” or “Difficulties” or “Obstacles” or “Determinants” or “Access” or “Disparity”) or (“Facilitators” or “Interventions” or “Program” or “Campaign” or “Distribution”) | TS=((“Barriers” OR “Challenges” OR “Difficulties” OR “Obstacles” OR “Determinants” OR “Access” OR “Disparity”) OR (“Facilitators” OR “Interventions” OR “Program” OR “Campaign” OR “Distribution”)) | ALL ( ("Barriers" OR "Challenges" OR "Difficulties" OR "Obstacles" OR "Determinants" OR "Access" OR "Disparity") OR ("Facilitators" OR "Interventions" OR "Program" OR "Campaign" OR "Distribution") ) |

# Appendix B: Recreated Demographic Health Surveys Tables

### 2015 – 2016 DHS Table 10.2: Vaccinations by source of information

| Age in Months | 12 - 23 | | | | 24 - 35 | | | |
|---|---|---|---|---|---|---|---|---|
| Information Source | Vaccination Card | Mother's Report | Any Source | Vaccinated by 12 months | Vaccination Card | Mother's Report | Any Source | Vaccinated by 12 months* |
| BCG | 82.7 | 13.3 | 96.0 | 95.6 | 69.5 | 26.2 | 95.7 | 94.4 |
| Penta 1 | 83.6 | 13.3 | 97.0 | 96.6 | 70.2 | 25.7 | 95.9 | 95.2 |
| Penta 2 | 81.3 | 12.6 | 93.9 | 93.4 | 69.5 | 24.4 | 93.9 | 92.9 |
| Penta 3 | 78.4 | 10.6 | 89.0 | 87.7 | 69.0 | 20.4 | 88.3 | 86.1 |
| Polio 0 | 58.7 | 8.6 | 67.3 | 67.2 | 47.1 | 17.2 | 64.3 | 63.8 |
| Polio 1 | 83.3 | 13.2 | 96.5 | 96.2 | 69.7 | 25.3 | 95.1 | 94.3 |
| Polio 2 | 80.1 | 11.8 | 91.9 | 91.4 | 69.0 | 22.5 | 91.5 | 90.5 |
| Polio 3 | 76.4 | 6.1 | 82.5 | 81.5 | 66.3 | 11.7 | 78.0 | 75.9 |
| Pneumo 1 | 82.4 | 12.8 | 95.3 | 94.9 | 65.0 | 23.2 | 88.2 | 87.4 |
| Pneumo 2 | 79.3 | 12.1 | 91.4 | 90.7 | 63.9 | 21.9 | 85.9 | 84.8 |
| Pneumo 3 | 75.6 | 10.5 | 86.1 | 84.5 | 62.2 | 18.9 | 81.1 | 78.9 |
| Rota 1 | 81.5 | 12.3 | 93.8 | 93.4 | 63.5 | 22.8 | 86.2 | 85.0 |
| Rota 2 | 77.7 | 11.7 | 89.4 | 88.4 | 61.8 | 21.0 | 82.8 | 80.6 |
| Measles 1 | 74.4 | 11.6 | 86.0 | 78.0 | 66.7 | 23.8 | 90.4 | 79.8 |
| Measles 2 | | | | | 24.1 | 7.4 | 31.5 | 28.7 |
| All Vaccinations | 70.1 | 5.3 | 75.3 | 67.9 | 62.7 | 10.3 | 72.9 | 65.4 |
| All age appropriate vaccinations | 49.5 | 2.6 | 52.1 | 48.1 | 17.4 | 2.2 | 19.6 | 16.5 |
| None | 0.2 | 2.0 | 2.3 | 0.0 | 0.1 | 3.0 | 3.0 | 0.0 |
| Number of Children | 1797 | 337 | 2134 | 2134 | 1280 | 537 | 1817 | 1817 |

