INDIVIDUAL AND CONTEXTUAL LEVEL FACTORS ASSOCIATED WITH INITIATION, COMPLETION AND UP TO DATE VACCINATION IN ROUTINE IMMUNIZATION PROGRAM: AN ANALYSIS OF PAKISTAN DEMOGRAPHIC AND HEALTH SURVEYS, 1990 AND 2006

by

Noor Sabah Rakhshani

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"Intended to be blank."

I. Abstract

Introduction

Pakistan has one of the highest infant mortality rates at 78 deaths per 1000 live births per year; one in every eleven children born in Pakistan dies before his or her fifth birthday. Timely and complete vaccination is a proven and highly cost effective public health intervention to reduce death and disability, especially in children. Among other causes, vaccine preventable infectious diseases are a significant contributor to child mortality in Pakistan.

Study methods

We assessed the association of contextual and individual level characteristics, using Pakistan Demographic and Health Survey (PDHS) data, with the initiation, completion and up to date (UTD) immunization for children 12 to 23 months old in Pakistan. The contextual level characteristics included province of residence, rural or urban place of residence and whether the child was issued a health card by the Expanded Program of Immunization (EPI) staff. The individual level determinants included the household wealth index, gender of the head of the household, maternal age, maternal education and ethnicity, gender and birth order of child and number of children under five years of age in the household. Design based analysis was carried out to account for the complex survey design of the Pakistan DHS 2006 and 1990 datasets. Using logistic regression analysis, we assessed the independent association of individual, household and contextual variables with initiation and completion of vaccination for the routine immunization schedule of children aged 12 to 23 months. Following unadjusted analysis, the independent effect estimates were assessed along with biological plausibility to select variables for adjusted multivariable logistic regression analysis. Confounding of variables was measured through stratified analysis. Interaction terms were included in the final model to assess their interactive effect but there were no statistically significant interactive effects of the variables in the final

models. Chi-square goodness of fit was used to compare appropriateness between different models.

Results

The results of the analysis of the PDHS 2006 showed the household wealth index and maternal education as statistically significant factors with vaccination initiation. Children in the richest household wealth index were more likely to initiate vaccination compared to children in the poorest wealth quintile. Similarly, children whose mothers had higher education were more likely to initiate vaccination. In 1990, maternal education was significantly associated with vaccination initiation but mothers with primary education did not behave differently from mothers with no education. Also household wealth was statistically significant; children in the richest wealth quintile had ten times higher odds of vaccination initiation compared to children in the poorest quintile. In 1990 province of residence was a significant predictor of vaccination initiation only in the province of Sindh.

In the PDHS 2006 data analysis, having a vaccination card and mothers' education were statistically significantly associated with vaccination schedule completion. In the PDHS 1990 analysis, the wealth index and maternal age were found to have a significant association with vaccination schedule completion. Between 1990 and 2006 immunization coverage improved significantly only among the middle wealth quintile with little improvement in households in the poorest and poor wealth quintiles. Having a health/immunization card was significantly associated with vaccination completion in both 1990 and 2006 and it was the only predictor of up to date immunization in the PDHS 2006 analysis. The children for whom the card was seen at the time of the interview were 21 times more likely to be UTD compared to children who were never issued a health card. The interaction terms of possession of health/immunization card, wealth index, and maternal education were not statistically significant.

Discussion

Although position in a higher wealth quintile and mothers' higher education are individual level characteristics, these associations may also suggest that the health care system is geared to cater to the needs of the population with better access to sources of income and human development. The government should increase its efforts to reach marginal populations with limited financial resources and access to social services like education, better transport and mass media. Once the health care system aims for equitable access of health care services, then even children in lower wealth quintiles are more likely to complete their vaccination schedule.

Increasing female literacy is crucial for improving the health of the population and thus reducing infant and under-five mortality. The government has strengthened its efforts to increase female enrollment and keep girls in school beyond primary level but it also needs to focus on the quality of education provided to these girls. The odds of immunization initiation and completion were similar for mothers with up to primary education and those without a formal education; therefore while girls are enrolled in primary school every effort should be made to educate them about health and benefits of preventive health services. It is recommended that the primary school curriculum needs to be updated to address the significance and effect of immunization.

Possession of a health card and seen at the time of the interview is a measure of maternal attitudes and understanding towards the importance of immunization completion but it is also the single most significant factor predicting vaccination completion. But in our sample only 13% of the mothers in 2006 were able to show the household held immunization record at the time of the interview and a quarter of children initiating the immunization schedule were never issued an immunization card according to the mothers' reports. The EPI program must invest in digitalization of immunization and health records for children. The importance of a health card in vaccination schedule completion has been documented in other parts of the world, including Pakistan. Therefore until digital immunization records are widespread, the EPI program must

make provision of waterproof, tear resistant and easily stored immunization cards to each and every child initiating the schedule. Also cards that have a better system of reminding mothers of the vaccine due dates are highly recommended to improve immunization completion, especially among mothers who do not have access to electronic reminder systems like cell phones and those who lack education. The EPI program needs to evaluate its performance on more stringent criteria. Instead of just reporting DTP 1 and 3 among children 12-23 months of age, it should also monitor Up to date (UTD) immunization status of children 52 weeks of age. Although vaccination and immunization programs are in their fourth decade of global introduction, there still is a need to create a social value for immunization to reap the maximum benefits of the vaccines on the health of children and the general population.

II. Committee of Final Thesis Readers

Committee members:

1. Lawrence H. Moulton

   Professor and chair of the committee

   Department of International Health

2. Laura Morlock

   Professor and Thesis advisor

   Department of Health Policy and Management

3. Jill A. Marsteller

   Associate Professor

   Department of Health Policy and Management

4. Saifuddin Ahmed

   Associate Professor

   Population, Family and Reproductive Health

5. Daniel Salmon

   Associate Professor and Thesis public health practitioner

   Department of International Health

Alternate Committee Members:

I. Albert Wu

   Professor

   Department of Health Policy and Management

II. James Tonascia

   Professor

   Department of Biostatistics

To Kaka, Mir Qudratullah Jamaldini, my godfather and uncle who always wanted me to excel academically

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Personal reflection: undertaking the DrPH journey

Reflecting on the five years journey in pursuing my doctoral degree in Health Care Management and Leadership has provided me with insights about me as a researcher, my strengths and weaknesses and why I decided to enroll in the program. I joined the doctoral program to understand and be able to plan, manage and lead health organizations and eventually health systems. At the end of my program I feel my training at Hopkins has given me the necessary skills and now it is time for me to use these in my professional life. I realize that my strengths lie in my paying attention to detail, understanding an issue and solving it in total to achieve meaningful results. I also have come to realize that I need to learn to delegate tasks and components of work to the experts in the given field.

As I think and reflect on my research journey and the five years I have spent at Hopkins, I have realized that a thesis is a journey that one should not embark on alone, and one has to seek as much input and help as one can from faculty and fellow researchers. I have gained the most understanding about my topic and research methods through my discussions with my program and schoolfellows and the faculty at Hopkins.

On a more personal level I have also realized that I have to listen to my body as often as I listen to my heart. Two years ago I started having severe body aches and a lack of will to do routine tasks. Even getting out of the bed each morning was becoming a challenge. I just kept on telling myself that this was just because I was being lazy and stressed with working on a thesis. After suffering for more than a year I visited my gynecologist, suspecting a premature menopause. I was wrong in my diagnosis: I was not stressed from work nor had premature menopause but was suffering from Hypothyroidism. I started on thyroxin and was amazed at how my body responded to it; now I no longer think I am lazy. I think this is what I would like to share with my fellow doctoral students: we must listen to our bodies, seek help and don't assume we are lazy.

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Chapter 1: Introduction

Problem Statement

In Pakistan, 88% of the children initiate the immunization schedule when they receive the first dose of Bacille Calmette Guerin (BCG) vaccine and 81% complete the entire schedule according to the Pakistan Social and Living Standards Measurement (PSLM) Survey 2010 – 2011. However, this coverage is far from uniform: in the Southwest province of Balochistan, 63% of the children initiate the immunization schedule but only half of the children complete the schedule. This discrepancy is further highlighted in the Pakistan Demographic and Health Survey (PDHS) 2006-07 which reported that almost 29% of the children under five years of age in the remote province of Balochistan did not receive any vaccine. According to the PDHS 2006-07, the gap in full immunization, defined as having received BCG vaccine, three doses each of Diphtheria-Purtussis-Tetanus vaccine (DTP) and Oral Polio Vaccine (OPV), is more marked in the rural areas compared to urban areas with 44% and 54% respectively having full coverage across all the four provinces of Pakistan. This gap is also seen across the socio-economic divide with 64% in the highest wealth quintiles and 26% in the lowest wealth quintiles having full coverage, and by gender with 44% and 50% for girls and boys fully vaccinated (Figure 1). A similar discrepancy was reported by the PDHS 1990-91, which showed national immunization coverage to be at 35% and full immunization for children up to 12 months of age at 22%. According to the PDHS 1990-91 the breakdown of percentages of children 12 – 23 months of age and fully immunized at the time of the interview in the four provinces was 38.6% for Punjab, 37.6% for Khyber Pakhtunkhwa (KPT), 25.3% for Sindh and 17.8% for Balochistan. The number of children never vaccinated was 28.3% at the national level and 57.2% for the province of Balochistan (Abdul Razzaque Rukanuddin, K. Zaki Hasan 1992).

The World Health Organization (WHO) recommends immunization coverage of 90% at the national level and at least 80% coverage at the sub-national level for every district. (Anonymous; WHO Department of Immunization, Vaccines and Biologicals, UNICEF Programme Division,

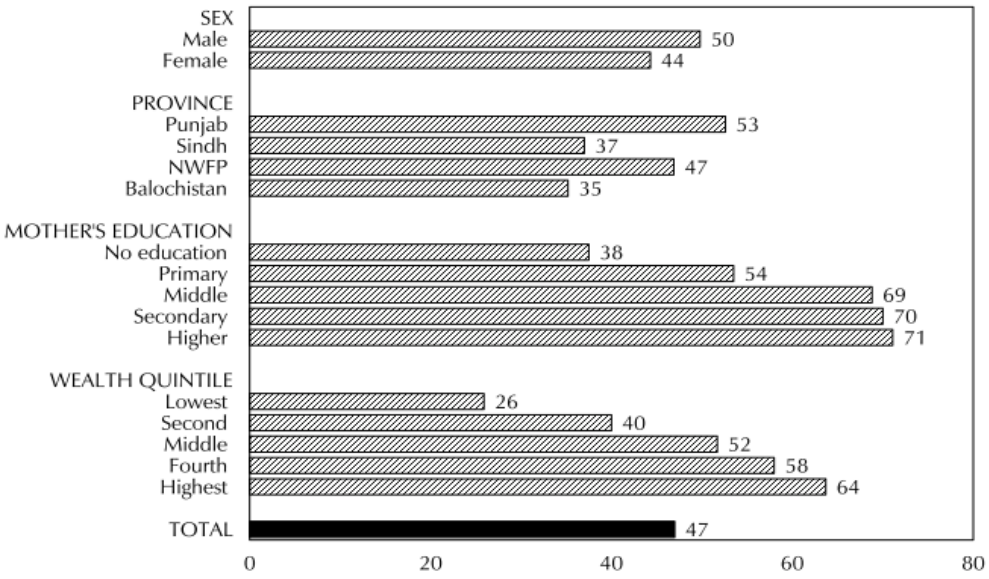
Health Section 2005) But even with the current efforts, 11 out of 142 districts in Pakistan have 50% or less coverage for the third dose of Diphtheria – Tetanus – Pertussis (DTP3) vaccine (World Health Organization December, 2010). The increase in vaccination coverage has been slow over the past two decades and the trends for vaccination completion are equally discouraging. Between 1990-91 and 2006 – 07 eight surveys have collected data on immunization coverage and completion on a national level in Pakistan. The results for national coverage of Bacille Calmette Guerin (BCG) and completion of the three doses of DTP from these eight surveys are presented in Figure 2. Due to the differences in survey methodologies and questionnaire design of these surveys any comparison of results would need to take these differences into account. The results from some of these surveys have biased findings; for example, the Pakistan Integrated Household Survey (PIHS) 2001-02 presented the number of children who received oral polio 1 compared to oral polio 2 as 68% and 91% respectively. Similarly the Pakistan Social and Living Standards Measurement Survey (PSLM) 2004-05 shows no dropout between the DTP first and third dose. These findings contradict the accepted pattern of vaccine dose completion and dropout rates (Anonymous).

The gap in immunization completion is a waste of resources and results in the suffering of children in the presence of an immunization program. The immunization program in Pakistan needs innovative and sustained efforts to close the gap between immunization initiation and completion as well as timely completion for all children across all the four provinces, gender and socio-economic divides. An understanding of the factors associated with vaccination initiation and completion is important for program improvement efforts to ensure not only universal coverage but that each and every child completes the immunization schedule in a timely and complete manner.

Pakistan Expanded Program of Immunization

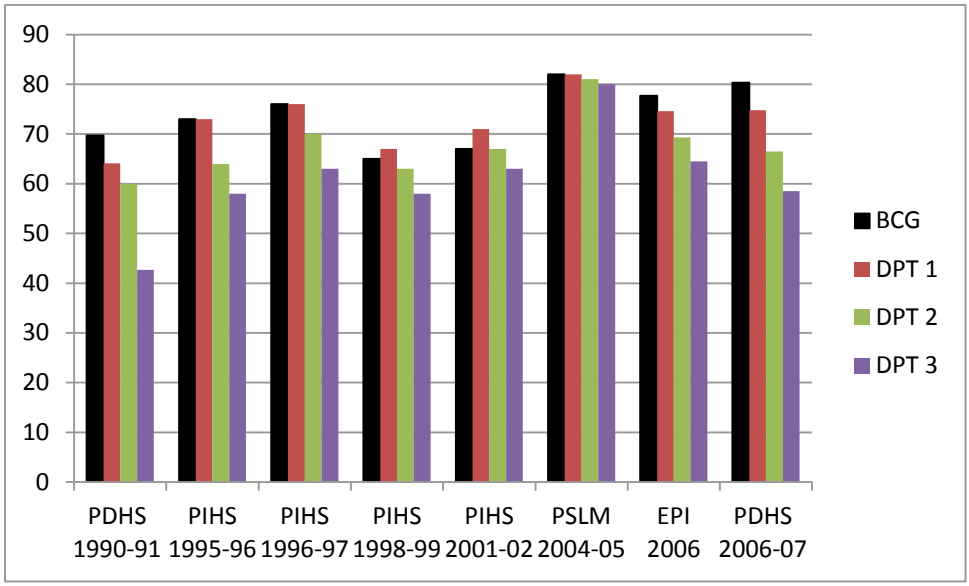
The Expanded Program of Immunization (EPI) for Pakistan provides vaccination against 9 vaccine preventable diseases to 1.5 million children annually. According to the EPI schedule every child must receive a single dose of Bacille Calmette Guerin (BCG) and a dose of Hepatitis B vaccines at birth; four doses of Oral Polio Vaccine (OPV 0,1,2,3) given at birth and at six, ten and fourteen months of age; three doses of Pentavalent vaccine, Diphtheria – Tetanus – Pertussis – Hepatitis B – Haemophilus Influenza type B (1,2,3) given at 6, 10 and 14 weeks; and Pneumococcal Conjugate Vaccine (PCV) administered at the same time as the Pentavalent. A single dose of measles vaccine is given at nine months of age followed by a booster dose at 15 months of age (World Health Organization December, 2010). The EPI Pakistan's aim is to attain full immunization against the nine vaccine preventable diseases in 80% of the districts by 2012 with the schedule to be completed by 11 months of age (Government of Pakistan 01, 2011).

Figure 1 Percentage of children age 12-23 months who are fully immunized, by background characteristics, PDHS 2006-07



Source: Pakistan DHS 2006-07 Report

Figure 2 Trends in vaccine coverage, percentage of children age 12-23 months who received BCG and DTP vaccine, 1991 – 2007, Pakistan



Pakistan Demographic and Health Survey (PDHS), Pakistan Integrated Household Survey (PIHS), Pakistan Social and Living Measurements Survey (PSLM), Expanded Program for Immunization (EPI)

Pakistan country context

The total population of Pakistan is 170 million and 14.5% of the population is under-five years of age (Government of Pakistan 2011). At a population growth rate of 1.9, 4 million births are estimated annually. Pakistan is a low-income country with a per capita GDP of 1,010 USD (United Nations Statistics Division 12, 2010) and 32.6% of the population lives below the Pakistan poverty line (The World Bank 01, 2011). The government is ever pressed for increasing funding in the public sector including health; however the annual budget allocation for health has been only 0.3 – 0.6% of the GDP for the past several decades. The public health services are the only source of providing vaccines for millions of children. Health programs like prevention of HIV/AIDS, child malnourishment prevention along with the EPI are either partially or fully funded by international donors. The distribution of resources and development programs in the country are based on the political affiliation of an area with the ruling government and not on empirical evidence or needs assessment. The political instability and mismanagement of resources has chronically affected large areas of the country. Many areas with difficult mountainous and dessert terrain have remained underdeveloped due to geographical isolation from economic and administrative centers at provincial and national levels. Historical budgeting is employed in the country for the allocation of resources and development in all sectors particularly health, education and social amenities. All this has led to weak infrastructure and low human development, resulting in poor health indicators. This is also highlighted by the PDHS 2006-07, which shows that regions with the highest malnourishment and lowest maternal education have the lowest immunization rates. The high dropout rate for multi-dose vaccines like DTP 1-3 is a challenge for the EPI program as documented in the two Pakistan demographic and health surveys for the years 2006-07 and 1990-91.

Several studies in Pakistan have highlighted that household level poverty and lack of education lead to poor health outcomes including low immunization levels especially in rural areas

(Mitchell et al. 2009, S7). Similarly, communities living in poverty and without adequate education end up with poor health outcomes. There are marked differences in the distribution of resources even within rural areas. Therefore rural areas in some regions of the country fare far worse in health than rural areas with better resources and human development indicators.

Pakistan is trying to achieve the Millennium Development Goal (MDG 4, target 4 A) to reduce its under five mortality by two thirds by 2015. Currently the under- five mortality in Pakistan is at 94 deaths per 1,000 live births per year, which represents a decline compared to the rates in 1990 but the rate has remained stagnant since 2003. Vaccination is an important approach in reducing child mortality (Jamil et al. 1999, 49-58). The DTP and measles vaccines avert an estimated 2.5 million deaths globally among all age groups each year (WHO Department of Immunization, Vaccines and Biologicals 2010). It is estimated that annually in Pakistan vaccination averts 100,000 deaths due to measles, 70,000 cases of neonatal tetanus and 20, 000 cases of paralytic poliomyelitis {{432 National Institute of Population Studies (NIPS), Macro International Inc 2008;}}. Pakistan recently introduced two new vaccines, Haemophilus influenzae type B (Hib) in 2008 and pneumococcal conjugate vaccine in 2012. The vaccine against Rota virus diarrhea is planned for introduction in 2013. The addition of these new vaccines is estimated to reduce child mortality by 15% (WHO EMRO 2013). Child mortality and morbidity can be reduced even further with an increase in the vaccination coverage and promoting timely vaccination completion. Timely completion of the vaccination schedule is crucial to attain maximum benefit from the intervention especially among the young (Akmatov et al. 2008, 3805-3811) and to prevent disease outbreaks (Luman et al. 2002, 935-939).