## 2015 – 2016 DHS Table 10.3: Vaccinations by background characteristics

| Age in Months | | 12 - 23 | | | | | | | | | | | | | | | | | | 24 - 35 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Background Characteristic | | BCG | Penta 1 | Penta 2 | Penta 3 | Polio 0 | Polio 1 | Polio 2 | Polio 3 | Pneumo 1 | Pneumo 2 | Pneumo 3 | Rota 1 | Rota 2 | Measles | All basic vaccinations | All age appropriate vaccinations | No vaccinations | Number of children | Measles | All basic vaccinations | Number of children |
| **Sex** | *Male* | 96.7 | 97.2 | 94.6 | 90.1 | 69 | 96.6 | 92.4 | 83.6 | 95.2 | 91.7 | 86.6 | 94.4 | 90.7 | 87.7 | 76.9 | 54.3 | 1.6 | 1093 | 32.7 | 20.7 | 954 |
| | *Female* | 95.3 | 96.6 | 93.2 | 87.8 | 65.4 | 96.3 | 91.3 | 81.4 | 95.3 | 91.1 | 85.6 | 93.1 | 88.1 | 84.2 | 73.7 | 49.9 | 2.9 | 1041 | 30.3 | 18.4 | 864 |
| **Birth Order** | *1* | 96.7 | 98.5 | 96.5 | 91.7 | 75.7 | 98.2 | 94.4 | 84.5 | 97.1 | 93.6 | 89.3 | 94.4 | 90.2 | 90.4 | 79.8 | 59.2 | 1.5 | 567 | 31.9 | 21.4 | 433 |
| | *2 - 3* | 96.6 | 97.1 | 94.6 | 89.2 | 69.3 | 97 | 93.3 | 82.8 | 95.9 | 92.2 | 86.7 | 94.9 | 90.6 | 87.7 | 75.7 | 53.7 | 1.8 | 732 | 35.9 | 24.8 | 640 |
| | *4 - 5* | 96.7 | 97.3 | 93.6 | 89.2 | 65.6 | 96.2 | 91 | 84.2 | 95.6 | 92.1 | 88.2 | 94.9 | 91.4 | 85.1 | 76.4 | 52.4 | 2 | 449 | 29.1 | 15 | 372 |
| | *6+* | 93 | 94 | 89 | 84.5 | 53 | 93.2 | 86.6 | 77.1 | 91.1 | 85.7 | 77.8 | 89.6 | 83.9 | 77.6 | 66.8 | 38.6 | 4.5 | 387 | 26 | 13.1 | 372 |
| **Residence** | *Urban* | 98.5 | 99 | 98.7 | 95 | 87.1 | 98.6 | 96.2 | 86.6 | 98.7 | 97.8 | 93.7 | 97.1 | 96.6 | 93.3 | 82.2 | 72 | 1 | 611 | 38.1 | 29.7 | 471 |
| | *Rural* | 95 | 96.1 | 92 | 86.6 | 59.3 | 95.6 | 90.2 | 80.9 | 93.9 | 88.8 | 83 | 92.5 | 86.6 | 83.1 | 72.6 | 44.2 | 2.8 | 1523 | 29.2 | 16.1 | 1346 |
| **Mainland/ Zanzibar** | *Mainland* | 95.9 | 97 | 93.9 | 88.9 | 67.2 | 96.5 | 91.8 | 82.4 | 95.2 | 91.3 | 85.9 | 93.7 | 89.4 | 85.9 | 75.2 | 52 | 2.3 | 2077 | 31.7 | 19.7 | 1768 |
| | *Urban* | 98.5 | 99 | 98.8 | 95 | 87.4 | 98.6 | 96.2 | 86.7 | 98.7 | 97.9 | 93.7 | 97.1 | 96.6 | 93.4 | 82.3 | 72.5 | 1 | 595 | 38.4 | 29.8 | 459 |
| | *Rural* | 94.9 | 96.1 | 91.9 | 86.4 | 59 | 95.6 | 90.1 | 80.7 | 93.8 | 88.7 | 82.8 | 92.4 | 86.4 | 82.9 | 72.3 | 43.8 | 2.8 | 1482 | 29.4 | 16.1 | 1309 |
| | *Zanzibar* | 98.6 | 97 | 95.5 | 93.4 | 71 | 96.9 | 93.8 | 85.6 | 97 | 93.8 | 91.8 | 95.7 | 91.9 | 89.4 | 80.8 | 55.9 | 1 | 57 | 25 | 17.3 | 49 |