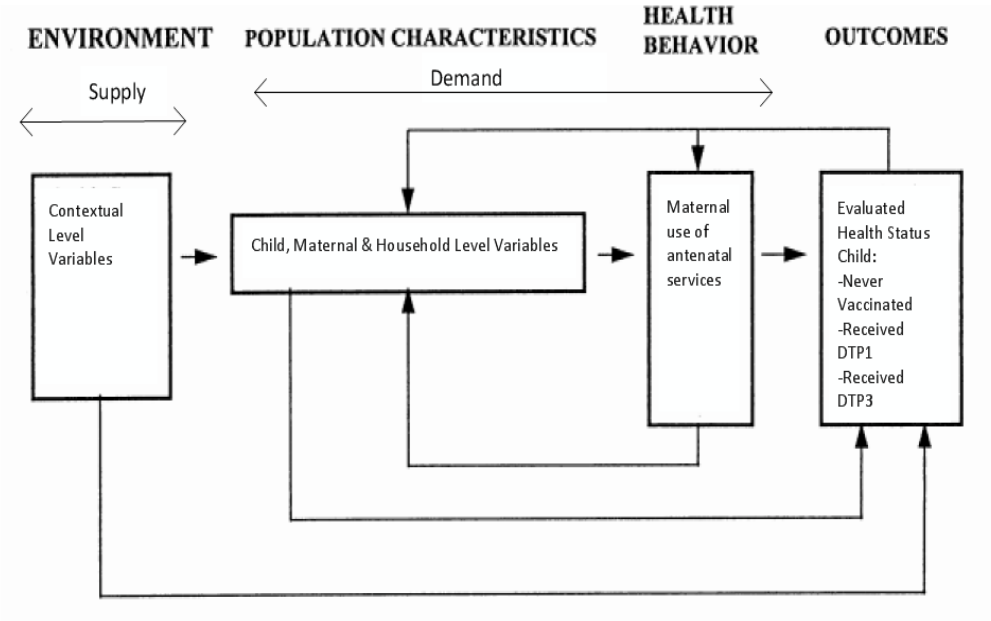
Public health significance

The factors associated with immunization completion and children never vaccinated have been extensively documented in the peer-reviewed literature but there are few studies that specifically look at factors associated with vaccination initiation. Several studies in Pakistan have been

conducted in the urban, semi-urban (Usman et al. 2010, 140-147) and rural areas (Cockcroft et al. 2009, S4; Shaikh et al. 2010, 806-810) to analyze the factors associated with vaccination completion rates in the country. But none of the studies have used a nationally representative dataset for their analysis nor have they assessed the factors associated with vaccination initiation and up to date immunization. Studies have assessed vaccination completion and child never vaccinated with the individual level characteristics such as sex of child, maternal education and household wealth; and contextual level characteristics such as health system structure, poverty levels and illiteracy levels. However, there is a lack of literature analyzing a cohort of children who have initiated the vaccination schedule but failed to complete it. There are many examples from developing countries of successful implementation of immunization programs in which 90% or higher immunization coverage and completion rates have been achieved. With all the wealth of information available for immunization program improvement, Pakistan has not been able to attain universal coverage and high immunization completion in all four provinces of the country. There is a need to understand the association of factors in the Pakistani context and identify population subgroups that have high immunization coverage and completion despite the individual and contextual odds against them.

Pakistan DHS 2006-07 is the most recent survey, has the largest sample size, and is the most nationally representative survey that covers both the rural and urban areas in the country. This data set is selected also because we want to be able to make a comparison with the PDHS 1990-91 dataset. Comparing the magnitude and direction of the change in associations of the individual and contextual level characteristics with immunization initiation, completion and UTD status between the PHDS 2006-07 and 1990-91 datasets will enable us to identify variables most malleable to change. The comparisons will also help identify which provinces are improving the immunization status of children, how communities in urban and rural places of residence are valuing childhood immunization and which population subgroups among the poorest, poor and middle quintiles have improved or declined in immunization completion over the time period.

Figure 3 Adapted from Andersen & Aday "Behavior model and access to health care" Framework



Conceptual Framework

To understand the relationship between the availability of the vaccination services (supply by the health care system) and the active utilization of the vaccination services (demand for vaccines by parents), four frameworks were identified, including: i) Mosley and Chen (Mosley and Chen 2003, 140-145); ii) Conceptual Framework for Social Determinants of Health (Solar and Irwin 2007); iii) Conceptual Framework for Health Research System (Pang et al. 2003, 815-820) and iv) Andersen & Aday "behavior model and access to health care" framework (Andersen 1995, 1-10). These frameworks were evaluated for their relevance to the study objectives and simplicity of use. Based on the criteria, the Andersen & Aday framework was selected to assess the immunization coverage in Pakistan. It identifies the determinants of a health outcome as a series of variables incorporating the 1) environment, 2) population characteristics and 3) health behavior of the population under investigation (Figure 3). According to the authors the components of the framework interact at different levels directly and/or through a series of interconnected associations. The health care system can be an independent predictor of health status and

consumer satisfaction and also interact with population characteristics. Whereas population predisposing characteristics can act as direct as well as intermediate predictors of health outcomes. The health status of a population can be an enabling resource as healthy people use more health services and the perceived health status can directly determine personal health practices and use of health services. Three components of the framework are not modeled because variables from the PDHS data set were not available to enable modeling with accuracy. We assume unknown risk across all levels for these three left out components. The components not included in modeling are i) population need, both perceived and prescribed, for immunization services, ii) personal health practices of the population and iii) perceived health outcomes. Consumer satisfaction with public health services for the treatment of a sick child (fever, diarrhea and pneumonia) is collected by the PDHS 2006-07 but not for immunization services. The components of the framework are described below and the variables proposed for use are given in Table 1.

Environment: The framework presents the environment which includes the 1) health care system and the 2) general external environment in which the study population lives. The general external environment can also include the political, social and economic factors and events that shape the movement of individuals and communities as well as uptake of services by them.

Population Characteristics: According to the framework several factors influence and determine the uptake of health services by a population which are: 1) predisposing characteristics of the population like the socioeconomic characteristics, 2) enabling resources available to the population to access medical care/services and 3) need for health services by the population. The population's need for health care services are both i) perceived needs by the population and ii) prescribed need by health care providers. The perceived health care needs are formed by the health education and messages disseminated to the population and their awareness regarding a

health condition. The prescribed need for health care services is directed by health providers' education, training, health protocols and policies.

Health behavior: The framework addresses health behaviors of a population by investigating: 1) personal health practices and 2) use of health services. The former includes variables like diet, exercise and self-care and the later involves use of formal health care services.

Outcomes: According to the framework three different outcomes can be evaluated through health services research, including: 1) perceived health status; 2) evaluated health status; and 3) patient satisfaction. The outcome for my research will be an evaluated health status identified as vaccination status and the DTP vaccine schedule initiation and completion among children 12 – 23 months of age and UTD among children 36-52 weeks of age in Pakistan. I propose to use these outcomes as these have been documented in the PDHS both by observing the vaccination card and the verbal confirmation by mothers.

Analytic limitations of the data set: The DHS data are specifically from a cross sectional survey to record health and demographic distributions of the population and less emphasis is placed on the health systems related data. The DHS also specifically collects data on maternal and child health but it does not elaborate on the knowledge, attitudes and practices (KAP) of the parents regarding immunizations, and collects little or no data on the quality of care of the public health system providing the immunization services. As several variables identified by the conceptual framework were not available in the PDHS data set their association could not be evaluated with the health outcome.

Table 1: Components of the Framework and variables proposed for analysis

Environment	Health care system	Distance to a health center (functioning basic health unit/maternal and child health center/government dispensary) Designated number of immunization service centers in the district Presence of a Lady Health Worker (LHW) in the village Visit by LHW Catchment area of the BHU/immunization service Number of immunization staff in the district
	External environment	Percentage of educated women in the district Motorized public transport Geographic location rural/urban
Population Characteristics	Predisposing Characteristics	Socio-economic status of the family (wealth index) Years of schooling of mother Years of schooling of father Age of mother Gender of child Birth order of child Received health messages on TV/radio Number of household members Number of children under five
	Enabling Resources	Mother able to decide the use of health services when child is ill Travel time to immunization services Regular source of care Child vaccination card seen
Health Behavior	Use of health care services	Use of antenatal services by mother
Outcome	Evaluated health outcome	DTP1 vaccination rate, DTP3 vaccination completion rate, up to date immunization status
	Patient satisfaction	Mother's satisfaction with care provider during a sick child visit to a public health facility

Table 2: Framework components and variables of interest captured by source of information

Framework Component	Interview question	Variable type	Source of information	Question Number in PDHS 2006-07 survey
Environment				
Health care system				
Availability of immunization services	Designated number of immunization service centers in the enumeration block/village by the government/NGO	Continuous, Count	health plan document	
Distance to a health center: functioning basic health unit, maternal and child health center, government dispensary)	Asked from the center of the largest village. How far is the following facility from here? Distance measured in kilometers (KM)		Community questionnaire	301
1) functioning BHU		Continuous, KM	Community questionnaire	
2) functioning MCH		Continuous, KM	Community questionnaire	

Framework Component	Interview question	Variable type	Source of information	Question Number in PDHS 2006-07 survey
3) functioning government dispensary		Continuous, KM	Community questionnaire	
4) rural health center		Continuous, KM	Community questionnaire	
Presence of a Lady Health Worker (LHW) in the village	Is there a lady health worker in the village?	Yes/No , Categorical	Community questionnaire	109
Visit by LHW	Does the LHW make house visits on a regular basis?	Yes/No , Categorical	Community questionnaire	111
Immunization services by LHW	What services LHW provides	Categorical	Community questionnaire	110
Catchment area of the BHU/immunization services	Number of estimated children 0-5 years in the catchment area of BHU	Continuous	health plan document	
Number of immunization staff in the district	Total number of immunization staff designated in the district	Continuous	health plan document	
External Environment				
Percentage of educated women in the district	Total percentage of educated women	Continuous	Education document	
Motorized public transport	Distance to motorized public transport	Continuous, KM	Community questionnaire	201

Framework Component	Interview question	Variable type	Source of information	Question Number in PDHS 2006-07 survey
Geographic location rural/urban	Identification	Categorical, Large city/ small city/ town/ rural	Women's questionnaire	
Population Characteristics				
Predisposing Characteristics				
Socio-economic status of the family (wealth index)	Calculated wealth index		Long Household questionnaire	
Age of mother	How old are you?	Continuous, Age in years		
Exact age of mother	In what month and year were you born?	Month/ Year		
Years of schooling of mother	Have you ever attended school?	Categorical, Yes/No	Women's questionnaire	112
	What was the highest class you have completed?	Continuous, class 1-16	Women's questionnaire	113
Mother able to read	Read this sentence	Categorical, Cannot read at all/Can read only parts of sentence/ Can read whole sentence/ No card with required language/ Blind or visually impaired	Women's questionnaire	115
Years of schooling of father	Did your husband ever attend school?	Categorical, Yes/No	Women's questionnaire	703
	What was the highest class he completed?	Continuous, class 1-16	Women's questionnaire	704

Framework Component	Interview question	Variable type	Source of information	Question Number in PDHS 2006-07 survey
Gender of child		Categorical, Boy/girl	Women's questionnaire	
Birth order of child				
Received health messages on TV/radio	In the last month have you heard a message about family planning on radio or TV?	Categorical, Radio: Yes/No, TV: Yes/No	Women's questionnaire	327
	What messages did it (radio/TV) convey to you?	Categorical, 11 categories, Maternal and child health/ other	Women's questionnaire	329
Number of household members		Continuous		
Number of children under five		Continuous		
Vaccination card seen	Does the child have a vaccination card?	Categorical, Yes: seen/ Yes: not seen/ No	Women's questionnaire	504
Ever had vaccination card	Did you ever have a vaccination card for child?	Categorical, Yes/ No	Women's questionnaire	505
Ever received vaccine: Children with vaccination card	Has the child received any vaccines that are not recorded on this vaccination card, including those during national immunization day campaign?	Categorical, Yes/ No/Do not know	Women's questionnaire	507

Framework Component	Interview question	Variable type	Source of information	Question Number in PDHS 2006-07 survey
Ever received vaccine, children without vaccination card	Did child ever receive any vaccine to prevent him/her from getting disease, including vaccinations received in a national immunization campaign?	Categorical, Yes/No/Don't Know	Women's questionnaire	508
Enabling Resources				
Mother able to decide the use of health services when child is ill	Who mainly takes the care seeking (other) decisions in the household? (question asked related to illness of child/baby)	Categorical, Husband/Mother/Mother in law/ father/ father in law/ grandmother/ grandfather/ uncle/ other/ don't know	Women's questionnaire/ Decision making mechanism and help seeking	935
	Who decided the care should be sought outside home?	Categorical, Husband/Mother/Mother in law/ father/ father in law/ grandmother/ grandfather/ uncle/ other/ don't know	Women's questionnaire/ Decision making mechanism and help seeking	939
Travel time to health services	How far is the nearest health facility from your house? (regarding usual sources of care if child is ill)	Continuous, KM	Women's questionnaire/ Decision making mechanism and help seeking	942
	How do you commute to the nearest health facility	Categorical, Taxi/Bus/Rickshaw/motorbike/ walking/other/don't know	Women's questionnaire/ Decision making mechanism and help seeking	943

Framework Component	Interview question	Variable type	Source of information	Question Number in PDHS 2006-07 survey
	How much is the transportation cost to the nearest health facility?	Continuous, Rupees		
Use of antenatal services by mother	The first time (for the latest birth) you went for antenatal care did you go because you had a problem or just for a check-up?	Categorical, For problem/ For check-up only	Women's questionnaire	409
	How many times did you receive antenatal care during this (latest birth) pregnancy?	Continuous, number of time/don't know	Women's questionnaire	412
Health Behavior				
Number of antenatal visits for last birth	How many times did you receive antenatal care during this pregnancy (latest) ?	Continuous	women's questionnaire	412
Outcome				
Evaluated Health Status				
DTP 3 completion DTP1 Up to date	Recorded from vaccination card/ verbal confirmation by mother	Categorical, Noted/not noted , Yes/ No	Women's questionnaire	506 and 509 E & F

Chapter 2: Literature Review

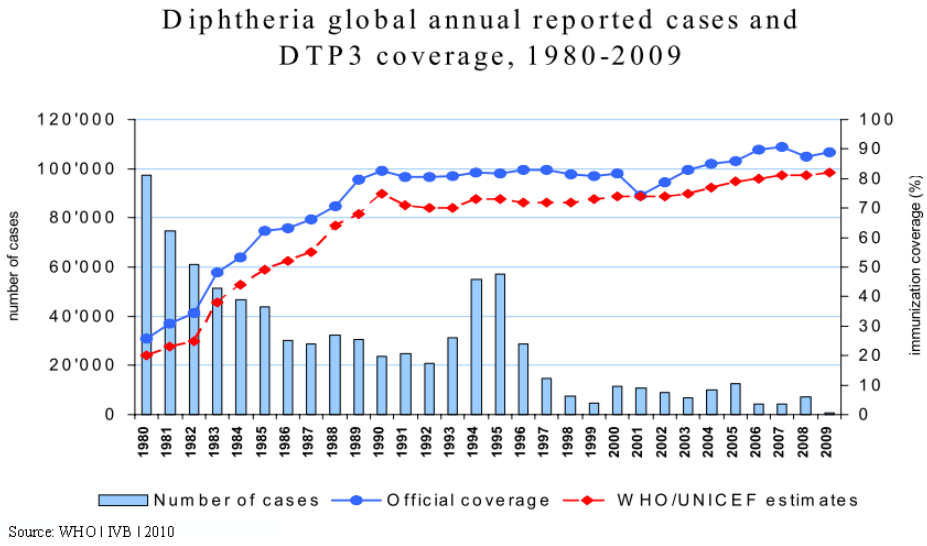
Overview of the global immunization coverage

The WHO and its member states' drive to attain universal coverage of childhood immunizaiton and the establishment of national immunization programs in the 1980s helped DTP3 coverage to increase and peak in the 1990s (Figure 4). The differences in coverage between national official figures and WHO/UNICEF estimates are more likely to be due to reporting formats, especially by populous countries like China and India (WHO Department of Immunization, Vaccines and Biologicals 2010). Qestions have been raised regarding the official reporting of immunization data suggesting that official records are higher than the actual coverage (Lim et al. 2008, 2031-2046). This concern has been addressed via dialogue on several scientific platforms (Bishai 2008, 2004-2005).

The selection of the outcome indicator for the assessment of immunization programs varies from study to study, with the choice being made according to the organizational and study objectives. The WHO recommends DTP3 completion as a measure to evaluate national immunization programs. The DTP "immunization coverage rate" (number of doses of DTP 1 administered to the target population / total estimated target population*100) is considered as a measure of assessing the access or supply of immunization services. The "dropout rates DTP1 to DTP 3" (DTP3 minus DTP1/ DTP1*100) is a measure of assessing the utilization or demand of immunization services. In a community having a proportion of children who are identified as "fully vaccinated" (a child who has received the recommended vaccines directed by the specific national immunization program) indicates a functional health care system that has capacity to provide services and follow up. It also indicates some weakness in the system for not reaching the entire population. Whereas having a large proportion of children who are identified as "never vaccinated" indicates a complete system failure requiring an immediate change in policy and resource allocation (Pande and Yazbeck 2003, 2075-2088). The WHO in collaboration with UNICEF in 2002 launched the initiative Reach Every District (RED) to increase the DTP3

vaccine coverage rate to 90% at the national level and 80% in all districts by 2010. The RED initiative identifies five operational components to reach its goal. The five coponents of the RED strategy are: 1) Effective planning and management of resources: ensuring effective management of human, financial and material resources at every governing level. 2) Reaching all target populations: reach out to previously under-served, unreached communities in giving support and access to services. 3) Supportive supervision: providing local staff with on-site training by supervisors. 4) Monitoring for action: promoting the use of data for action through utilization of data quality self-assessment tools at all governing levels. 5) Linking services with communities: linking communities with health services, through regular meetings between communities and health staff. In 2009 WHO recommended that every district in a country make a "Micro-planning strategy to increase immunization coverage" and routinely collects information on the percentage of districts in a country with a plan (Figure 4).

Figure 4 Global coverage of DTP3 vaccine and the reported cases of Diphtheria



The differences in immunization coverage across socio-economic strata (Williams et al. 1995, 439-446) gender, geographic location (Williams et al. 1995, 439-446; Gore et al. 1999, 1011-1027) and ethnic divides (Som et al. 2010, 406-412) are almost universal, as seen in high, middle and low income countries (Rosenthal et al. 2004, e296-302). Immunization coverage and vaccination completion rates are comparatively higher for families with high income (Cui and Gofin 2007, 664-671) and high maternal education (Phukan, Barman, and Mahanta 2009, 249-252) (Torun and Bakirci 2006, 125) compared to low income families and those living in poverty, which have the lowest rates (Minh Thang et al. 2007, 41-58). The male child is better cared for than a female child. Urban areas have better health facilities, immunization coverage and vaccination completion rates compared to rural areas (Pande and Yazbeck 2003, 2075-2088). Indigenous minorities and migrant populations have low immunization coverage rates (Groom et al. 2008, 938-944) and overall poor health status compared to the general population. (Bondy et al. 2009, 169-175)

A systemic review of the literature from low and middle income countries to identify the risk factors for a child being unvaccinated or under-vaccinated has been done by Dietz et-al (Vance Dietz 2009). They identified and calculated the percentages of different variables identified by various studies as significant predictors of a child being un-vaccinated and under-vaccinated. They identified four overarching themes from across 209 studies. The general themes were categorized as: i) family characteristics, ii) immunization system, iii) communication and information and iv) parental attitudes and knowledge. Immunization systems issues were identified by the majority of studies as the most important predictor of a child being incompletely vaccinated. Within the immunization system category, proximity to a vaccination center was most significant followed by missed opportunities (not having a vaccination card, vaccinator absent, and wrong contradiction). The other health system factors related to children being incompletely vaccinated were shortage of supplies and limited availability of reproductive health services.

Parental knowledge and unfavorable attitudes towards vaccines was the major risk factor for a child never being immunized. Parental lack of knowledge about immunization, and fear or misconceptions of vaccines were the two main association observed by the study. Low motivation among caregivers, religious/traditional beliefs against vaccines and gender bias were among the other common findings observed under the heading of parental attitudes and knowledge. Risk factors related to communication and information included lack of exposure to media/radio, miscommunication by health workers and lack of community ownership of the EPI program. Family characteristics which have been identified as risk factors for a child being unvaccinated or not fully immunized include low maternal education followed by low-socioeconomic status and living in a large household, number of siblings ≥5 and belonging to a migrant or minority group. We can also categorize various factors affecting vaccination uptake into supply and demand factors. Population characteristics like socio-economic status, maternal education, birth order and gender of child, parental behavior of accepting or refusing immunization (Salmon et al. 2009, 17-23), and household decisions for spending on health (Andersson et al. 2005, 72) creates the demand for health services.

The health care system setup and the general external environment in which the populations live affect the access or supply of these services. Health care system and general environmental characteristics of the area greatly affect the immunization completion among children (Sia et al. 2007, 201-206). Children who live in a district with adequate staff for immunization, whose mothers use antenatal services and those children visited by health workers have better vaccination completion rates than children who do not have these advantages (Sia et al. 2009, 416). Literature from developing counties has also identified less tangible health systems factors like leadership and commitment of district health officers to predict increases in coverage at the district level (Haddad et al. 2009, S15), and poor communication and unprofessional attitudes of the health care providers as factors that discourage parents from seeking immunization services

for their children (Sanou et al. 2009, S10). Institutional delivery and use of ante-natal services by mothers (Sia et al. 2009, 416; Antai 2009, 181) have also been identified as significant predictors of increased immunization coverage among children.

Global Expanded Program on Immunization

The World Health Organization undertook the initiative to control the small pox epidemic in 1966 and by 1980 the disease was eradicated. Building on the success of the small pox eradication, the initiative to immunize children was undertaken. In 1974 the Expanded Program on Immunization was launched through the World Health Assembly resolution (resolution WHA27.57). At that point in time, globally less than five percent of the children up to one year of age were immunized against six diseases , including polio, diphtheria, tuberculosis, Pertussis (whooping cough), measles and tetanus. The technical processes of surveillance, preventive measures, and human resource networks created during vaccination campaigns to contain the small pox epidemic laid the foundation for the EPI program.

The present day WHO immunization service delivery program has developed extensively and extends into global immunization strategies, financing, goals and policies. The program provides training initiatives and materials, vaccine management logistic support and conducts comprehensive multi-year planning to assist national EPI programs globally. The immunization delivery is provided through EPI centers, health facilities and school based programs. Numerous complementary programs to support the larger EPI goals include the Reach Every District (RED) strategy and Project Optimize (WHO Immunization Service Delivery 2013).

Expanded Program on Immunization (EPI) Pakistan: A Review

The Expanded Program of Immunization (EPI) for Pakistan was initiated in 1978 and currently provides vaccination against 9 vaccine preventable diseases to 1.5 million children annually. According to the EPI schedule every child must receive a single dose of Bacille Calmette Guerin (BCG) and a dose of Hepatitis B at birth, four doses of Oral Polio Vaccine (OPV 0,1,2,3) given at

birth and at six, ten and fourteen months of age, three doses of Pentavalent vaccine, Diphtheria – Tetanus – Pertussis – Hepatitis B – Haemophilus Influenza type B (1,2,3) given at 6, 10 and 14 weeks and Pneumococcal Vaccine (also given along the Pentavalent vaccine schedule at 6, 10 and 14 weeks). A single dose of measles vaccine is given at nine months of age followed by a boaster dose at 15 months of age (World Health Organization December, 2010). The EPI Pakistan's aim is to attain full immunization against the nine vaccine preventable diseases in 80% of the districts by 2012 with the schedule to be completed by 11 months of age (Government of Pakistan 01, 2011). Supplementary immunization activities (SIA) are also conducted in which a child receives all doses of vaccines offered irrespective of his/her immunization status. Since 1994, in addition to the routine schedule, special immunization days are conducted to give oral polio vaccine to children up to five years of age as part of the global Polio eradication initiative. The EPI Pakistan recently added two new vaccines to its routine schedule, Haemophilus Influenza type B was introduced in November 2008 and Pneumococcal conjugate vaccine was added to the schedule in September 2012. The program introduced Rotavirus vaccine in 2013. The EPI Pakistan has set the objectives to eliminate neo-natal tetanus and Measles by 2015 (WHO EMRO 2013). According to the PDHS survey a child is considered as fully immunized if he/she receives a single dose of BCG, four doses of OPV and three doses of DTP vaccine.

Government of Pakistan health policies

The 1973 constitution of Pakistan mandates universal health coverage to the population and provision of preventive health services to every Pakistani national. Pakistan came into existence on August 14, 1947 and in 1960 the first Five-Year-Plan by the Planning Commission of Pakistan was released which addressed the health needs of the country. Since 1990, the Planning Commission has replaced the five-year plans with annual plans, which also address the health planning needs. Since 1990, three national health policies have been announced in 1990, 1997 and 2011 and the fourth one is in progress. The Planning Commission of Pakistan annual plan for

2012-13 does not provide any strategic plan of increasing vaccination coverage and completion rates and provides information only on the allocation of the federal funds for the program. There is not much of a difference in the content regarding immunization between the years 2011-12 and 2012-13 Government of Pakistan (GoP) annual plans (Planning Commission: Government of Pakistan 2012).

Health policy in Pakistan, similar to other sectors like water, sanitation, education, women and youth etc., has suffered from disowner-ship by policy makers and implementers alike. The health policy formulation has been reduced to mere formality without vigorous follow through and accountability (Masoud 2011).

In 2011 the 18th amendment to the 1973 constitution was made which in addition to other changes, pronounced provincial autonomy with health planning, financing and delivery devolved to provincial governments (Nuri, Hanif, and Khan 2011). Under the new changes the federal ministry of health was abolished but all the major national health programs, like EPI, HIV& AIDS prevention, and the National Tuberculosis Prevention Program were to function as vertical programs and maintain their autonomy with provincial divisions working in each of the four provinces. In 2013 the GoP created the federal ministry of Public Health, which also oversees the vertical programs supported by donor agencies, but not the EPI program.

In the health policy and planning documents released by GoP, iImproving the vaccination coverage rates and reducing dropout rates have been addressed on the policy agenda of the Government of Pakistan for several years in a row. But this has been without effective ground implementation as evident that Pakistan is still one of the three polio endemic regions in the world.. In 2009 the government mandated that it would eradicate Polio by 2010 but the disease is still not controlled. The government's policy to deliver routine immunization, door to door, through the lady health workers (LHW) never materialized. Currently the LHW program is

challenged by lack of funds, uneven deployment of workers and performance in different districts in the country. Currently the LHW are deployed to deliver polio vaccines only during national immunization days.

The Expanded program on immunization (EPI) Pakistan was a special cell working under the federal ministry of health but after the 2011 devolution mandated by the 18th amendment it has been transformed into an autonomous body. It's program objectives are set by the organization and are mandated by the WHO and UNICEF guidelines.

A functional national vaccine advisory committee and proactive technical advisory groups are strategic in ensuring success for childhood immunization programs (The National Vaccine Advisory Committee. 1999, 363-370). A growing number of countries in the developed and developing world have fully functional national technical advisory groups (TAGs) on immunization policy and introduction of new vaccines for the respective countries (Blau et al. 2012, 2588-2593; Cho 2012, 1-5; John 2010, A88-90) but Pakistan still lacks a formally recognized and functional immunization national technical advisory group. Pakistan's neighbor India established its National TAG India in 2001 and in Pakistan the first ever TAG on Polio eradication commenced its activities only in August of 2012.

Budgetary allocation for the EPI

In the year 2000 the total cost for the EPI program was about $24 million/annum of which 44% went for salaries and only 33% for vaccines and syringes. The federal and provincial governments contribute 68% of all expenditures on routine EPI but only 43% of non-salary costs. In 1997 expenditures on EPI represented about 4% of all public expenditures on health. Pakistan has introduced two new vaccines, Hib B in 2008 and PCV in 2012, in the routine immunization program and introduced Rotavirus vaccine in 2013 with financial assistance from Global Alliance for Vaccine and Immunizations (GAVI.) Economic and sensitivity analysis of the introduction of the three vaccines has shown it to be cost-effective. However introduction of

new vaccines in the routine immunization program without financial assistance from GAVI would result in taking up 40% of the EPI budget and 15% of the national health budget. These pose major challenges for the national government which must increase funding for procuring new vaccines, and therefore results in continued dependence on external funding sources (Brenzel et al. 2011).

Funding sources and donors for EPI Pakistan

The Government of Pakistan (GoP) through its Social Action Plan (SAP), Phases I and II has taken the initiative to increase public spending in health and social welfare. As of 2003 GoP was providing 18.7 million of the 31.8 total EPI budget and international donors funded the remaining 13.1 million. Vaccines provided by the EPI are shown in

Table 3). The key supporters of the EPI Pakistan are WHO and UNICEF; they support the program through technical assistance and procurement of vaccines. The major financial supporter of the program is GAVI through its Vaccine Fund, additional financial support is provided by Japan International Cooperation Agency (JICA), World Bank, Center for Disease Control (CDC), Rotary International and Department for International Development UK (DFID) (Federal EPI/CDD Cell 2003).

Table 3 Routine Immunization Schedule for Children in EPI-Pakistan, 2012

Age	Antigen	Dose	Site of administration
At Birth	BCG	0.05ml	Intradermaly on right upper arm
	OPV 0	2 drops	Oral
	Hepatitis –B	0.5ml	Intramuscular injection on antero-lateral side of left thigh
6 weeks	Pentavalent -I	0.5ml	Intramuscular injection on antero-lateral side of right thigh
	OPV-I	2 drops	Oral
10 weeks	Pentavalent-II	0.5ml	Intramuscular injection on antero-lateral side of right thigh
	OPV-II	2 drops	Oral
14 weeks	Pentavalent-III	0.5ml	Intramuscular injection on antero-lateral side of right thigh
	OPV-III	2drops	oral
6 weeks	Pneumococcal	0.5ml	Intramuscular injection on antero-lateral side of left thigh
10 weeks	Pneumococcal	0.5ml	Intramuscular injection on antero-lateral side of left thigh
14 weeks	Pneumococcal	0.5ml	Intramuscular injection on antero-lateral side of left thigh
9 months	Measles-I	0.5ml	Subcutaneous injection on left upper arm
15 months	Measles-II	0.5ml	
Pentavalent includes DTP+HepB+Hib			
If child is seen between 12-15 months 2nd dose of measles is given			

Factors associated with initiation of immunization schedule (low, middle and high income countries)

The majority of studies have reported the determinants of vaccination completion and very few, if any, have specifically looked at factors associated with vaccination initiation.

Factors associated with completion of immunization schedule

Maternal education: The importance of mother's education and attending institutions of higher learning cannot be over emphasized in facilitating better health outcomes for themselves and their children (Sanou et al. 2009, S10). In low and middle income countries maternal education is a stronger predictor of immunization coverage for children than higher economic status of the household (Waters et al. 2004, 668-675). Analysis conducted using the Cameroon DHS and large scale studies in Bangladesh show that maternal education facilitates complete immunization only when the mother has attended formal education beyond the primary level (Jamil et al. 1999, 49-58; Waters et al. 2004, 668-675). Education improves mothers' understanding of the basis of disease as well as their comprehending health messages more effectively. Knowledge transfer regarding importance of immunization through mass media and health care providers plays a key role in improving immunization and the education of mothers facilitates this transfer (Bondy et al. 2009, 169-175).

Sex of Child: In low and middle-income countries the female child is often discriminated against at birth. The preference for sons results in the female child being malnourished, with low educational attainment as well as poor health outcomes including immunization. The culture and social values, especially in South East Asian countries, result in the female child being 30-40% less likely to complete immunization compared to a male child (Jamil et al. 1999, 49-58; Pande and Yazbeck 2003, 2075-2088).

Socio-economic status of the household: Households in the lower wealth quintiles have poorer health outcomes compared to households in higher wealth quintiles and this is a global

phenomenon across a spectrum of health outcomes. The same holds for immunization completion of children, observed universally (Sia et al. 2007, 201-206) and in Pakistan (Usman et al. 2010, 140-147; Shaikh et al. 2010, 806-810).

Age at receiving first dose of DTP (1) vaccine: Age at first contact with the immunization services is a strong predictor of the vaccine completion in Pakistan (Usman et al. 2010, 140-147). This is because families who are aware of the importance of the vaccination of the child will bring in the child early and are thus more likely to complete the schedule in a timely manner.

Use of maternal health services: An emerging predictor of vaccination completeness is the culture of vaccination that arises from the constant interaction of the population with the health care system. Mothers' use of antenatal services and assisted delivery also increases the vaccination completeness among their children (Sanou et al. 2009, S10). Use of ante-natal services by the mothers and opinions about the health center even in volatile situations, like facing food insecurities, facilitate vaccination completion (Sullivan et al. 2010, 53-59).

Communication and message dissemination: Health care providers' communication skills and behavior, mass media campaigns and behavior change material affect the uptake as well as completion of immunization services. In Burkina Faso communication problems were identified by 66.8% of the parents as a major concern that prevented them from participating in immunization activities. Ineffective communication skills of health providers and their discriminating behavior, especially in rural areas, result in parental misguidance and thus incomplete vaccination of their children. Frequent and comprehensive communication is a significant factor in increasing the vaccination completion rate but the health workers are also challenged to provide it during immunization sessions. The reasons indicated by the health workers are that they have to not only provide the vaccine but also document the information in registers and health cards which bars them from giving time for communication. It is important for funding and provider agencies to allocate funds for additional human resources to provide

effective communication for immunization activities. (Sanou et al. 2009, S10). Similar results were observed in Bangladesh: mothers' lack of understanding of key immunization details like timing, multiple doses, spacing and benefits of full immunization was in part due to poor communication of messages to mothers. The information provided during health education campaigns, Information—Education—Communication (IEC) materials and communication by service providers inadequately reach socio-economically deprived mothers who actually need it the most (Jamil et al. 1999, 49-58). The behavior of the health teams and their interaction with the population, especially the role played by the leadership, are emerging variables being investigated to predict immunization completion among children (Sia et al. 2007, 201-206).

Parental understanding of the diseases prevented by vaccines and the reasons for children falling sick even after vaccination also improve the vaccination coverage and completion in the absence of societal mistrust of immunization programs (Dugas et al. 2009, S9-698X-9-S1-S9). It is very important to provide the exact information about the diseases that are prevented by routine EPI vaccines, as parents have also stated Malaria as a vaccine preventable disease. This can lead to a false sense of security and disappointment when fully vaccinated children fall sick with diseases not covered by the EPI vaccines. Knowledge about the importance of vaccination is a significant determinant of complete vaccination rates: parents who are illiterate but had this information had children with higher vaccination completion rates.

Health systems related factors

Performance and ownership of the immunization program: In Cameroon the districts that had monthly supervisory visits by the immunization program supervisory staff had higher immunization completion rates compared to districts that were not visited on a monthly basis (Waters et al. 2004, 668-675). Home visits by vaccination staff and communication of health messages through providers may also improve vaccination completion rates. (Oyo-Ita et al. 2011,

CD008145). The systematic review done by Rainey et al. has identified 838 reasons for under-vaccinated children. Among these, 45% were related to the health care system (Rainey et al. 2011, 8215-8221).

Immunization card: The importance of the immunization card cannot be over emphasized as studies have pointed out that children who had immunization cards were more likely to complete their vaccination schedules (Waters et al. 2004, 668-675). In the United States among medically underserved populations, the children of parents who had vaccination record cards were more likely to be UTD at three months of age (Rosenthal et al. 2004, e296-302). A redesigned vaccination card with a plastic jacket and a holder to hang it, coupled with educating mothers, improved the DPT3 completion rates in a cohort of children in Pakistan (Usman et al. 2010). Community level determinants like child place of residence and having an immunization card are strong predictors of immunization in addition to individual level determinants like mother's ideation towards immunization, (knowledge of disease prevented by vaccines and perceived social approval of immunization). (Babalola 2009, 550-558).

Access: Physical access to vaccination services is a significant factor in determining vaccination initiation and completion and has been reported by numerous researchers across the globe. The household distance from a vaccination center and availability of immunization services have been cited by various researchers as statistically significant factors. There are marked differentials in immunization coverage and completion rates across the rural-urban divide and for various geographically challenging regions like mountainous areas and deserts.

Factors associated with refusal or never vaccinated

The factors associated with children never being vaccinated are in turn related to inequity in health status and include poverty, being among the minorities and belonging to rural areas. These variables associated with inequity interact with one another, e.g poor minorities and poor rural

children and further worsen the situation for these children. Mother's education at the secondary level and higher has shown again and again to protect against non-immunization and the children of mothers with no education, even in socialist countries like Vietnam, show a high rate of no immunization. Individual factors like sex of child and birth order of the child are associated with incomplete vaccination but are not often reported for children never vaccinated (Minh Thang et al. 2007, 41-58). Parental knowledge and attitudes are the major risk factor for a child never being immunized. The systemic review by Dietz et al. has identified parental lack of knowledge about immunization as a major observed associated factor, followed by fear or misconception of vaccines. Low motivation among caregivers, religious/traditional beliefs against vaccines and gender bias were among the other common findings observed for children never being vaccinated (Vance Dietz 2009).

The health systems level factors associated with children never vaccinated also include unavailability of health centers and the low quality of services provided, such as the number of days the center is open and provides vaccine.

Challenges facing the Expanded Program on Immunizations - Pakistan

Mistrust of vaccines amidst the polio epidemic: The current conflict in the Northern areas of Pakistan between government forces and the Taliban has spilled over to major cities in the form of acts of terror against civilians and social services. The Taliban's mistrust of the immunization program as an instrument to infiltrate and spy on their ranks has resulted not only in children being deprived of vaccine protection but also resulted in the targeted killing of immunization staff. In December 2012 five female workers, administering polio vaccine during supplementary immunization days, were shot dead in the metropolitan city of Karachi. In January 2013 another attack on aid workers by the Taliban left 6 female health workers and a male doctor dead just 75 miles from the national capital Islamabad. The Taliban militants have used the polio immunization program as a hostage to negotiate their demands over several instances and in April

2013 announced their "conditional support of the program" but the mistrust against vaccines still lingers among the residents of the communities (Sherazi 2013).