| | *Unguja* | 99.9 | 99.2 | 98.3 | 97 | 75 | 99.2 | 96.4 | 85.5 | 99.2 | 95.8 | 94.3 | 97.8 | 94.2 | 93.1 | 81.1 | 56.2 | 0 | 38 | 27.1 | 20.4 | 30 |
| | *Pemba* | 96.5 | 92.5 | 90.1 | 86.4 | 63.2 | 92.4 | 88.8 | 85.9 | 92.5 | 90.1 | 87.2 | 91.8 | 87.5 | 82.4 | 80.4 | 55.3 | 2.8 | 19 | 21.8 | 12.5 | 19 |
| **Zone** | *Western* | 93.2 | 93.4 | 84.3 | 77.5 | 58.9 | 93.9 | 83.1 | 73.5 | 89.8 | 80 | 72.7 | 86.9 | 75.1 | 77.8 | 66.1 | 39.7 | 4.9 | 293 | 24.1 | 11.3 | 211 |
| | *Northern* | 97.2 | 98.4 | 97.3 | 95 | 62.7 | 97.7 | 93.8 | 86.2 | 98.4 | 97.3 | 94.3 | 96.3 | 95 | 88.9 | 81.7 | 53.1 | 1.6 | 193 | 43.9 | 34.3 | 178 |
| | *Central* | 97 | 98.1 | 96.9 | 96 | 65.7 | 97.2 | 95.5 | 90.1 | 97.7 | 95.9 | 94.7 | 97.5 | 95.1 | 90.7 | 83.2 | 55.7 | 1.9 | 245 | 39.3 | 23.3 | 167 |
| | *Southern Highlands* | 99.4 | 99.4 | 99.4 | 96.7 | 80.7 | 98.7 | 96 | 91.4 | 98.9 | 98.9 | 96.2 | 97.5 | 94.7 | 90.6 | 83.4 | 66.3 | 0.6 | 120 | 24.6 | 16.3 | 90 |

| Age in Months | | 12 - 23 | | | | | | | | | | | | | | | | | | 24 - 35 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Background Characteristic | | BCG | Penta 1 | Penta 2 | Penta 3 | Polio 0 | Polio 1 | Polio 2 | Polio 3 | Pneumo 1 | Pneumo 2 | Pneumo 3 | Rota 1 | Rota 2 | Measles | All basic vaccinations | All age appropriate vaccinations | No vaccinations | Number of children | Measles | All basic vaccinations | Number of children |
| | *Southern* | 98.8 | 99.2 | 95.4 | 89.3 | 93.6 | 98 | 93 | 85.4 | 99.2 | 95.4 | 89.3 | 96.8 | 93.5 | 89.2 | 79.6 | 75.1 | 0 | 86 | 28.4 | 20.8 | 80 |
| | *South West Highlands* | 94.8 | 96.6 | 92.3 | 88.1 | 67.7 | 97.6 | 91.5 | 75.9 | 96.5 | 92.3 | 86.1 | 94.9 | 90.6 | 83.1 | 66.7 | 45.7 | 2.4 | 193 | 30 | 15 | 155 |
| | *Lake* | 94.2 | 96.6 | 93.5 | 85.5 | 53.6 | 95.7 | 91.4 | 80.2 | 93.2 | 87.9 | 80.3 | 91.4 | 86.4 | 83.2 | 70.5 | 38.9 | 2.7 | 615 | 23.1 | 12.3 | 619 |
| | *Eastern* | 98.6 | 97.8 | 97.2 | 93.8 | 91.1 | 97.1 | 95 | 86.5 | 97 | 96.5 | 92 | 97.1 | 96.4 | 91.9 | 83 | 76.5 | 1.1 | 332 | 49 | 34.9 | 268 |
| | *Zanzibar* | 98.6 | 97 | 95.5 | 93.4 | 71 | 96.9 | 93.8 | 85.6 | 97 | 93.8 | 91.8 | 95.7 | 91.9 | 89.4 | 80.8 | 55.9 | 1 | 57 | 25 | 17.3 | 49 |
| **Region** | *Dodoma* | 100 | 100 | 100 | 98.6 | 81.1 | 97.2 | 97.2 | 88.5 | 100 | 100 | 97.2 | 100 | 100 | 98.4 | 87 | 70.9 | 0 | 82 | 42.4 | 22.9 | 62 |