In areas of low vaccine coverage parental refusal or suspicion of vaccines are cited but it is important to understand low coverage in the absence of active refusal. In-depth ethnographic studies among low educated rural communities in Burkina Faso show that the low uptake of vaccination is affected by both the parental perceptions of disease and how vaccines may prevent diseases. Engaging household members like grandmothers, fathers and heads of households in addition to mothers, regarding the vaccination of the child results in greater acceptance and better completion of immunization schedules (Dugas et al. 2009). The EPI information campaign has not so far been able to promote dialogue with caregivers of children to encourage timely vaccination and initiation. A study in Lasbella district, Balochistan has reported that there are positive parental attitudes towards vaccines even though only 50% of the children in the study population were vaccinated against measles. Increasing the discussion with mothers and families results in better acceptance and uptake of immunization services (Mitchell et al. 2009, S7). Physical access of vaccination services, especially among geographically dispersed populations, poses another major challenge in reaching all children and promoting the uptake of timely and complete vaccination.

Slow response to epidemics: According to the WHO figures, the number of reported cases of measles in Pakistan rose from 4000 in 2011 to 14, 000 in 2012. In the most populous province of Pakistan, Punjab, 129 measles related deaths were reported during January to April 2013. Measles vaccination coverage is low in the country and parental attitudes have been blamed, but the 2012-13 epidemic was attributed mainly to the lack of available Measles vaccines. In the southern part of Punjab where the 2012-13 epidemic started, it was reported that in the region entire pockets of the population were without measles vaccine coverage (Galpin 2013). It is common practice in Pakistan to dismiss concerned officials in the event of media outrage over a breakdown of public

services without addressing the underlying faulty mechanisms that lead to disasters and epidemics.

Lack of vital registries: Reporting biases in vaccination coverage rates in many countries including Pakistan result in the over estimation of the vaccination coverage rates. The reporting biases can result from workers reporting vaccinating larger numbers of children to meet the program projections, and the program using number of doses distributed as a proxy measure for the number of children vaccinated while ignoring the wastage rates that take place in the cold chain. Because central records rely on district records, it becomes hard to obtain an accurate measure of vaccination coverage rates. In Pakistan the vaccination coverage rates in densely populated areas are based on projections of the population growth and may not take into account the Total Fertility Rate (TFR,) and the death rates that change the denominator; this practice introduces error in the reporting of the coverage rates (Bos and Batson 2000).

Maintaining financial sustainability: Historical budgeting instead of needs based budgeting is prevalent in the Pakistan health care system and is also seen among various developing countries (Lagarde, Haines, and Palmer 2009, CD008137). This practice is among the major challenges facing the immunization program in Pakistan. During 1991-95 withdrawal of donor support for the EPI program resulted in a reduction of the immunization coverage levels from 86% to 47%. Inadequately trained EPI staff, districts not prioritizing health and diversion of resources away from health are among the key challenges facing the immunization program. The current levels of coverage are supported by the combined efforts of the donor community, Government of Pakistan and GAVI support for new and underused vaccines (Federal EPI/CDD Cell 2003).

Among many low and middle-income countries, including Pakistan, public service budgeting is based on historical and instrumentalist (relying on preset formula for resource allocations) methods of resource allocation in the absence of mechanisms incorporating measures of needs and systematic needs assessment. As long as this method is employed, the health care system

will be slow in responding to the growing needs of the population, including the provision of adequate immunization services.

Timeliness of immunization

It is important that children complete their recommended immunizations by the first year of life as infant deaths due to infectious diseases contribute to the bulk of under-five mortality. Timely completion of the vaccination schedule is crucial to attaining maximum benefit from the intervention, especially among the young, (Akmatov et al. 2008, 3805-3811) and to prevent disease outbreaks (Luman et al. 2002, 935-939).

In Burkina Faso timeliness was highest for the vaccines given at birth, namely BCG, and was lowest for vaccines given in late infancy, mainly for DTP3 and measles, and this pattern was more pronounced in rural areas (Ouédraogo et al. 2013, 45-56). Even in developed countries like the United States, strict adherence to the immunization schedule may be low: only 28.3% of the children in a managed care initiative were found to be up-to-date with their immunization status. Children of younger mothers, belonging to low-income households and those not having a public provider were less likely to be up-to-date (Cotter et al. 2002). A study by Luman et.al assessed vaccination delays among US children and found that 1 in 3 children under 2 years of were under-vaccinated for more than 6 months. Unmarried mothers and those without a college degree, having more than 2 children, being non-Hispanic or black, and having more than one provider were all associated with children more likely to be under-vaccinated for their ages. The standard measures of vaccination coverage mask the risk children face during the period of under-vaccination, and may delay the timely corrective actions to be implemented (Luman et al. 2005, 1367-1374; Luman et al. 2005, 1204-1211). Research studies from South Africa have identified lack of immunization timeliness among children in poor areas compared to well off areas and for vaccines given in older ages (Fadnes et al. 2011, 404-2458-11-404). The researchers used Kaplan-Meier time-to-event analysis to calculate coverage and timeliness of 8 vaccines provided

to children up to two years of age by the routine immunization program of South Africa. Vaccination timeliness is not routinely measured even in the majority of developed countries; a study from Australia has also identified vaccination timeliness to be low among indigenous population children less than 12 months compared to non-indigenous children (Hull and McIntyre 2006, 4403-4408). An analysis of DHS data from 45 low and middle-income countries using survival analysis and devising an index combining coverage and timeliness show that the median of the delays was from 2.3 weeks for BCG, 2.4 weeks for DTP1, 2.7 weeks for Measles and 6.2 weeks for DTP3 vaccine. In 12 countries with the longest delays 25% of the children were delayed more than 10 weeks for BCG, 8 weeks for DTP1, 11 weeks for Measles and 19 weeks for DTP3. The median of the national coverage rate at the recommended 12 weeks time frame was only at 57%, but at 12 months it increased to 88%, fulfilling the WHO recommendations (Clark and Sanderson 2009, 1543-1549). An immunization measure based on timeliness of administration, calculated as an absolute score and assessing the relative differences among subgroups, allows for better monitoring of the immunization status of children and timely interventions (Glauber 2003, e39-45).

Success stories of vaccine/immunization programs

The reasons for under-vaccination differ from non-vaccination among children and any solutions to address the two outcomes should address the specific causes of under-vaccination and non-vaccination. Under-vaccination and non-vaccination due to limitations set by the health care system can be remedied by improving out-reach services, ensuring regular supply of vaccines and training the immunization staff for better program management. In instances where under-vaccination and non-vaccination is due to parental attitudes and knowledge towards vaccines a more tailored approach within the local context is needed (Rainey et al. 2011, 8215-8221).

In Pakistan a food/medicine voucher program was shown to be effective in improving up-to-date immunization by two fold among children up to 18 weeks of age. The socio-behavioral changes

take a longer time to take effect but an incentives based approach has the potential of improving the timeliness and completion of the immunization schedule (Chandir et al. 2010, 3473-3478).

Conditional cash transfers provide financial incentives to mothers for enrolling and keeping their children in school, seeking antenatal care, making well child visits and completing routine immunization. The World Bank discussion paper on innovative ways to improve vaccination rates has shown that conditional cash transfers in Mexico and Nicaragua have been instrumental in improving vaccination coverage and completion rates among children (Barham, Brenzel, and Maluccio 2007).

A systemic review of the approaches to improving immunization coverage and completion rates among children report that these can be categorized into four strategies: 1) bringing immunization services closer to communities, 2) increasing demand for vaccines through information dissemination, 3) changing practices in fixed sites and 4) introducing innovation for quality management (Ryman, Diet, and Cairns 2008).

According to Ryman et.al in their review paper on methods of improving immunization rates in low and middle income countries, interventions to bring immunizations closer to the communities consisted of reaching out to the communities by increasing outreach, provision of vaccines and dissemination of material through schools, visiting homes to identify and refer un-vaccinated children, increasing times vaccinations are offered and the number of vaccination centers, active mobilization of community men and women to keep track of children in need of immunization, and encouraging community members to complete vaccination of their children.

Information dissemination to increase vaccination was carried out through the routine channels of the mass media and more interactive methods of creating community resource rooms for families to visit. Information dissemination was also carried out through non-health related social programs like micro-credit programs encouraging women to vaccinate their children.

Changing practices at fixed health center sites promoted practices like inquiring about the vaccination status of all admitted children and ensuring they are up-to-date, setting up the vaccination room closer to the doctors' consultation room and using vaccination reminder stickers to reduce drop-out rates among children.

Innovative management practices to improve vaccination rates among children by various programs have been carried out such as introducing modern reporting systems, providing program planners with up to date information about the catchment area and target population, giving food incentives, training lower cadre health providers to administer vaccines in low performing clinics and use of community information data to develop specific interventions for the area.

Most interventions to improve vaccination rates reported by scientific papers are usually not designed as randomized controlled intervention studies in the first place. Therefore it is difficult to tease apart overall improvement of services in an area from the effects of a single intervention. Also any intervention to improve routine immunization will need to produce multifaceted improvement in vaccination coverage, timeliness and completion.

A Cochrane review evaluating interventions in low and middle-income countries to improve vaccination identified 6 studies with robust scientific methods and reported their findings. They identified key interventions as 1) facility based health education, 2) combination of facility based health education and redesigned card, 3) evidence based discussions, 4) information campaigns and 5) village based immunization discussions. Although the quality of scientific evidence for each of the interventions is from low to moderate, there have been reported increases. According to the reviewers, home visits and health education may also improve vaccination. An earlier Cochrane review has shown parental reminders for vaccination to be effective in improving

immunization coverage and completion but there is a lack of technologies in low and middle-income countries to support such a reminder system (Oyo-Ita et al. 2011, CD008145).

Cell phone based vaccine reminders to improve vaccination timeliness and completion have been received and implemented enthusiastically in high-income, low and middle-income countries (LMIC). Parental willingness to enroll in receiving vaccine reminders is also encouraging among high and LMIC countries (Diallo et al. 2012, 291-295; Clark et al. 2011, e1100-5). However, the results of the effectiveness of this intervention to improve completion and timeliness are still under investigation, especially in LMICs.

A study conducted in rural western Kenya to improve routine immunization schedule timeliness employed a cell phone based reminder text message and a conditional cash transfer for mothers on completing their child's vaccine doses on time. The intervention aimed at creating the demand for vaccines through sending mothers reminders and giving them an incentive to respond in a timely manner. Infants 0-3 weeks of age whose mothers had cell phones and were willing to participate were enrolled in the study. The results were encouraging as 90% of the children received DTP1 (scheduled at 6 weeks of age) and 86% of the children received DTP2 (scheduled at 10 weeks of age) in a timely manner, within a 4 weeks window period. The study showed the feasibility of scaling the intervention and parental acceptance of the intervention in addition to improving timeliness (Wakadha et al. 2013, 987-993).

In a study conducted in a Midwestern metropolitan area in Kansas, United States, a cell phone based vaccine reminder system was evaluated and showed a 20-30% increase in the timeliness of the vaccine schedule. The major issue with the use of mobile phone reminders is that low income parents frequently report loss of service, mainly due to payment delays, thus losing access to timely messages. Low technology strategies such as sending automated postal and electronic mail, or calling land-lines in cases where cell phone service is lost, may not be present to back-up

the intervention. There also are technological limitations to integrating the medical records with the cell phone service; therefore reminders cannot be created ahead of time plus each reminder has to be hand created (Ahlers-Schmidt et al. 2012, 5305-5309).

Validity of the measures of immunization status

The outcome variable of our analysis, immunization status of children, was recorded/verified during the PDHS data collection in two ways: 1) noting from the immunization card the vaccines a child had received (date vaccine was administered written on the card or administered vaccine marked/ticked on the card) and 2) in the absence of the health/immunization card at the time of the interview (immunization card never issued, mother was not able to produce it, no longer had immunization card) the status was confirmed by the mother's report, following the standard practice for household surveys. We have taken into consideration the validity of the outcome measure in our analysis in order to be able to correctly interpret the results and to be able to make sound policy recommendations. To better understand the validity of our outcome measure, we have reviewed the literature reporting on accuracy of maternal recall and immunization card in confirming the immunization status of children during household surveys from low and middle-income countries. The validity of maternal recall and confirmation from the immunization card is discussed below as reported by the published literature.

Validity of maternal/personal recall

Demographic and health surveys carried out in developing countries, especially in South Asia, rely on maternal recall for confirmation of immunization status and evaluation studies of DHS data report maternal recall to be accurate and reliable for confirmation of childhood immunization status (Brown et al. 2002). Researchers have also evaluated validity of maternal recall by comparing maternal recall with the vaccination card (Valadez J and Weld H 1992, 120-122), and more recently in KwaZulu-Natal with provider facilities based records and have reported maternal recall to be comparable to the written record. Analysis of DHS data from 45 developing

countries by Murray et al,, using probit models with sample selection (after adjusting for survey design effects) to reflect the number of valid vaccinations ,has also reported maternal recall to be accurate and reliable (Murray et al. 2003, 1022-1027).

The sensitivity of self-report of public health interventions is associated with community knowledge and coverage; the higher the coverage of an intervention, the higher is the sensitivity of self-report for that intervention. A study from rural China (low middle-income country) reporting on the validity of women's self-report reports that the overall validity is high for self-reported coverage for DPT vaccine and measles vaccine (Liu et al. 2013). Comparing facility based records to personal recall in urban Bangladesh, Salimuzzaman et.al have reported that accuracy of maternal recall increases with increasing maternal education, economic status and age (Khan and Khan 2012).

There is a substantial amount of literature from the developing world that supports the validity of maternal recall in accurately identifying the vaccination status of children; however, one has to be mindful of possible biases as the validity of maternal recall varies with different vaccines. Mothers may be able to recall with 97% accuracy the BCG vaccine of a child as reported by Babu et al. (Babu et al. 2010) since this is the first dose in the schedule and there is a resulting scar on the left upper arm to remind mothers. But it may not be easy for parents to accurately confirm if their child is fully vaccinated or has received a specific vaccine in a multi-dose schedule. For multiple dose vaccines, with the increasing number of vaccines in the immunization schedule and with the increasing age of the child the accuracy of maternal/parental recall becomes susceptible to biases. The majority of the studies in the developing countries assessing the validity of maternal recall have calculated its accuracy by comparing recall to the household held immunization records as there are no provider based health records to be used as the gold standard. Lumen et al., presenting their findings from the Commonwealth of Northern Mariana Islands, a low/middle income country, report recall to have less than 50% specificity (Luman,

Ryman, and Sablan 2009, 2534-2539) when compared to the provider based health records/electronic health records for estimating immunization coverage. According to them, mothers/parents recall overestimates coverage when they were asked if they considered their children to be fully immunized. There are fewer studies from low-middle income countries reporting comparison of recall to medical provider records. According to the systematic review by Miles et Al., four studies comparing recall to facility based medical records show that maternal/parental recall tends to overestimate the immunization status of their children. (Miles et al. 2013, 1560-1568).

Validity of household held immunization records

The household held immunization record or immunization card is regarded as more accurate compared to maternal recall when assessing immunization status of a child, especially during household surveys. Studies assessing the accuracy of maternal recall have compared it to the immunization card to calculate the validity of recall. There is a limited number of studies from developing countries reporting the accuracy of the household held immunization card; the majority of these studies are from developed countries. Household held immunization records are also susceptible to biases as parents may forget to bring the card to the vaccination center during visits for immunization or the facility staff my fail to enter the administered vaccines in the card. The only study from a low/middle income country reporting results that compare household held immunization records to facility based records states that vaccination coverage estimated by household held card among 2, 4 and 6 years olds was 35-50% lower than coverage based on medical records. This study by Luman et Al., carried out in Northern Mariana Islands, reports that compared to medical records, the immunization card underestimates coverage.

Reviewing papers from one middle income and fifteen high-income countries comparing household held immunization records to provider records, Miles et al. report that coverage based on immunization cards tends to underestimate true coverage by a median of 13 percentage points.

The combined median validity measures of coverage based on immunization cards from 16 papers had 84% specificity and 77% sensitivity (Miles et al. 2013, 1560-1568).

There is only one study from a developing country reporting the combined sensitivity of household held immunization cards and recall. When compared together, the combined information from card and recall or household sources, has less than 60% sensitivity to estimate true coverage as calculated from medical records (Luman, Ryman, and Sablan 2009, 2534-2539). Assessing measles conjugate vaccine (MCV1) coverage among a cohort of children in Bangladesh, Hayford et al. used six measures, collecting information from a household held immunization card, maternal recall, EPI records and serum markers to arrive at unbiased estimates of coverage. The study used the card+ recall as the gold standard and calculated prevalence ratios for MCV1 coverage to adjust for differences among indicators. They report maternal recall to give MCV1 coverage estimates 7.7% higher than the gold standard (card + recall). After accounting for sero-conversion rates and the assay sensitivity and specificity provided by the manufacturer they found non-significant differences in coverage calculated separately from maternal report/recall and coverage calculated by serum indicators when compared to the combined measure of card and recall. They recommend using card+recall as a gold standard in the absence of provider based medical records and vaccine registries and advocate for establishment of electronic medical records for childhood immunization (Hayford et al. 2013, 1211-2458-13-1211).

In our analysis we have used the combined measure of card and maternal recall to create our outcome variable for all the three objectives. In the PDHS immunization status was confirmed by the card whenever available and only in its absence was maternal recall used to confirm immunization status. The survey questionnaire does not provide for recording the immunization status by both sources so the concordance between maternal recall and card confirmed immunization status couldn't be calculated for the PDHS data sets. In areas of high card

retention rates, like Bangladesh (83%), maternal recall has high concordance with the immunization card. But in our study sample card retention was low; in PDHS 2006 only 13% of the mothers were able to show the card at the time of the interview. We have used the combined measure of card and maternal recall to confirm immunization status for two reasons: 1) to be able to have an adequate sample size and 2) in the absence of medical records, card+recall is regarded as the best available data source to increase accuracy and completeness (Hayford et al. 2013, 1211-2458-13-1211). The provider based records are susceptible to biases when these are introduced for the first time as not all facilities are fully prepared to adopt electronic medical records and differences in coding may add to the biases of arriving at accurate estimates. But in the long run, provider based records are the most reliable and should be regarded as the gold standard.

Chapter 3: Methods

Specific aims

The specific aims of this study are:

- To evaluate the association of individual and contextual level factors with immunization initiation among children 12-23 months of age in Pakistan by analyzing the PDHS 2006-07 and PDHS 1990-91 datasets.
- To evaluate the association of individual and contextual level factors with immunization completion among children 12-23 months of age in Pakistan by analyzing the PDHS 2006-07 and PDHS 1990-91 datasets.
- To evaluate the association of individual and contextual level factors with up to date (UTD) immunization among children 36 – 52 weeks of age in Pakistan using the 2006-07 Pakistan Demographic and Health Survey (PDHS) data analysis results.

Research Hypotheses

The research hypothesis for each specific aim includes the following:

*Spec*ific Aim 1: Contextual level variables, more than individual level variables, are likely to be associated with immunization initiation among children 12-23 months of age in Pakistan.

Specific Aim 2: Contextual level variables, more than individual level variables, are likely to be associated with immunization completion among children 12-23 months of age in Pakistan.

Specific Aim 3: Contextual level variables, more than individual level variables, are likely to be associated with up to date (UTD) immunization status among children 36 – 52 weeks of age in Pakistan.

Description of the source of study data

Demographic and Health Survey

The Demographic and Health Survey (DHS) evolved out of the world fertility surveys and contraceptive use prevalence surveys that were conducted in the 1970s and 1980s. The earlier

DHS versions primarily collected data on reproductive and child health with a focus on fertility trends, contraceptive use and nutritional status of mothers and children in developing countries. The DHS questionnaire, design and field implementation techniques undergo constant quality improvement and to date, the Phase 1 module (implemented in 1984-89) has evolved into the current Phase 6 modules (being implemented during 2008-2013). The Phase 6, core DHS questionnaire modules collect data on a wide range of maternal and child health topics including knowledge, attitudes and practices (KAP) regarding maternal and child health, population experience with and quality of reproductive and child health services and population health decision making. Additional modules on special topics like HIV and AIDS, Malaria and domestic violence are also included in the questionnaire according to specific data needs of countries. Since 1984, 230 nationally representative DHS household surveys have been conducted in more than 80 countries.

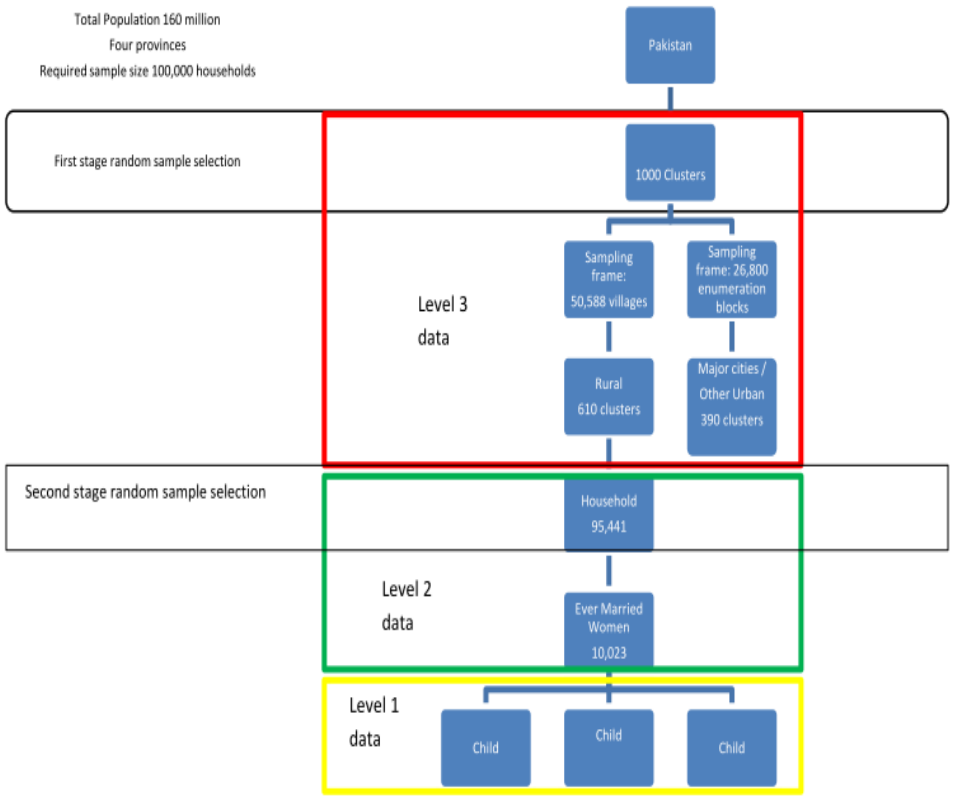
The surveys are conducted by Measure DHS, a USAID funded entity, and the country team. Measure DHS provides the standard procedures, methodologies, and manuals to guide the survey process and the country team supports the logistics and manpower needed to carry out the survey. In Pakistan the National Institute of Population Studies, a Government of Pakistan (GOP) entity, provided financial assistance in terms of in-kind contribution of government staff time, office space, and logistical support and Macro International provided financial and technical assistance for the survey through the MEASURE DHS program.

The DHS survey is responsive to the data needs of the host countries, U.S. Agency for International Development, as well as researchers interested in understanding adult and child health issues. Since 1984, 1117 articles using DHS data have been published in over 200 journals but there are no publications assessing how DHS results are used by local policy makers for decision making. (Short Fabic, Choi, and Bird 2012, 604-612)

Pakistan Demographic and Health Survey

The first Pakistan Demographic and Health Survey was conducted in 1990-91 and the second in 2006-07. In the 2006-7 PDHS additional information was collected to derive national estimates of maternal and infant mortality and child health. The implementing partners were the Ministry of Population and Welfare, National Institute of Population studies, Macro International, USAID, WHO and UNICEF. The PDHS 2006-07 and 1990-91 datasets have been obtained from the DHS Measure web site by a formal request. The data are in the public domain but the individual study participants cannot be identified.

Figure 5. DHS 2006-07 Survey Design and Number of Households and Eligible Women Interviewed



Pakistan Demographic and Health Survey 2006-07

A cross-sectional, nationally representative demographic and health survey was conducted in 2006-07 to address the monitoring and evaluation of maternal and child health and family planning programs in Pakistan (Figure 5). The survey also aimed to derive national estimates for maternal and child mortality and for this a sample of 100,000 households was set.

Table 4. Number of households selected, and interviews conducted for the PDHS 2006-07 (numbers below are for households that were available for interview)

	Residence				Total
	Total Urban	Major City	Other Urban	Rural	
Households Selected	40,827	21,297	19,530	61,210	102,037
Total Households interviewed	37,909	19,729	18,180	57,532	95,441
Short Questionnaire	34,223	17,822	16,401	51,963	86,186
Long Questionnaire	3,686	1,907	1,779	5,569	9,255
Eligible Women Interviewed	3,830	1,929	1,901	6,193	10,023

The survey employed a two-stage stratified, random sampling design. In the first stage 1000 sample points (clusters) were selected with probability proportional to size (population) from across Pakistan. The sampling frame for the rural areas consisted of 50,588 villages/mouzas/deh as numerated according to the 1998 national population census. The sampling frame for the urban areas was 26,800 enumeration blocks and each consisted of 200-250 households. The population of major cities (population more than 500,000) was stratified into low, middle and high-income areas and treated as a separate stratum. A total of 610 sampling points/clusters from the rural and 390 sampling points/clusters from the urban areas were selected. Due to political unrest and community refusal data were not collected from 20 sampling points/clusters in Federally Administered Tribal Areas (FATA), 4 sampling points/clusters in the province of Baluchistan and 4 sampling points/clusters in Khyber Pakhtunkhwa, the former North West Frontier Province (NWFP). Data were collected from a total of 972 sampling points/clusters from the four provinces of Pakistan, excluding the FATA and Federally Administered Northern Areas (FANA). In the second stage from each cluster (enumeration block/village) 105 households were selected by random selection and a total of 102,060 households were identified.

From the 105 households selected in the second stage in each cluster 10 houses were randomly selected for conducting the survey using the women's questionnaire and long household questionnaire. This resulted in 9720 households being selected constituting 10% of the total (102,972 household) sample size. The short questionnaire was to be used to collect information from the remaining 92,340 households constituting the remaining 90% of the total sample size (Table 4).

The short questionnaire collected data about basic demographic and household information and to identify any maternal and child death in the past three years. Any adult in the household was eligible for interview. The long questionnaire collected detailed information on socio-demographic characteristics and the women's questionnaire collected data about maternal and

child health including immunization history from ever-married women ages 12-49 years. The "community questionnaire" was used to collect information in each rural sample point on the availability of health, education, communication and civic facilities and services.

Pakistan Demographic ad Health Survey 1990-91

The survey in 1990-91 was conducted to collect data on household socio-demographic variables, men and women's contraceptive knowledge and use, family size preferences, child health and vaccination status, reproductive history, education and economic status.

A two stage stratified sampling design with probability proportional to size (population in rural areas and number of households in urban areas) was adopted. The sampling frame for the urban areas was enumeration blocks consisting of 200-250 households each based on the 1989 Housing Establishment Census. The sampling frame for the rural areas was villages according to the 1980 Housing Censes (Table 5).

Table 5 Numbers of Primary Sampling Units and Households covered, Eligible Women and Husbands Interviewed in the Four Provinces PDHS 1990-91 (numbers below are for households that were available for interview)

	PSU	Households	Eligible Women	Eligible Husbands
Punjab	155	2598	2207	461
Sindh	110	2071	1798	364
KPT	82	1609	1665	313
Baluchistan	60	915	941	216
Total	407	7193	6611	1354

A total of 7420 Primary sampling units (PSU) were taken as the master sample and 8019 households forming the secondary sampling units (SSU) were selected. The selected households covered 408 primary sampling units (PSU). The number of households (SSU) was fixed and every 18th household was selected in the urban domains as well as the rural domain of Punjab province. For the rural domains of the remaining three provinces of Sindh, former NWFP and Baluchistan 25 SSU were selected from each PSU. A subsample was formed by selecting every 3rd household for interview of eligible husbands of the ever-married women (Table 6).

Table 6 Survey Sample Size for Rural Areas 1990-91

Number of Primary Sampling Units and Households covered, Eligible Women and Husbands Interviewed in the Four Provinces PDHS 1990-91 (numbers below are for households that were available for interview)

	PSU	Households	Eligible Women	Eligible Husbands
Punjab	83	1420	1212	249
Sindh	40	904	739	158
KPT	40	910	916	169
Baluchistan	19	357	360	82
Total	182	3591	3227	658

Description of the study instrument and its development

The 2006-07 Pakistan Demographic and Health Survey (PDHS) was conducted using the standard DHS core questionnaire. The core questionnaire consisted of the community questionnaire, short household questionnaire, long household questionnaire, and ever-married women's questionnaire. The household questionnaire collected detailed information on the household characteristics and basic demographic data on household income, number of family members etc. The ever-married women's questionnaire consists of 9 sections and collected detailed information about the reproductive health information from women. It also collected information on the last three births of a woman and the health outcomes of these children including ante-natal care, place of delivery and post-natal care, breastfeeding, nutrition, respiratory infections, diarrhea and immunizations. Detailed immunization history was collected including information on age of child and date of receiving specific antigens. However the reasons for not completing the vaccination schedule and indirect costs associated with seeking vaccination were not collected. In 2006-07 information was also collected using the modules on child and maternal death to identify cause of death in this population and arrive at national estimates for child and maternal mortality.

Study Assessment: According to the PDHS protocol the information for immunization status of a child was noted from the vaccination record card of a child if it was present and shown to the interviewer at the time of data collection. Where parents were not able to bring forth the vaccination record card to show to the interviewer, or the card was lost or was never issued by the EPI programs the mother's report of the vaccination was used. If the mother reported that a polio dose was not given at birth than it was assumed that polio vaccine was given with DTP vaccines. This approach was used in order to not confuse the mother about the oral polio vaccine dose 0 given at birth with the subsequent doses OPV1-3 given at 6, 10 and 14 weeks along with DTP.

Study Population

Inclusion criterion: Children 12-23 months of age were included in the analysis as ideally the EPI vaccination schedule should be completed by twelve months of age and children up to 23 months of age are most susceptible to the vaccine preventable infections. The exclusion criterion was set for children less than 12 months and more than 23 months of age as this is also the criterion used by the WHO and EPI program for reporting vaccination among children. A subset of children up to 52 weeks of age or one year was selected to assess the Up to Date (UTD) vaccination status for objective three. The EPI Pakistan objective is to complete the vaccination schedule by 11 months of age but to attain an adequate sample size for our analysis we set the criterion for children up to 12 months or 52 weeks of age to assess timeliness of the UTD status.

The DTP vaccine schedule was selected to analyze immunization initiation and completion as WHO recommends monitoring DTP vaccine status for immunization program evaluations. A child who had not received any vaccine dose of DTP, BCG and polio at the time of the interview was labeled as never vaccinated. BCG is a onetime single dose vaccine. Since polio drops can be given more than the recommended schedule during mass immunization days, polio was not included in the initiation and completion outcome variables.

Children who received a single dose of BCG, three doses of DTP (1-3) and OPV (1-3) and a single dose of Measles by 52 weeks of age were identified as Up to Date (UTD) for our analysis.

Definition of Populations for Analysis: Children receiving specified vaccines, all specified vaccines, and no specified vaccine, according to information on the vaccination card or report by mother/ respondent.

Specified Vaccine:

1. BCG—Anti-tuberculosis to be received shortly after birth.

2. DTP—Triple vaccine for diphtheria, pertussis and tetanus, received in three doses at 6, 10, and 14 weeks after birth

3. Polio—Received in three doses usually given at same time as DTP, plus an additional dose at birth in Pakistan and several countries in Asia and Africa.

4. Measles—The recommended age is at 9 months and a booster dose at 15 months of age.

5. Up to date (UTD)—child was given single dose BCG, three doses of DTP, three doses of polio (excluding. the dose given shortly after birth), and single dose of measles by 52 weeks of age.

6. No vaccinations—none of the specified vaccinations was given.

Definition of Sub-Group population in different analyses:

1. All children age 12 to 60 months of age captured by the PDHS 2006-07 and 1990-91. This age group was assessed for retention of household held immunization card.

2. Children between 12 and 23 months of age who received the specified vaccines. Where the information is present on a vaccination card shown to the interviewer, the date of the vaccination is used, otherwise as reported by the mother.

3. Children 36-52 weeks of age who received single dose BCG, three doses of DTP, three doses of polio (excluding. the dose given shortly after birth), and single dose of measles. The vaccination status recorded from the vaccination card and/or mothers report.

Analytic methods

Data cleaning

In keeping with the standard data cleaning protocols (Van den Broeck et al. 2005, e267) the DHS data sets are vigorously checked to ensure quality control at several stages of data collection,

entry and compilation. Paper based questionnaires from the field are checked for correctness of how responses were categorized and open-ended responses are recoded as needed. All data from the paper copy is double data entered into electronic files and cross checked for consistency and corrective action taken where needed. To identify potential problems, quality control tables on response rates, age displacements and completeness of data are generated to check for any inconsistencies. The entered data are checked and corrected for missing data, dates of events and weights and imputations are carried out as needed (Measure DHS 2013)

Creation of data set

The data set used for analysis was a subset of the PHDS 2006-07 and 1990-91 data. It included information on all children 12-23 months of age regarding their vaccination status and variables selected for analysis. The analysis was run separately for the two data sets. This approach was used because although the survey methodologies and questionnaire design for the PDHS 2006-07 and 1990-91 surveys were the same, the quality of execution was different.

The PDHS 2006-07 data subset file entitled Birth Recode (PKbr52FL) was selected and opened using Stata 11 version. The PKbr52FL dataset contains information on 27,223 children 0-15 years of age. From the dataset all children 12-23 months of age were selected. The final dataset contains information on all 1639 children 12-23 months of age, 1104 children 12-23 months of age who have received DTP1 and 872 children 12-23 months of age who have received DTP3. It is a large dataset with several hundred variables, but we focused on a total of 15 variables of interest.

Creation of variables

Binary and multinomial outcome variables were created in order to examine the study hypotheses (Table 7). The binary variable, B_DTP1 coded as 0 and 1, represented children who did not receive the DTP1 vaccine dose coded as 0 and children who received the first dose of DTP vaccine coded as 1. The children who received the first dose of DTP (DTP1) included children

for whom the vaccine date was noted on the health/immunization record card, as reported by the mother and/or the vaccine was marked on the card as having been given. Children for whom the data were missing or their mothers reported as "don't know" were all coded as missing data.

A multinomial variable was also created for vaccination initiation with "No DTP1" coded as 0, "DTP1 date noted/marked on the card" coded as 1, and "DTP1 reported by the mother" coded as 2. This was done to see if various predictors affected the outcome differently if the children receiving DTP1 vaccine as noted on the card differed from those reported by the mother.

The binary variable B_DTP3 was coded as 0 for receiving no DTP3 vaccine and 1 for receiving the DTP3 vaccine dose. The latter category was children among those who received the DTP1 vaccine or initiated the DTP vaccination who continued to complete the schedule. A multinomial variable was also created, with "No DTP3" coded as 0, "DTP3 date noted/marked on the card" coded as 1 and "DTP3 reported by the mother" coded as 2. This approach was used to see if various predictors affected the outcome differently if the children receiving DTP3 vaccine was noted on the card versus reported by the mother (Table 8).

The binary variable Up to date (UTD) immunization status of a child was coded 0 for a child who was not up to date and coded 1 for a child who was UTD. A child was considered UTD for immunization if he/she had received a single dose of BCG, 3 doses of DTP and OPV 1 to 3 and a single dose of measles vaccine by 52 weeks of age.

Table 7 Description of coding procedures for dependent variables used for analysis of the PDHS data

Vaccination Initiation	
B_DTP1 Confirmed by noting vaccine date on card, vaccine marked on card and/or reported by the mother	Coded 0= did not receive DTP1 Coded 1= received DTP1
M_DTP1	Coded 0= did not receive DTP1 Coded 1= vaccine date noted on card and/or vaccine marked on the card Coded 2= reported by the mother
Vaccination Completion	
B_DTP3 Confirmed by noting vaccine date on card, vaccine marked on card and/or reported by the mother	Coded 0= did not receive DTP3 Coded 1= received DTP3
M_DTP3	Coded 0= did not receive DTP3 Coded 1= vaccine date noted on card and/or vaccine marked on the card Coded 2= reported by the mother
BCG	Coded 0= did not receive BCG Coded 1= received BCG
Up to Date (UTD)	Coded 0= did not complete the schedule Coded 1= received BCG, OPV 1-3, DTP 1-3 and Measles

The BCG vaccine is the first vaccine dose in the immunization schedule and is given at birth. Children born in a health center/hospital are very likely to receive it due to availability and not because of parental efforts; therefore we did not consider this as an indicator of parental health seeking behavior. Children born at home and in remote areas without easy access to a health center may or may not receive the BCG vaccine but for children who do, it shows the parental attitude towards vaccine acceptance. The Polio vaccine was not selected as an outcome variable as oral polio drops are often given to children during mass immunization campaigns with vaccination teams visiting children door to door. As this does not allows us to assess population health seeking behaviors we did not use it as an outcome.

The contextual level variables

The contextual characteristics such as the level of infrastructure development in an area, the design and functioning of the health care system and extent to which a community has attained socio-economic development along with individual characteristics like household wealth and maternal education and age are hypothesized to predict the health seeking behavior and health outcomes of a population. The selection of contextual level variables and individual level variables for explaining the variance in the outcomes, was guided by the study conceptual framework, work by other researchers and data availability.

Province: The place where a family resides is a strong determinant of preventive health seeking behavior of the population as each province has a different population density and distribution of health services. The most populated province of Punjab has a population density of 353 persons/ square km (national average is 164 person/km ^{2} (Government of Punjab 2013): it has many more health posts providing services to a larger population. Similarly there are many more schools and higher education institutions resulting in better educated communities, and several centers of economic growth where a larger population resides in urban and semi-urban areas with associated amenities. The province of Baluchistan is the largest in terms of land mass but is also the least

populated with a population density of 16 person/Km^2 (Pakistan Ministry of Information and Broadcasting 2006). This situation poses a great challenge to the health care service delivery system due to a widely distributed population and 70% of the areas being rural areas.

Area of residence: Whether the place of residence is urban or rural profoundly determines the availability of health services, ease of access to the services and travel requirements that can affect the parental attitudes towards vaccination, including its timely initiation and completion. Many urban areas in Pakistan have fewer governmental health posts compared to the rural areas but with better ease of access like the availability of motorized transport. Similarly parents in urban areas may be inclined to seek vaccination for their children, as many private schools require vaccination completion records for admission.