| | *Arusha* | 97.4 | 97.4 | 97.4 | 97.4 | 44.8 | 97.4 | 97.4 | 93.9 | 97.4 | 97.4 | 97.4 | 93.9 | 93.9 | 83.8 | 83.8 | 41.3 | 2.6 | 68 | 51.4 | 38.9 | 77 |
| | *Kilimanjaro* | 100 | 100 | 100 | 97.7 | 92.5 | 100 | 100 | 95.6 | 100 | 100 | 93.9 | 100 | 100 | 95.7 | 93.4 | 84.3 | 0 | 36 | 56 | 45.8 | 25 |
| | *Tanga* | 95.9 | 98.5 | 96.3 | 92.2 | 64.4 | 97 | 88.7 | 76.6 | 98.5 | 96.3 | 92.2 | 96.7 | 93.8 | 90.1 | 75.5 | 49.8 | 1.5 | 89 | 32.3 | 25.8 | 75 |
| | *Morogoro* | 100 | 95.9 | 94.7 | 90.9 | 86.6 | 95.9 | 94.7 | 83.9 | 95.9 | 94.7 | 89.3 | 95.9 | 94.3 | 90.4 | 80.7 | 69.3 | 0 | 86 | 62 | 39.1 | 105 |
| | *Pwani* | 98.1 | 100 | 98.1 | 92.1 | 91.7 | 100 | 96.3 | 80.4 | 98.2 | 96.3 | 88.8 | 98.3 | 96.4 | 84.3 | 74.2 | 66.2 | 0 | 44 | 16.9 | 16.9 | 31 |
| | *Dar Es Salaam* | 98.1 | 98.1 | 98.1 | 95.4 | 93 | 96.9 | 94.9 | 89 | 97.3 | 97.3 | 93.9 | 97.3 | 97.3 | 94.2 | 85.9 | 81.9 | 1.9 | 201 | 46.1 | 35.7 | 132 |
| | *Lindi* | 100 | 98.1 | 96.3 | 88.4 | 93.9 | 98.1 | 96.3 | 85 | 98.1 | 96.3 | 88.4 | 95.9 | 91.8 | 90.2 | 80.7 | 76.2 | 0 | 36 | 31.2 | 20.8 | 37 |
| | *Mtwara* | 97.9 | 100 | 94.8 | 89.9 | 93.3 | 97.9 | 90.6 | 85.7 | 100 | 94.8 | 89.9 | 97.4 | 94.8 | 88.5 | 78.8 | 74.2 | 0 | 50 | 26 | 20.8 | 43 |
| | *Ruvuma* | 100 | 100 | 100 | 96.9 | 80.3 | 100 | 95.8 | 91.3 | 100 | 100 | 96.9 | 97.1 | 93.3 | 90.1 | 81.4 | 60.6 | 0 | 60 | 23.1 | 16.8 | 39 |
| | *Iringa* | 98 | 98 | 98 | 95.8 | 87 | 95.8 | 93.8 | 87.8 | 98 | 98 | 95.8 | 98 | 98 | 91.9 | 84 | 78.6 | 2 | 37 | 17.1 | 14.5 | 25 |
| | *Mbeya* | 97.8 | 100 | 95.7 | 95.7 | 82.1 | 100 | 93.9 | 76.4 | 100 | 95.7 | 91.8 | 97.1 | 92.8 | 86.2 | 67 | 51.5 | 0 | 101 | 22.9 | 9.2 | 80 |
| | *Singida* | 95.9 | 97.2 | 93.4 | 91.9 | 65.9 | 97.2 | 92.6 | 86.6 | 95.9 | 92 | 91.2 | 95.9 | 92 | 86.2 | 79.5 | 52.9 | 2.8 | 78 | 22.1 | 10 | 57 |
| | *Tabora* | 91.1 | 91.8 | 79.3 | 69.1 | 449.3 | 92.6 | 77.9 | 67.6 | 90 | 77.9 | 70 | 85.4 | 70.2 | 70.6 | 58.9 | 30.6 | 6.1 | 177 | 15.9 | 5.4 | 115 |

| Age in Months | | 12 - 23 | | | | | | | | | | | | | | | | | | 24 - 35 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Background Characteristic | | BCG | Penta 1 | Penta 2 | Penta 3 | Polio 0 | Polio 1 | Polio 2 | Polio 3 | Pneumo 1 | Pneumo 2 | Pneumo 3 | Rota 1 | Rota 2 | Measles | All basic vaccinations | All age appropriate vaccinations | No vaccinations | Number of children | Measles | All basic vaccinations | Number of children |