Health card: A child is issued a vaccination record card or "health card" by health care providers/vaccinators at birth or after receiving the first dose of vaccine. The health card can be a simple one recording only vaccines administered and it can be a more detailed card that notes the well child visits and charts the growth and development of the child. In other instances the mother is issued a pre-natal card, which is used to record the vaccines she has received as well as those administered to her child. It is made of paper and very prone to tear and damage. The date for each vaccine received is entered and the date for the next visit may or may not be noted on the card. The parents are required to take care of it and reproduce it at each vaccination visit. Its provision to parents is a health system's related variable and there are numerous reported cases where the health posts run short of health/immunization cards for months. It also becomes a population health behavior variable as parents who appreciate the value of timely and complete immunization are more likely to save it. But parents who do not have structured dwellings and/or appropriate storage space can easily lose it.

Individual level characteristics

Mothers' education: Mothers who have a higher number of years of education are more likely to seek better health services for themselves and their children. This is an almost universal finding across all fields of human behavior research. During our exploratory analysis we used the variable both as a continuous variable, i.e. number of years of schooling as well as a categorical variable, coded as no education, primary, secondary and higher. After observing the results of the bivariate data analysis it was seen that there is no difference in the behavior of mothers with no education and mothers with primary education; therefore it was re-coded for selection into the final model as no education or up to the primary level, versus secondary education and higher.

Household wealth index: People belonging to higher wealth quintiles have better means to access health services as they are secure from wage loss due to time spent visiting health providers and can spend money for transportation. It is also seen universally that households with higher wealth seek more health services, including preventive health care and have better health outcomes. We wanted to explore if household wealth influenced immunization services uptake differentially by place of residence and province.

The household wealth index was calculated differently for the 1990 and 2006 Pakistan Demographic Surveys. In 1990 fewer variables measuring household possession of durable goods were used to calculate the wealth index while in 2006 more variables were used to calculate the wealth index and it was more precise. But for the purposes of our analysis we assumed that the household wealth variables were comparable in the two time periods.

Head of household: If the head of the household is a female than the decision making process may be different than when the head of the household is male. We wanted to explore if this factor influenced health-seeking behavior in Pakistan and thus it was included among the predictor variables.

Birth Order: The first-born child usually receives preferential treatment and also parents may be more enthusiastic regarding the health of the child and have more time to devote to care seeking. But this can also be a limiting factor as many first time parents are not aware of where, when and how to access health services which can result in a delay of the immunization schedule of the child.

Sex of child: Differential treatment is observed for girls and boys as the female child is more likely to suffer from malnourishment and delay in seeking health care if the child is sick. We wanted to observe if a differential parental behavior is observed for timely completion of vaccination in Pakistan.

Number of children under five years of age: the first- born child may receive preferential treatment but it can also result in low immunization as first time mothers are not educated enough on the need for vaccination. As the birth order of a child increases and number of young children increase a mother is held back from seeking timely preventive health services, as she has to care for other siblings who also need attention.

Types of analyses performed

Design based analysis was employed to account for the complex nature of the data due to the sampling design.

Design based analysis for weighted DHS data

Descriptive analyses were performed to compare the distributions of various variables between the groups, using appropriate statistical tests: chi-square for categorical variables and t-tests for continuous variables. The child vaccination status was the dependent variable in the analysis and maternal, child and household characteristics the correlates, as present in the PDHS 1990-91 and 2006-07 data sets for each child.

Logistic regression analysis was used for survey design by the STATA "svy" command to adjust for the clustering and intra-class correlation effects on the sample. In univariate logistic regression analyses, unadjusted effects of the potential associated factors with outcome variables of initiation, completion, and up to date immunization were performed. The independent associations of the factors were assessed through computation of odds ratios along with the 95% confidence intervals generated from the parameter estimates. Multivariable analyses were then performed to examine the associations of independent variables with outcome variables, adjusting for the confounding effect s of other variables. Independent variables with a p-value of 0.25 and less based on their unadjusted parameter estimates, or those which the theoretical framework identified as of importance, were considered for the adjusted regression analyses. The variables were entered one by one, starting from the most significant variable in the univariate analysis. The significance of an individual independent variable in the adjusted analyeis was assessed by its confidence interval for the odds ratio and the Wald's statistic. Variables not found as having a significant association (p-value > 0.05) with an outcome, not confounding the relationship of other variables, or theoretically not important, were subsequently removed from the model. The overall significance of each model was assessed by the likelihood ratio test. After developing the final model, plausible interactions among the independent variables were evaluated. Assessment of the final model for goodness of fit was done through the Hosmer-Lemeshow test. Adjusted OR's and their 95% confidence intervals generated from parameter estimates were used for interpretation of the model.

Specific Aim I

Assess individual and contextual determinants of vaccination initiation, defined as receiving DTP1 vaccine, among children 12-23 months of age in 1990 and 2006 in Pakistan.

Research question

What variables determine the vaccination initiation, defined as receiving DTP1 vaccine, among children 12-23 months of age in 1990 and 2006 in Pakistan?

Research Hypothesis

Contextual level determinants, more than individual level variables, are likely to be associated with vaccination initiation, defined as receiving DTP1 vaccine, among children 12-23 months of age in 1990 and 2006 in Pakistan.

Data Sources: Pakistan Demographic and Health survey data for the years 1990 and 2006. The file "Children recode", PKKR21FL.DTA of the1990 survey and PKKR52FL.DTA of the 2006-07 survey were selected for the analysis. The outcome variable was created as a binary variable and an alternate analysis was also performed whereby the outcome was in the form of a multinomial variable. The binary variable, B_DTP1, was coded as 0 and 1: children who did not receive the DTP1 vaccine dose were coded as 0 and children who received the first dose of DTP vaccine were coded as 1.

The multinomial variable M_DTP1 was coded as 0 for No DTP1, DTP1 date noted/marked on the card was coded as 1 and DTP1 reported by the mother was coded as 2. This was done to see if various predictors affected the outcome differently if the children receiving DTP1 vaccine were confirmed by noting the information from the health/immunization cards or were reported by the mothers.

Predictor variables included in the analysis were as follows:

- "Region" or province the child lived in categorized into Punjab, Khyber Paktunkhwa, Sindh and Baluchistan.
- "Place of residence" coded as urban and rural
- "Wealth" which consisted of the household wealth index coded as poorest, poor, middle, rich, and richest
- Sex of the head of household
- "Mother education" coded as no education or primary education, and up to middle and higher
- Birth order of child
- Sex of child

Statistical analysis

Frequency distributions for the sample were calculated for children who had received DTP1 vaccine verses those who had not received DTP1 as well as the individual and contextual level characteristics of the population. The results were presented in frequency distribution tables. Differences in the sample characteristics between children who had received DTP1 vaccine versus those who did not receive DTP1 vaccine were also calculated and the results presented in percentages as well as absolute numbers. The analysis was done using a binary logistic regression for the binary outcome and multinomial logistic regression analysis was performed for the multinomial outcome.

Sample size and power calculation

The PDHS 2006-07 final data set selected for analysis contains information on immunization status of 1**639** children 12-23 months of age, **1104** children 12-23 months of age who have received DTP1 and **872** children 12-23 months of age who have received DTP3. The sample size is adequate and allows with 80% power and alpha set at 0.05 to detect a 5% difference in immunization rates between two groups of children.

The PDHS 1990-91 dataset contains information on immunization status for 1215 children 12-23 months of age, 769 children 12-23 months of age who have received DTP1, 493 children 12-23 months of age who has received DTP3 and 561 children who received Measles vaccine. The sample size is adequate and allows with 80% power and alpha set at 0.05 to detect a 5% difference in immunization rates between two groups of children

Specific Aim II

Assess individual and contextual determinants of vaccination completion, defined as receiving DTP3 vaccine, among children 12-23 months of age in 1990 and 2006 in Pakistan.

Research question

What variables determine the vaccination completion, defined as receiving DTP3 vaccine, among children 12-23 months of age in 1990 and 2006 in Pakistan?

Hypothesis

Contextual level determinants, more than individual level variables, are likely to be associated with vaccination completion, defined as receiving DTP3 vaccine, among children 12-23 months of age in 1990 and 2006 in Pakistan.

Data Sources: Pakistan Demographic and Health survey data for the years 1990 and 2006. The file "Children recode", PKKR21FL.DTA of the1990 survey and PKKR52FL.DTA of the 2006-07 survey were selected for the analysis.

Outcome Variable: A binary variable B_DTP3 for vaccination completion was created. It was coded as 0 for children who did not receive the third dose of DTP vaccine and 1 for those children who received the third dose of DTP vaccine.

The multinomial outcome variable M_DTP3 was created to assess the outcome according to the way vaccination completion was verified. It was coded as 0 for No DTP3, coded as 1 for DTP3 date noted/marked on the card and as 2 for DTP3 reported by the mother.

Predictor variables

- Contextual level variables: province of residence, place of residence and child having a vaccination card.

- Individual level variables: household wealth index, sex of the head of the household, maternal education, maternal age, sex of the child, birth order of child and number of children under five years of age in the household.

Statistical analysis

Descriptive analyses were done to assess the population characteristics and sample distributions in relation to the outcome and predictor variables. The sample proportions and their SEs and 95% CIs were examined while assessing the sample distributions.

Missing data: Percentages of missing data were calculated for each of the predictor variables. The variables with 3-7% missingness were analyzed excluding the missing data. For variables, which had more than 7% missing data, multiple imputation techniques were employed to correct for the missing values.

Explanatory analyses were carried out in two steps: Univariate regression analysis was performed for all the predictor variables and the estimates, p-values, and 95% confidence intervals noted for each. Adjusted analysis, using binary logistic regression, was used to assess the associations between children completing the vaccination schedule with maternal, child, and household characteristics and contextual factors. For the selection of the final model we started with the full model and noted the estimate, p-value and Mean SE for each variable. Variables that were statistically insignificant were dropped one at a time. After the removal of each variable the change in estimate and significance were noted. The model with the highest pseudo R^2, and lowest Mean SE was retained. In addition to the pseudo R^2 and Mean SE, stepwise Akaike Information Criteria (AIC) was also considered to select the most parsimonious model. Some variables were retained in the final model regardless of the level of significance if they were considered as important to the conceptual model. Design based analysis was carried out by specifying in the program that the data were survey data collected through a complex sampling

framework, thus accounting for the hierarchical nature of the data as children were nested within households and households were nested within clusters/PSUs.

To assess the collinearity among the predictor variables the Variance Inflation Factor analysis (VIF) was carried out. Sets of variables that were not significantly associated with the outcome variable in the multivariate analysis but were highly significant in the univariate analysis as indicated by the F-statistic were checked for collinearity. The VIF command in STATA is only applicable after linear regression. To overcome this limitation the model with the predictor variables was fit using an alternate outcome (age of mother as a continuous variable) and followed by the VIF command. The highly collinear predictor variables were identified and necessary correction was made. All analyses were performed keeping in view the survey design with stratified cluster sampling by using the svy function in STATA. When setting the command for design-based analysis, the variables for stratum, primary sampling units and sampling weights were specified which accounts for the clustering of the survey data. We also assessed the goodness-of-fit of the model by running appropriate tests using the svylogitgof. The sample size considerations and power calculations were the same as those performed for Specific Aim I.

Sample size and Power calculation:

The PDHS 2006-07 dataset contains information on immunization status of 1639 children 12-23 months of age, 1104 children 12-23 months of age who have received DTP1 and 872 children 12-23 months of age who have received DTP3. The sample size is adequate and allows with 80% power and alpha set at 0.05 to detect a 5% difference immunization rate in two groups of children.

The PDHS 1990-91 dataset contains information on immunization status on 1215 children 12-23 months of age, 769 children 12-23 months of age who have received DTP1 and 493 children 12-23 months of age who have received DTP3 and 561 children who received Measles vaccine. The

sample size is adequate and allows with 80% power and alpha set at 0.05to detect a 5% difference in immunization rate in two groups of children

Specific Aim III

Research question

What variables are associated with up to date (UTD) immunization among children 36-52 weeks of age in Pakistan?

Research Hypothesis

Contextual level variables, more than individual level variables, are likely to be associated with the status of UTD immunization among children 36 to 52 weeks of age in Pakistan.

Data Sources: Pakistan Demographic and Health survey 2006

Outcome Variable: Up to date (UTD) immunization status of a child. For our analysis a child is considered UTD for immunization if he/she has received a single dose of BCG, 3 doses of DTP and OPV 1 to 3 and a single dose of measles vaccine by 52 weeks of age.

Predictor variables: These included the place of residence, province of residence, household wealth quintile, maternal age, maternal education, birth order of child, sex of child and number of children under five years of age in the household.

Sample size and power calculations: The PDHS 2006-07 data set selected for the UTD analysis contains information on immunization status of **775** children, 36-52 weeks of age among whom 544 (70.19%) had not completed the recommended schedule and only 231 (29.81%) had completed the recommended schedule. The sample size is adequate and allows with 80% power and alpha set at 0.05to detect a 5% difference in immunization rates between two groups of children.

Statistical analysis

Descriptive analysis was done to assess the population characteristics and sample distributions in relation to the outcome and predictor variables. The sample proportions and their SEs and 95% CIs were examined while assessing the sample distributions. For sample characteristics, percentages and frequencies were calculated.

Missing data: The percentage of missing data was calculated for each predictor variable. The variables with 3-7% missingness were analyzed, omitting the cases with missing data. For variables which had more than 7% missing data, multiple imputation techniques were employed to supply values for the analysis.

Explanatory analysis was carried out in two steps: Univariate regression analysis was performed for all the predictor variables and the estimate, p-value, and 95% confidence interval noted for each. Adjusted analyses using binary logistic regression and multinomial logistic regression were performed to assess the associations between children completing the vaccination schedule and maternal, child, and household characteristics and contextual factors. For the selection of the final model we started with the full model and noted the estimate, p-value and Mean SE for each variable. Variables that were statistically insignificant were dropped one at a time. After the removal of each variable the change in estimate and significance was noted. The model with the highest pseudo R^2, and lowest Mean SE was retained. In addition to the pseudo R^2 and Mean SE, a stepwise Akaike Information Criteria (AIC) was also used to select the most parsimonious model. Some variables were retained in the final model regardless of the level of significance due to their importance in the conceptual model. Design based analysis was carried out by specifying in the program that the data were survey data from a complex sampling framework, thus accounting for the hierarchical nature of the data as children were nested within households and households were nested within clusters/PSUs.

To assess the collinearity among the predictor variables the Variance Inflation Factor analysis (VIF) was carried out. Sets of variables that were not significantly associated with the outcome variable in the multivariate analysis but were highly significant in the bivariate analysis as indicated by the F-statistic were checked for collinearity. The VIF command in STATA is only applicable after linear regression. To overcome this limitation the model with the predictor variables was fit using an alternate outcome (age of mother as a continuous variable) and followed by the VIF command. The highly collinear predictor variables were identified and the necessary correction was done.

Predictors of an immunization card retention

We analyzed the data from the Pakistan demographic and health surveys 1990 and 2006 for children between the ages of one year and five years. The information on having an immunization card was available for 4670 and 6371 children from the PDHS 1990 and 2006 surveys respectively. The information was available for three variables, including when the mothers were asked if the child had an immunization card, when the information on receipt of DTP1 vaccine was recorded and when the information on receipt of DTP3 vaccine was recorded. The primary variable of interest was if the respondents provided information on receipt of vaccine by presenting the card or the respondent reported that the child received the vaccine in the absence of the card. Using descriptive statistics while adjusting for the survey design, we compared the information on basic socio-economic variables with the reporting/presence of an immunization card. For the analysis of determining the factors associated with retaining a card, the outcome was defined as a binary variable. Those cases that reported no vaccination were excluded from the analysis. We looked at the independent effect of socio-economic variables on the immunization card retention/versus mother's report only using logistic regression analysis. The analysis was performed only for the 2006 data. We performed adjusted multivariate analysis for variables that showed a statistically significant independent effect on immunization card retention. Odds ratios

and their respective confidence intervals were calculated to assess the effects of various variables on immunization card retention. We used chi-square as a test of significance for categorical variables and means for continuous variables.

Human subjects issues

The PDHS data are publicly available and the identity of individuals cannot be traced. Therefore an exemption was obtained from the Johns Hopkins Institutional Review Board for ethical approval of Human Subjects Research (HSR). The institutional exemption letter was granted on April 15, 2011 and is attached in the appendices.

Table 8: Definition of Outcome Variables used for analysis

Variable	Definition	Population Base	Numerator	Denominator	Calculation
DTP 1 completion	Children 12-23 months of age who received the first dose of Diphtheria, Pertussis and Tetanus vaccine dose	Children up to five years of age born to mother who slept in the household the night before the interview	Children ages 12-23 months who received DTP1	All children ages 12-23 months	DTP1 completion rate: (numerator/denominator)* 100
DTP 3 completion	Children 12-23 months of age who received the third dose of Diphtheria, Pertussis and Tetanus vaccine dose	Children up to five years of age born to mother who slept in the household the night before the interview	Children ages 12-23 month who received DTP3	All children ages 12-23 months	DTP3 completion rate: (numerator/denominator)* 100
Child UTD	Children 36-52 weeks of age who have received one dose of BCG and Measles vaccine and three doses of DTP and Polio vaccine	Children up to five years of age born to mother who slept in the household the night before the interview	Children ages 36-52 weeks who received single dose of BCG and Measles vaccine and three doses of DTP and Polio vaccine	All children ages 36-52 weeks	UTD rate: (numerator/denominator)* 100

Variable	Definition	Population Base	Numerator	Denominator	Calculation
No vaccine At the time of interview	Children 12-23 months of age who have not received any vaccine dose at the time	Children up to five years of age born to mother who slept in the household the night before the interview	Children ages 12-23 months received no vaccination	All children ages 12-23 months	No Vaccination: (numerator/denominator)* 100

Chapter 4: Results

Specific aim 1

Assess individual and contextual determinants of vaccination initiation, defined as receiving DTP1 vaccine, among children 12-23 months of age in 1990 and 2006 in Pakistan.

Vaccination initiation

Descriptive analysis

PDHS 2006-07

According to our set criterion 23% of the children 12-23 months of age did not initiate the vaccination schedule and missed receiving the DTP1 vaccine. The province of Punjab, being the most densely populated and having the largest population in the country, represented 56.8% of the sample size and 69% of the total sample was residing in rural areas. The province of Balochistan represents 6% of the total population of Pakistan and 4.04% of our sample size. The various wealth quintiles were almost equally represented in the sample. Only a small proportion of the households (7.3%) had a female as a head of household, whereas the remainders of the household heads were men. It was alarming to see that 63.38% of the mothers had no education, 15% had up to the primary level and 15.57% had secondary education. Only 6.01% of the mothers had education above the secondary level and higher. As the age of marriage has increased in Pakistan, only a small proportion of mothers (3.87%) were in the age group of 15-19 years old whereas half of the mothers were in the age group of 20-29 years. The dilemma of the missing girl child is also observed in Pakistan as 52.79% of the sample was male and 47.21% were female children. A quarter of the children, 24.88%, were never issued a health/immunization card and only 23.74% of the mothers were able to produce the card at the time of the interview (Table 9).