| | *Rukwa* | 94.5 | 95.2 | 93.9 | 84.6 | 59.6 | 97.5 | 94.9 | 78.5 | 95.2 | 93.9 | 84.6 | 95.2 | 93.9 | 87 | 71 | 43.9 | 2.5 | 67 | 43.1 | 23.1 | 48 |
| | *Kigoma* | 96.2 | 95.7 | 91.8 | 90.2 | 73.5 | 95.7 | 90.8 | 82.5 | 89.5 | 83.2 | 76.9 | 89.2 | 82.6 | 88.7 | 77 | 53.4 | 3.1 | 117 | 33.9 | 18.4 | 96 |
| | *Shinyanga* | 90.9 | 90.9 | 87.9 | 72 | 45.7 | 92 | 86.9 | 70.3 | 90.9 | 85.2 | 75 | 97.1 | 83.1 | 68.6 | 55.5 | 33.7 | 8 | 84 | 30.8 | 12.2 | 82 |
| | *Kagera* | 100 | 100 | 100 | 95 | 62.9 | 100 | 100 | 93.5 | 98.2 | 98.2 | 94.4 | 98.2 | 97 | 97.4 | 87.5 | 50.8 | 0 | 106 | 51 | 37.3 | 104 |
| | *Mwanza* | 89.4 | 97.1 | 93.2 | 87 | 73.2 | 93.2 | 88.4 | 76.2 | 95.5 | 89.1 | 80.1 | 91.3 | 85.9 | 87.8 | 69.8 | 51.9 | 1.4 | 130 | 11.6 | 4.8 | 134 |
| | *Mara* | 97.4 | 98.2 | 96.2 | 92 | 48.7 | 98.2 | 95.2 | 79.4 | 95.4 | 93.7 | 87.4 | 94.7 | 93.6 | 88 | 73.4 | 31.8 | 1.8 | 97 | 18.3 | 9.3 | 113 |
| | *Manyara* | 95.1 | 97.1 | 97.1 | 97.1 | 50.6 | 97.1 | 96.6 | 94.8 | 97.1 | 95.4 | 95.4 | 96.6 | 93.2 | 87.2 | 82.8 | 43.7 | 2.9 | 85 | 56 | 39.6 | 48 |
| | *Njombe* | 100 | 100 | 100 | 97.5 | 71.7 | 100 | 100 | 97.5 | 97.5 | 97.5 | 95 | 97.5 | 92.9 | 89.9 | 87.4 | 61.6 | 0 | 23 | 33.8 | 17.3 | 26 |
| | *Katavi* | 84.1 | 87.3 | 75 | 67.7 | 32.5 | 88.6 | 73.6 | 66.9 | 86.6 | 74.3 | 67.7 | 85.9 | 73.1 | 60.9 | 54.1 | 27.6 | 11.4 | 26 | 27.6 | 18.1 | 27 |
| | *Simiyu* | 96.7 | 97.2 | 94.9 | 83.9 | 45.3 | 97.2 | 93.3 | 84.6 | 91.7 | 87 | 76.3 | 88.5 | 79.8 | 73.9 | 68.1 | 34.7 | 2.8 | 98 | 21 | 8.5 | 94 |
| | *Geita* | 91.7 | 95 | 88.1 | 80.2 | 38 | 93.4 | 84.3 | 75.9 | 85.9 | 73.2 | 67.3 | 87.4 | 77.8 | 79 | 65.6 | 24.9 | 3.6 | 100 | 9.9 | 2.1 | 91 |
| | *Unguja North* | 99.1 | 96.9 | 96.9 | 96.1 | 80.8 | 96.9 | 96.1 | 94.1 | 96.9 | 96.9 | 94.5 | 96.9 | 93.4 | 90.9 | 88 | 69.7 | 0 | 9 | 35.5 | 31.7 | 9 |
| | *Unguja South* | 100 | 100 | 98.2 | 96.4 | 70.9 | 100 | 96.2 | 89 | 100 | 98.2 | 96.4 | 100 | 96.2 | 97.5 | 89 | 65.3 | 0 | 5 | 28.9 | 20.2 | 5 |
| | *Town West* | 100 | 100 | 98.9 | 97.6 | 73.6 | 100 | 96.6 | 81.1 | 100 | 94.8 | 93.7 | 97.6 | 94.1 | 92.9 | 76.5 | 48.8 | 0 | 23 | 21.9 | 14 | 16 |
| | *Pemba North* | 95.9 | 89.9 | 88.1 | 83.2 | 67.9 | 91 | 87 | 83.4 | 89.9 | 88.1 | 84.5 | 88.7 | 84.6 | 80.1 | 77.7 | 56.9 | 2.8 | 11 | 17 | 11.3 | 10 |
| | *Pemba South* | 97.2 | 95.7 | 92.5 | 90.4 | 57.4 | 94.2 | 91 | 88.9 | 95.7 | 92.5 | 90.4 | 95.7 | 91.2 | 85.2 | 83.6 | 53.3 | 2.8 | 9 | 27.2 | 13.9 | 9 |
| **Mother's Education** | *No education* | 89.9 | 91.7 | 85.5 | 79.2 | 52 | 89.4 | 82.5 | 75.4 | 87.6 | 80.4 | 76.8 | 86.7 | 80.1 | 75.9 | 66.8 | 40.4 | 6.6 | 419 | 23.7 | 12.5 | 384 |
| | *Primary Incomplete* | 95.6 | 95.4 | 89 | 81.7 | 59.5 | 95.3 | 87.1 | 73.8 | 94.3 | 88 | 80.2 | 92.6 | 86.1 | 76.8 | 63.3 | 37.9 | 2 | 263 | 28.4 | 12 | 250 |
| | *Primary* | 97.9 | 98.7 | 97 | 92.8 | 69.5 | 98.7 | 95.5 | 86.6 | 97.4 | 94.6 | 88.6 | 95.9 | 92.2 | 89.4 | 79.6 | 54.8 | 1 | 1084 | 31 | 19.5 | 934 |

| Age in Months | | 12 - 23 | | | | | | | | | | | | | | | | | | 24 - 35 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Background Characteristic | | BCG | Penta 1 | Penta 2 | Penta 3 | Polio 0 | Polio 1 | Polio 2 | Polio 3 | Pneumo 1 | Pneumo 2 | Pneumo 3 | Rota 1 | Rota 2 | Measles | All basic vaccinations | All age appropriate vaccinations | No vaccinations | Number of children | Measles | All basic vaccinations | Number of children |
| | *Complete* | | | | | | | | | | | | | | | | | | | | | |
| | *Secondary+* | 97.5 | 98.8 | 97.9 | 94.1 | 83.6 | 98.9 | 95.2 | 84.8 | 98.3 | 97 | 93.7 | 96.5 | 94.3 | 94.1 | 81.2 | 68 | 1.1 | 368 | 48.6 | 38.5 | 249 |
| **Wealth Quintile** | *Lowest* | 92.5 | 93.4 | 89.2 | 80.3 | 49.6 | 92.7 | 86.1 | 74.3 | 90.1 | 84.9 | 75.1 | 87.8 | 82.6 | 77.4 | 65.2 | 34.8 | 5.7 | 498 | 22.5 | 9.4 | 432 |
| | *Second* | 95.3 | 96.4 | 90 | 87.4 | 56.5 | 96.4 | 90.3 | 84.6 | 93.6 | 87 | 84.8 | 93.1 | 85.3 | 80.1 | 73 | 42.5 | 1.7 | 443 | 28.3 | 15 | 395 |
| | *Middle* | 97 | 97.3 | 95 | 90.6 | 68.1 | 97.3 | 93 | 83.3 | 96.4 | 92.8 | 86.4 | 95.5 | 90.1 | 88.6 | 78.5 | 51.5 | 1.7 | 397 | 34.1 | 22.4 | 379 |
| | *Fourth* | 97.6 | 99.7 | 98.3 | 93.7 | 77.4 | 98.7 | 95.9 | 86 | 98.9 | 95.9 | 92.3 | 97.1 | 94.7 | 92.7 | 80 | 62 | 0.3 | 418 | 36.7 | 24.7 | 313 |
| | *Highest* | 98.5 | 98.8 | 98.7 | 95.4 | 91 | 98.2 | 95.8 | 86.3 | 98.8 | 98.9 | 94.9 | 97 | 96.8 | 94.3 | 83 | 76.1 | 1.2 | 378 | 40.2 | 31.6 | 298 |
| **Total** | | 96 | 97 | 93.9 | 89 | 67.3 | 96.5 | 91.9 | 82.5 | 95.3 | 91.4 | 86.1 | 93.8 | 89.4 | 86 | 75.3 | 52.1 | 2.3 | 2134 | 31.5 | 19.6 | 1817 |

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