Characteristics of children who did and did not initiate the vaccine schedule: The highest percentage of children (37.18%) who did not initiate the vaccination schedule were from the province of Baluchistan. The percentage of children who did not receive any DTP1 vaccine was

similar in the provinces of Sindh and Khyber Pakhtunkhwa at 30.33% and 29.15% respectively. The best performing province in terms of children initiating the DTP schedule was Punjab, as 82.03% received the DTP1. Among children who were never issued a health/immunization card 76.27% never received the DTP1 vaccine, and among those for whom a card was seen at the time of the interview 97.74% had initiated the DTP vaccine schedule. The children in the poorest wealth quintile fared worst as nearly half, 45.78%, never initiated the DTP vaccine schedule. A similar discrepancy was seen among mothers with no education as 32.2% of children whose mothers had no education were never vaccinated with DTP1. Children belonging to the youngest (35.2%) and oldest mothers (42.93%) were more likely than the children of mothers in other age groups not to initiate the DTP vaccination schedule. It was observed that households headed by a female had a higher percentage of children vaccinated for DTP1 at 86.1%, compared to households headed by a male family member at 75.91%.

PDHS 1990-91:

Sample characteristics: In exploratory analysis of the data of the first Pakistan DHS survey it was observed that among children 12-23 months of age, 36.58% did not initiate the DTP vaccination schedule (Table 10). A much larger proportion of the sample was selected from the province of Punjab (63.88%) as it was the most highly populated province in the country and had a better infrastructure to reach the population. The national rural urban divide of 70/30% was also observed in the sample as 69.32% and 30.68% was from the rural and urban areas respectively. The remaining three provinces of Sindh, Khyber Paktunkhwa and Baluchistan were represented in the sample at 19.9%, 12.84% and 3.37% respectively. In our sample 34.29% of the children were never issued a health/immunization card and only 27.43% of the mothers were able to produce the card at the time of the interview.

The various wealth quintiles were almost equally represented in the sample. A much smaller proportion of the households (4.19% %) were headed by a female and 95.81% were headed by a

male family member. Mothers with no education constituted 76.83% of the sample mothers, 10.46% had up to the primary level, and 11.82% had secondary education, while merely 0.89% of the mothers in the sample had higher education. Adolescent mothers in the age group of 15-19 years constituted only 4.96% of the sample and the majority of the mothers were in the age group of 20-29 years. The sample contained an equal proportion of male and female children at 49.51% and 50.49% respectively.

Characteristics of children who did and did not initiate the vaccine schedule: An alarming 61.01% of the children in the province of Baluchistan did not initiate the DTP vaccination schedule and the percentage of children who did not receive any DTP1 vaccine in the provinces of Sindh and KPT were at 44.28% and 37.58% respectively (see Table 11). The province of Punjab fared well as 66.84% of the children initiated the DTP schedule. Among children who were never issued a health/immunization card 93.06% never received DTP1 vaccine and among those for whom a card was seen at the time of the interview 97.14% had initiated the DTP vaccine schedule. The children in the poorest wealth quintile fared worst as more than half, 61.83%, never initiated the DTP vaccine schedule. As social inequity, illiteracy and poverty occur side by side, 43.83% of mothers with no education never initiated the DTP1 schedule for their children. Children belonging to the youngest mothers (47.72%) and children belonging to the oldest mothers (53.16%) were more likely than the children of mothers in other age groups to have never been vaccinated with the DTP1 vaccine. The households headed by a female and those headed by a male family member had a similar proportion of children vaccinated for DTP1 at 70.44% and 62.78% respectively.

Unadjusted analysis: vaccination initiation

PDHS 2006

The binary outcome for immunization initiation was defined as children receiving the DTP1 vaccine, coded as 0 for “did not receive DTP1” and 1 for “received DTP1.” Using logistic

regression analysis, the binary outcome for immunization initiation was regressed separately against each of the contextual and individual level variables (see Table 12).

The first contextual level variable was province of residence, coded as Punjab, Sindh, Khyber Paktunkhwa (KPT) and Baluchistan. Assessing the factors associated with vaccination initiation, the unadjusted analysis for the 2006 data showed that children in the province of Sindh (OR 0.5; 95% CI 0.34—0.74) and KPT OR 0.53; 95% CI 0.33—0.86) were half as likely as children in Punjab province to receive DTP1. The children in the province of Baluchistan fared the worse in the country regarding the vaccination initiation (OR 0.37; 95% CI 0.23—0.6). The second contextual level variable, "place of residence" was coded as 0 for Urban and 1 for rural. It was also statistically significant and children in the rural areas were less likely than children in urban areas to initiate vaccination (OR 0.4; 95% CI 0.29—0.58).

The variable "having health card" was coded with "no card" as 0, "yes seen" as 1, "yes, but not seen" as 2 and "no longer has card" as 3. Compared to children who were never issued an immunization/health card (acting as the reference category), children who were issued a card and it was seen at the time of the interview were very likely to initiate the immunization schedule (OR 139.25; 95% CI 68.2—284.31). Even if the mothers were not able to produce the health card at the time of the interview, their children did significantly better than children with no card at all (OR 49.6; 95% CI 28.93—85.02). Even the point estimate and 95% CI for children who no longer had a card (as the immunization schedule lasts until 9 months of age) was better compared to children who were never issued a card (OR 28.55; 95% 15.31—53.23).

For the individual level variable "household wealth" the reference category was the Poorest and compared to them children in the "poor" category did not do much differently, (OR 2.03; 95% CI 1.32—3.12); the children in the "middle" category did comparatively better (OR 3.93; 95% CI 2.35—6.58) than the poorest children. The children in the "rich" (OR 6.34; 95% CI 3.64—11.02),

and “richest” (OR 7.89; 95% CI 4.27—14.58) quintiles had much better comparable odds of initiating vaccination compared to the poorest children.

In the unadjusted analysis mother’s education was coded with “No education” as 0 which was the reference category. The other categories were coded “primary” as 1, “secondary” as 2 and “higher” as 3. Compared to children belonging to mothers with no education the odds of children initiating vaccination for mothers with primary education was 3 times higher (OR 2.9; 95 CI 1.74—4.81). As the education level of the mothers increased to secondary level the odds doubled (OR 7.5; 95% CI 3.78—14.9) and the odds of children initiating vaccination for children whose mothers had higher education was 11 times that of children whose mothers had no education (OR 11.04; 95 CI 2.24—54.55). Sex of the child was a significant determinant of initiating vaccination (ref male, OR 0.72; 95% CI 0.53—0.98); the “birth order” of a child, which was a continuous variable showed that children with higher birth order had a lower odds of vaccination initiation or a delay in vaccination initiation (OR 0.88; 95%CI 0.83—0.94).

PDHS 1990

The binary outcome for vaccination initiation was regressed against the contextual and individual level variables using binary logistic regression. In 1990-91 the children in the province of Balochistan were less likely to receive DTP1 compared to children in the province of Punjab (OR 0.32; 95% CI 0.18-0.56). Similarly children in the provinces of Sindh (OR 0.62; 95%CI 0.42-0.91) and KPT (OR 0.82; 95%CI 0.53-1.27) were also less likely to receive DTP1 but the results were statistically significant only in Sindh . Children in the rural areas were less likely to initiate immunization compared to children in the urban areas (OR 0.29; 95% CI 0.19-0.43) (See Table 13).

A child who had been issued a health/immunization card was very likely to initiate the vaccination schedule. Compared to children who were never issued a health/immunization card

(reference category), children for whom the card was seen at the time of the interview had odds that were staggeringly higher (OR 455.53, 95% CI 135.59-1530.46). The odds for children who were issued a card but mothers were unable to produce it at the time of the interview were still high (OR 142.14; 95% CI 64.16-314.91), and for children who no longer had the card the odds were still significant (OR 61.60; 95% CI 15.69-241.87) compared to children who were never issued a card.

Household wealth was also a significant determinant of children initiating the vaccination schedule in 1990-91 but the findings were statistically significant for higher wealth quintiles compared to households in the poorest quintile (reference category). For households in the "poor" (OR 2.23; 95%CI 1.16-4.15) and middle category (OR 2.23; 95%CI 1.23-4.10) the odds of immunization initiation were higher than children in the poorest wealth quintile. The households in the "rich" quintile (OR 3.63; 95% CI 1.93-6.81) and richest quintile (OR 12.75; 95% CI 6.79-25.05) had considerably higher odds of initiating immunization for children (Table 13).

Among the individual level variables mother's education was statistically significant for all categories; children whose mothers had secondary and higher education were 5 times (OR 5.22; 95% CI 2.60-10.51) more likely to initiate vaccination compared to children belonging to mothers with no education (No education was the reference category). Children belonging to mothers with primary education had four times the odds of vaccination initiation (OR 4.27; 95% CI 2.31-7.89) compared to mothers with no education. Among the individual variables sex of household head, mother's age, sex of child, birth order of child (measured as a continuous variable), were not statistically significant. At a p-value of 0.03, the number of children under-five years old was a significant predictor (Table 13).

Adjusted analysis: vaccination initiation

PDHS 2006

A binary logistic regression model was run with all the variables in the model and the only statistically significant variable was household wealth. As a high correlation of having a health card with vaccination initiation was observed, this variable was not selected for inclusion into the adjusted analysis. During model selection it was observed that mothers with no education did not behave differently from mothers with up to primary education, therefore the two categories were merged. Similarly households in the poorest wealth quintile did not differ from households in the poor wealth quintile; therefore the two categories were merged. This resulted in both the variables being statistically significant. Two variables--household wealth index and maternal education--were seen as the two main determinants of vaccination initiation in the final model (Tables 14-16).

PDHS 1990

For further analysis only the variables that were observed to be statistically significant during the univariate analysis were selected for the adjusted model. In the adjusted model province of residence was statistically significant for the province of Sindh (Punjab ref, Sindh OR 0.45, 95% CI 0.30-0.66). Children in Baluchistan were also less likely to initiate vaccination compared to children in Punjab and the results were statistically significant at 0.01 (OR 0.38; 95% CI 0.20-0.74). The individual level variable household wealth was statistically significant for households in all wealth quintiles compared to the poorest category (Poorest ref., Poor OR 2.00; 95% CI 1.05-3.80, Middle OR 2.11; 95% CI 1.09-4.10, Rich OR 3.09; 95% CI 1.63-5.86, Richest OR 10.55; 95% CI 5.17-21.51). Among the individual level variables maternal education was a statistically significant predictor of vaccination initiation but the results were statically significant only for the category "primary education" (No Education ref., Primary OR 2.77; 95% CI 1.50—5.13 and Secondary and Higher OR 1.78; 95%CI 0.78—4.05, p-value 0.17). (Table 17)

Table 9 Characteristics of Children 12 to 23 months of Age in the Pakistan Demographic and Health Survey (PDHS) 2006

	Proportion	SE	95% Confidence Interval		Sample size
Received DTP1					
No	0.23	0.01	0.20	0.26	
Yes	0.77	0.01	0.74	0.80	1493
Province					
Punjab	0.57	0.01	0.54	0.59	1692
Sindh	0.25	0.01	0.23	0.27	
Kyber Patunkhwa	0.14	0.01	0.13	0.16	
Balochistan	0.04	0.00	0.03	0.05	
Area of residence					
urban	0.31	0.01	0.29	0.33	
rural	0.69	0.01	0.67	0.71	
Wealth Index					1692
Poorest	0.22	0.01	0.19	0.25	
Poorer	0.22	0.01	0.19	0.24	
Middle	0.19	0.01	0.17	0.21	
Richer	0.19	0.01	0.17	0.22	
Richest	0.18	0.01	0.15	0.20	
Household Head					1692
male	0.93	0.01	0.91	0.95	
female	0.07	0.01	0.05	0.09	
Mother's Education					1692
No Education	0.63	0.02	0.60	0.67	
Primary	0.15	0.01	0.13	0.17	
Secondary	0.16	0.01	0.13	0.18	
Higher	0.06	0.01	0.05	0.08	
Mother's Age					1692
15-19	3.87	0.01	0.03	0.05	
20-24	0.25	0.01	0.22	0.28	
25-29	0.29	0.01	0.26	0.31	
30-34	0.25	0.01	0.22	0.28	
35-39	0.12	0.01	0.10	0.14	
40-44	0.04	0.01	0.02	0.05	
45-49	0.02	0.01	0.01	0.03	
Sex of Child					1692
Male	0.53	0.02	0.50	0.56	
Female	0.47	0.02	0.44	0.50	

Table 9 (contd.): Characteristics of Children 12 to 23 months of Age in the Pakistan Demographic and Health Survey (PDHS) 2006

	Proportion	SE	95% Confidence Interval		Sample size
Health Card					1541
No card	0.25	0.02	0.22	0.28	
Yes, seen	0.24	0.02	0.21	0.27	
Yes, not seen	0.39	0.02	0.35	0.42	
No longer has card	0.12	0.01	0.10	0.14	
Missing	0.00	0.00	0.00	0.00	
Number of Children <5 years in the household					1692
Mean	2.34	0.05	2.24	2.45	

Table 10 Characteristics of Children 12 to 23 Months of Age in the Pakistan Demographic and Health Survey (PDHS) 1990

	Proportion	SD	95% Confidence Interval	
Received DTP1				
No	36.58	0.02	32.73	40.41
Yes	62.56	0.02	58.60	66.51
Province				
Punjab	63.88	0.18	60.28	67.49
Sindh	19.9	0.01	17.30	22.52
Khyber Pakhtunkhwa	12.84	0.01	10.65	15.02
Balochistan	3.37	0.01	1.93	4.82
Area of residence				
Urban	30.68	0.02	27.39	33.96
Rural	69.32	0.02	66.04	72.61
Wealth Index				0.00
Poorest	16.85	0.02	12.40	21.30
Poor	23.36	0.02	19.31	27.41
Middle	18.79	0.02	15.67	21.91
Rich	21.59	0.02	17.49	25.67
Richest	19.41	0.02	16.45	22.35
Household Head				
Male	95.81	0.01	93.91	97.71
Female	4.19	0.01	2.29	6.09
Mother's Education				
No Education	76.83	0.02	73.33	80.34
Primary	10.46	0.01	8.07	12.84
Secondary	11.82	0.01	9.52	14.11
Higher	0.89	0.00	0.17	1.62

Table 10 (contd.): Characteristics of Children 12 to 23 months of Age in the Pakistan Demographic and Health Survey (PDHS) 1990

	Proportion	SD	95% Confidence Interval	
Mother's Age				
15-19	4.96	0.01	3.42	6.50
20-24	20.08	0.01	17.39	22.77
25-29	33.70	0.02	28.95	38.45
30-34	20.05	0.02	16.56	23.55
35-39	13.39	0.01	10.57	16.20
40-44	5.94	0.01	3.85	8.03
45-49	1.88	0.01	0.83	2.92
Sex of Child				
Male	49.51	0.02	45.56	53.46
Female	50.49	0.02	46.54	54.44
Health Card				
No card	34.29	0.02	30.59	37.99
Yes, seen	27.43	0.02	23.58	31.28
Yes, not seen	34.65	0.02	30.48	38.82
No longer has card	3.62	0.01	2.32	4.93

Table 11 Characteristics of Children 12 to 23 months of Age in the Pakistan Demographic and Health Survey (PDHS) 1990

	Did not Receive DTP1	Received DTP1		
	Freq. (%)	Freq. (%)	Total	p-value
Province				<0.01
Punjab	138 (33.16)	330 (66.84)	468	
Sindh	128 (44.28)	189 (55.72)	317	
Khyber Pakhtunkhwa	106 (37.58)	213 (62.42)	319	
Balochistan	98 (61.01)	76 (38.99)	174	
Area of residence				<0.001
Urban	177 (18.96)	481 (81.04)	658	
Rural	293 (44.88)	327 (55.12)	620	
Wealth Index				<0.001
Poorest	92 (61.83)	49 (38.17)		
Poor	102 (42.12)	103 (57.88)		
Middle	104 (41.98)	152 (58.02)		
Rich	112 (30.87)	212 (69.13)		
Richest	60 (11.25)	292 (88.75)		
Household Head				<0.32
Male	454 (37.22)	770 (62.78)	1224	
Female	16 (29.56)	38 (70.44)	54	
Mother's Education				
No education	423 (43.83)	531 (56.17)	954	
Primary	24 (15.45)	109 (84.55)	133	
Secondary	23 (13.98)	155 (86.02)	178	
Higher	0	13 (100)	13	
Mother's Age				<0.69
15-19	34 (47.72)	33 (52.28)	67	
20-24	99 (32.41)	185 (67.59)	284	
25-29	137 (37.23)	267 (62.77)	404	
30-34	94 (37.21)	170 (62.79)	264	
35-39	64 (35.33)	101 (64.67)	165	
40-44	30 (38.44)	40 (61.56)	70	
45-49	12 (53.16)	12 (46.84)	24	

Table 11 (continued): Characteristics of Children 12 to 23 months of Age in the Pakistan Demographic and Health Survey (PDHS) 1990

	Did not Receive DTP1	Received DTP1		
	Freq. (%)	Freq. (%)	Total	p-value
Sex of Child				0.6805
Male	226 (35.95)	399 (64.05)	625	
Female	244 (37.81)	409 (62.19)	653	
Health Card				<0.000
No card	406 (93.06)	23 (6.94)	429	
Yes, seen	9 (2.86)	349 (97.14)	358	
Yes, not seen	39 (8.6)	395 (91.14)	434	
No longer has card	6 (17.88)	40 (82.12)	46	

Table 12: Odds ratios for individual and contextual characteristics associated with the receipt of the first dose of DTP vaccine among children aged 12 to 23 months, using logistic regression analysis, Pakistan Demographic and Health Survey 2006

	Odds Ratio	p-value	95% CI for OR	
Province				
Punjab	REF			
Sindh	0.50	0.001	0.34	0.74
KPT	0.53	0.011	0.33	0.86
Balochistan	0.37	0	0.23	0.60
Area of residence				
Urban	REF			
Rural	0.41	0	0.29	0.58
Wealth Index				
Poorest	REF			
Poor	2.03	0.00	1.32	3.12
Middle	3.93	0.00	2.35	6.58
Rich	6.34	0.00	3.64	11.02
Richest	7.89	0.00	4.27	14.58
Household Head				
Male	REF			
Female	1.97	0.03	1.07	3.62
Mother's Education				
No education	REF			
Primary	2.89	0.00	1.74	4.81
Secondary	7.50	0.00	3.78	14.88
Higher	11.04	0.00	2.24	54.55
Mother's Age				
15-19	REF			
20-24	1.86	0.11	0.88	3.93
25-29	1.93	0.09	0.91	4.13
30-34	1.98	0.07	0.94	4.15
35-39	1.82	0.14	0.82	4.06
40-44	1.23	0.67	0.47	3.25
45-49	0.72	0.65	0.18	2.96
Mean Age of Mother	0.99	0.58	0.96	1.02

Table 12 (contd.) Odds ratios for individual and contextual characteristics of population associated with receipt of first dose of DTP vaccine in children aged 12 to 23months old using logistic regression analysis, Pakistan Demographic and Health Survey 2006

	Odds Ratio	p-value	95% CI for OR	
Sex of Child				
Male	REF			
Female	0.72	0.04	0.53	0.98
Health Card				
No card	REF			
Yes, seen	139.25	0.00	68.21	284.31
Yes, not seen	49.59	0.00	28.93	85.02
No longer has card	28.55	0.00	15.31	53.23
Number of Children <5 years in the Household (continuous)	1.02	0.74	0.89	1.18
Birth order of child (continuous)	0.88	0.00	0.83	0.94

Table 13: Odds ratios for individual and contextual characteristics associated with receipt of the first dose of DTP vaccine among children aged 12 to 23 months, using logistic regression analysis, Pakistan Demographic and Health Survey 1990

	Odds Ratio	p-vlaue	95% CI for OR
Province			
Punjab	REF		
Sindh	0.62	0.016	0.42 - 0.91
Khyber Pakhtunkhwa	0.82	0.385	0.53 - 1.27
Balochistan	0.32	<0.000	0.18 - 0.56
Area of residence			
Urban	REF		
Rural	0.29	<0.000	0.19 - 0.43
Wealth Index			
Poorest	REF		
Poor	2.23	0.012	1.16 - 4.15
Middle	2.23	0.009	1.23 - 4.10
Rich	3.63	<0.000	1.93 - 6.81
Richest	12.75	<0.000	6.79 - 25.05
Household Head			
Male	REF		
Female	1.412313	0.356	0.68 - 2.95
Mother's Education			
No education	REF		
Primary	4.27	<0.000	2.31 - 7.89
Secondary and Higher	5.22	<0.000	2.60 - 10.51
Mother's Age			
15-19	REF		
20-24	1.9	0.12	0.84 - 4.31
25-29	1.54	0.25	0.74 - 3.22
30-34	1.54	0.26	0.73 - 3.26
35-39	1.67	0.24	0.71 - 3.95
40-44	1.46	0.43	0.56 - 3.79
45-49	0.8	0.74	0.22 - 2.92

Table 13 (contd.): Table odds ratios for individual and contextual characteristics of population associated with the receipt of first dose of DTP vaccine in children aged 12 to 23months old using logistic regression analysis, Pakistan Demographic and Health Survey 1990

	Odds Ratio	p-value	95% CI for OR
Sex of Child			
Male	REF		
Female	0.92	0.68	0.63 - 1.35
Health Card			
No card	REF		
Yes, seen	455.53	<0.000	135.6 - 1530.5
Yes, not seen	142.14	<0.000	64.2 - 314.9
No longer has card	61.60	<0.000	15.7 - 241.9
Number of Children <5 years in the Household	1.19	0.033	1.0 - 1.4
Age of Child (months)	1.01	0.73	0.96 - 1.07
Birth order of child (continuous)	0.95	0.076	0.9 - 1.00

Table 14: Adjusted odds ratios of the full model for contextual and individual level variables associated with the receipt of the first dose of DTP vaccine among children aged 12 to 23 months, using logistic regression analysis, Pakistan Demographic and Health Survey 2006

	Odds Ratio	p-value	95% Confidence Interval	
Province				
Punjab	REF			
Sindh	0.64	0.053	0.41	1.01
KP	0.64	0.06	0.39	1.03
Balochistan	0.58	0.05	0.34	0.99
Place of Residence				
Urban	REF			
Rural	0.85	<0.45	0.55	1.30
Wealth Index				
Poorest	REF			
Poorer	1.80	<0.012	1.14	2.85
Middle	2.85	<0.000	1.66	4.88
Richer	3.34	<0.000	1.85	6.03
Richest	2.49	0.017	1.18	5.25
Household Head				
Male	REF			
Female	1.88	0.048	1.01	3.52
Mother's Education				
No Education				
Primary	1.74	0.042	1.02	2.98
Secondary	3.96	<0.000	1.90	8.25
Higher	5.69	0.035	1.13	28.71
Sex of Child				
Male	REF			
Female	0.77	<0.12	0.55	1.07
Birth Order of Child (continuous)	0.95	<0.15	0.89	1.02

Table 15: Describing the adjusted odds ratio of reduced model for contextual and individual level variables of population associated with the receipt of first dose of DTP vaccine in children aged 12 to 23months old using logistic regression analysis, Pakistan Demographic and Health Survey 2006

	Odds Ratio	p-Value	95% Confidence	
Province			Lower limit	Upper limit
Punjab	REF			
Sindh	0.65	0.06	0.41	1.01
KP	0.65	0.08	0.40	1.05
Balochistan	0.61	0.07	0.36	1.04
Place of Residence				
Urban				
Rural	0.81	0.34	0.53	1.24
Wealth Index				
Poorest				
Poorer	1.78	0.02	1.12	2.84
Middle	2.87	0.00	1.68	4.91
Rich	3.41	0.00	1.89	6.17
Richest	2.59	0.01	1.21	5.54
Household Head				
Male	REF			
Female	1.82	0.06	0.98	3.38
Mother's Education				
No Education				
Primary	1.85	0.03	1.08	3.19
Secondary	4.12	0.00	2.00	8.48
Higher	6.19	0.03	1.22	31.44

Table 16 Describing the adjusted odds ratio of final model for contextual and individual level variables of population associated with the receipt of first dose of DTP vaccine in children aged 12 to 23months old using logistic regression analysis, Pakistan Demographic and Health Survey 2006

	Odds Ratio	p-Value	95% Confidence	
Wealth Index				
Poorest	REF			
Poorer	1.86	0.01	1.20	2.90
Middle	3.22	0.00	1.92	5.40
Richer	3.94	0.00	2.28	6.80
Richest	2.96	0.00	1.49	5.89
Household Head Gender				
Male	REF			
Female	1.89	0.05	1.01	3.55
Mother's Education				
No Education	REF			
Primary	1.96	0.02	1.14	3.37
Secondary	4.46	0.00	2.16	9.24
Higher	6.58	0.02	1.28	33.85

Table 17: Adjusted odds ratios for initiation of immunization among children 12 to 23 months of age, using logistic regression analysis in the Pakistan Demographic and Health Survey 1990

	Odds Ratio	P>t	95% confidence interval for OR	
Maternal Education				
No Education	REF			
Primary Education	2.77	0.00	1.50	5.13
Secondary and Higher	1.78	0.17	0.78	4.05
Province of Residence				
Punjab	REF			
Sindh	0.45	0.00	0.30	0.66
Khyber Pakhtoonkhwa	0.87	0.54	0.56	1.35
Balochistan	0.38	0.01	0.20	0.74
Wealth Quintiles				
Poorest	REF			
Poor	2.00	0.03	1.05	3.80
Middle	2.11	0.03	1.09	4.10
Rich	3.09	0.00	1.63	5.86
Richest	10.55	0.00	5.17	21.51

Specific aim 2

Assess individual and contextual determinants of vaccination completion, defined as receiving DTP3 vaccine, among children 12-23 months of age in 1990 and 2006 in Pakistan.

Vaccination completion

Descriptive analysis

PDHS 2006

Sample characteristics: Among children who completed the DTP1 vaccine (the sample for the Specific Aim 2 analysis), 61.57% were from Punjab, 22% and 13.21% from Sindh and KPT and 3.22% of the sample was from Balochistan; this distribution is representative of the population distribution in the country. This distribution of the proportions is reflective of the percentage distribution for the overall sample. The sample distributions for place of residence, household wealth quintiles and maternal and child characteristics are also representative of the population (Table 18).

Sample characteristics for children who did and did not complete the vaccine schedule: The percentage of children who completed the DTP3 schedule in the sample is the lowest in the province of Sindh at 71.44% and the highest percentage of children who completed the vaccination schedule was observed in the province of Punjab at 80.77% (see Table 19). It is also observed that once the children initiate the vaccination schedule the completion rates are very similar among provinces. The percentage of children who completed the DTP 3 vaccine in the provinces of Baluchistan and KPT was at 77.77% and 83.49% respectively. Among children who were never issued a health/immunization card, half (55.46 %) never completed the DTP3 vaccine and among those for whom a card was seen at the time of the interview 90.74% had completed the DTP vaccine schedule. The children in the poorest wealth quintile still fared worst, as 31.66% never completed the DTP vaccine schedule. Among mothers with no education 27.18% never completed the DTP3 schedule for their children. Among the age groups of mothers with the

highest numbers of observations in our sample, the results for the 20-39 year old mothers were very similar. Children in households headed by female and male members had similar vaccination completion rates at 80.68% and 78.82%. A similar result was seen in the vaccination completion rates for male and female children which were similar at 80.1% and 77.58% (Table 19).

PDHS 1990

Sample characteristics: Among children 12-23 months of age who had initiated the DTP vaccination schedule 65.98% completed it. The sample distributions according to the province of residence, place of residence, household characteristics and maternal and child characteristics are relatively representative of what has been observed for the total 1990 sample (Table 20).

Sample characteristics for children who did and did not complete the vaccine schedule: The highest percentage of dropouts was seen in the province of Sindh, as 40% of the children did not receive the DTP3 vaccine. In the 1990-91 sample, the DTP completion rate was similar between the provinces of Punjab and Baluchistan at 66.08% and 62.68%. One of the explanations for this can be that in 1990 a majority of the sample in Balochistan was selected from urban areas and remote districts were not included in the sampling frame. The observations from Baluchistan were mostly from urban areas where access is not an issue. The percentage of children who did not receive DTP3 vaccine in the province of KPT was 25.72%. Among children who were never issued a health/immunization card only 33.31% completed the schedule, but due to a very small number of observations, 5 in total, we cannot make a reliable estimate. Among children for whom a card was seen at the time of the interview 84.64% had completed the DTP vaccine schedule. The distributions of children in the five wealth quintiles were comparable, suggesting that once parents initiate the immunization schedule they are more likely to continue and complete it. Children belonging to the youngest mothers had the lowest completion of DTP3 but the proportion of children completing the schedule was similar for the all other age categories. In

1990-91, households headed by a female had a higher proportion of children completing the schedule at 86.35 compared to those headed by a male at 64.98% (Table 21).

Unadjusted analysis: vaccination completion

PDHS 2006

The binary outcome variable for vaccination completion was coded as 0 for children who "did not receive DTP3" vaccine and as 1 for children who "received DTP3" vaccine. Binary logistic regression analysis was run separately for each of the individual and contextual level predictor variables against the outcome.

Among the contextual level variables, province of residence was statistically significant only for the province of Sindh (OR 0.60; 95% CI 0.40—0.88) with Punjab as the reference. The odds of a child completing the third dose of DTP vaccine in Baluchistan (OR 0.83; 95% CI 0.41—1.68) and Khyber Pakhtunkhwa (OR 1.20; 95% CI 0.71—2.04) were not much different than children in the province of Punjab and the results were also statistically insignificant. Children in the rural areas compared to children in urban areas were less likely to complete DTP 3 vaccinations (OR 0.70; 95% CI 0.47—1.06) but the results were not statistically significant, suggesting that this is not a significant determinant in Pakistan (Table 22).

Completing the DTP3 vaccine dose and having a health card was statistically significant for all categories of the variable. With reference to children having "no card," children who had a card and it was seen at the time of the interview were 12 times more likely to complete the DTP3 vaccine (OR 12.20; 95% CI 5.41—27.52); children who had a card but the mothers were unable to show it at the time of the interview were 4 times (OR 4.53; 95% CI 2.29—8.97) as likely to complete DTP3. Even children who no longer had the card were 3 times as likely as children with no card (OR 3.40; 95% CI 1.51—7.66) to complete the DTP3 vaccination (Table 22).

Logistic regression results for household wealth was statistically significant only for households in the higher two quintiles of wealth for the "rich" (OR 2.57; 95% CI 1.36—4.86) and "richest" (OR 3.57; 95% CI 1.93—6.59). Compared to children in the poorest wealth quintile, children in the poor (OR 1.08; 95% CI 0.61—1.91) and middle (OR 1.71; 95% CI 0.96—3.05) quintiles did not fare very differently (Table 22).

Maternal education was a significant predictor of DTP3 vaccination completion only for children with mothers who had education above primary level: for mothers with secondary education the odds were 3 times (OR 3.32; 95% CI 1.78—6.22) and for mothers with higher education the odds were four times higher (OR 4.67; 95% CI 2.70—8.08). The logistic regression results for mothers with up to primary education (OR 1.43; 95% CI 0.84—2.45) compared to mothers with no education were not statistically significant. Other individual level variables like sex of household head, mother's age, sex of the child, age of child and birth order of the child were not statistically significant (Table 22). Age of child (in months) and birth order of the child were coded as continuous variables.

PDHS 1990

We looked at the factors that are associated with vaccination schedule completion in the same way as we did for PDHS 2006 (see Table 23). Among the contextual variables, overall province of residence was not statistically associated with vaccination completion. However, for a child who resided in the province of Sindh, the odds of completion of the vaccination schedule were lower compared to being a resident of the province of Punjab (OR: 0.6; 95% CI 0.37 – 0.96). There was no statistical difference for residence in Khyber Pakhtunkhwa (OR: 1.34; 95% CI 0.65 – 2.73) or Baluchistan (OR: 0.92; 95% CI 0.18 – 4.68) for vaccination schedule completion compared to the province of Punjab. Children in rural areas had higher odds of completing the vaccination schedule compared to children in urban areas, although the association was not statistically significant (OR: 1.37; 95% CI 0.75 – 2.49). The only other contextual level variable

significantly associated with vaccination completion was having a health/immunization card that was seen at the time of the interview.

A similar increasing trend for the wealth index being a predictor of vaccination schedule completion was found, wherein those in the higher income quintile had higher odds of completing the vaccination schedule compared to the poorest wealth quintile, although the associations were not statistically significant (Poor=OR: 0.70; 95% CI 0.30 – 1.62, Middle=OR: 1.05; 95% CI 0.47 – 2.35, Rich=OR: 2.03; 95% CI 0.93 – 4.46, Richest= OR: 2.34; 95% CI 0.98 – 5.56). Although statistically insignificant, sex of the household head was associated with vaccination schedule completion. The children from households headed by women were more likely to complete the vaccination schedule compared to the children from households headed by a male (OR=3.11; 95% CI 0.8 – 12.0). Educational level of the mother was assessed as well for its association with vaccination schedule completion. We did not find any statistically significant association of mother's education with vaccination schedule completion (Primary= OR: 0.82; 95% CI 0.44 – 1.53, secondary=OR: 1.12; 95% CI 0.62 – 2.02, Higher than secondary=OR: 0.76; 95% CI 0.11 – 5.41). Being a female child did not have a statistically significant association with vaccination schedule completion compared to being a male child (OR=0.84; 95% CI 0.55 – 1.29). Similarly birth order of the child also did not have an association with completion of the vaccination schedule of the child (OR=1.12; 95% CI 0.99 – 1.26) (Table 23).

The number of women with education higher than secondary was very small so we merged the two categories secondary and higher to see if there was a change in the association. Again there was not a wide difference in the vaccination completion rates between children belonging to mothers with no education compared to children whose mothers had up to primary education (OR 0.83; 95% CI 0.46—1.50) and the children belonging to mothers with secondary and higher education (OR 1.36; 95% CI 0.84—2.20), but the results for both the groups was statistically insignificant. Children belonging to older mothers, 25-35 years, (OR 1.95; 95% CI 1.16—3.29)

and above 35 year of age (OR 3.01; 95% CI 1.51—6.00) had higher odds of completing the vaccination schedule compared to children belonging to mothers less than 25 year of age and the results for both the groups were statistically significant. Among the individual level variables, sex of child and birth order of the child was not statistically significant (Table 23).

Adjusted analysis: Vaccination completion

PDHS 2006

In the full binary logistic regression model, only having a vaccination card was statistically significant among the contextual level characteristics. Children having an immunization card (confirmed by data collectors) had more than ten times higher odds of vaccination schedule completion compared to those without a card. Children who had a card but the mothers were not able to show it at the time of the interview and gave a verbal history of vaccination were approximately four times more likely to complete the vaccination schedule of their children compared to those who were not issued an immunization card ("yes, seen" OR 10.6; 95% CI 4.62—24.39, "yes, card not seen" OR 3.88; 95% CI 1.94 - 7.74 and "no longer has card" OR 3.14; 95% CI 1.36 – 7.23). Among the individual level characteristics only mothers' education was statistically significant in the full model. For mothers with secondary education, the odds of their children completing the DPT3 vaccination were two times higher and for mothers with higher than secondary education the odds of their children completing the DPT3 vaccination were almost four times higher compared to mothers with no education ("Secondary" OR 2.74; 95% CI 1.51 – 4.97 and "Higher" OR 3.7; 95% CI 2.07 – 6.59). In the final model the only two statistically significant variables were mother's education and child having a health card. After recoding into a categorical variable, mothers' age also had a significant effect on vaccination completion. With ten years increase in maternal age, the likelihood of immunization completion increased by forty percent (Table 24).

PDHS 1990

In the adjusted model all the contextual and individual level variables were included for analysis in the full model and none of them were statistically significant. In the second model the five categories of household wealth were re-coded into two. The first category included households in the poorest, poor and middle quintile and the second category included households in the rich and richest quintile. The individual level variable mothers age was also recoded into three categories of less than 25, 25-<35 and greater than or equal to 35 years of age. The sex of the household head and sex of child were also included in the second model. Households in the rich or richest wealth quintiles had higher odds of vaccination completion compared to middle or lower wealth quintiles (OR 1.82; 95% CI: 1.24 – 2.68). Sex of head of the household had no effect on vaccination completion of the child whereas mothers' age was statistically significantly associated with vaccination completion. Mothers in the age category of 25 to less than 35 were more likely to have their child's vaccination completed compared to those younger than 25 years of age (OR: 1.9; 95% CI: 1.13 – 3.19). Mothers' who were 35 years or older were also more likely to complete the vaccination schedule of their child compared to those mothers who were twenty-five years of age or younger (OR: 3.3; 95% CI: 1.63 – 6.66) (Table 25).

Table 18: Sample characteristics of those who received the first dose of DTP vaccine among children 12 to 23 months of age in the Pakistan Demographic and Health Survey (PDHS) 2006

	Proportion	95% Confidence Interval		Sample size
Province				1109
Punjab	61.57	58.72	64.43	
Sindh	22.00	19.32	24.68	
Khyber Pakhtunkhwa	13.21	11.53	14.89	
Balochistan	3.22	2.49	3.94	
Area of residence				1109
Urban	35.57	32.48	38.65	
Rural	64.43	61.35	67.52	
Wealth Index				1109
Poorest	14.52	11.98	17.07	
Poorer	20.02	16.78	23.26	
Middle	20.57	17.45	23.68	
Richer	23.28	19.82	26.74	
Richest	21.61	17.80	25.42	
Household Head				
Male	91.48	88.67	94.29	1109
Female	8.52	5.71	11.33	
Mother's Education				1109
No Education	54.72	50.89	58.56	
Primary	16.99	13.78	20.21	
Secondary	20.24	16.42	24.06	
Higher	8.04	5.82	10.27	
Mother's Age				1109
15-19	3.10	1.76	4.45	
20-24	25.59	22.06	29.13	
25-29	28.91	25.51	32.30	
30-34	25.47	21.66	29.28	
35-39	12.32	9.99	14.65	
40-44	3.29	1.79	4.78	
45-49	1.32	0.23	2.41	

Table 18 (continued): Sample characteristics of those who received the first dose of DTP vaccine among children 12 to 23 months of age in the Pakistan Demographic and Health Survey (PDHS) 2006

	Proportion	95% Confidence Interval		Sample size
Sex of Child				1109
Male	55.38	51.33	59.43	
Female	44.62	40.57	48.67	
Health Card				1109
No card	7.70	5.64	9.77	
Yes, seen	31.08	26.83	35.33	
Yes, not seen	46.94	42.46	51.42	
No longer has card	14.28	11.49	17.07	

Table 19: Characteristics of children who received and did not receive the third dose of DTP vaccine among children 12 to 23 months of age who received the first dose of DTP vaccine in the Pakistan Demographic and Health Survey (PDHS) 2006

	Did not Receive DTP3	Received DTP3	Total	Sample size	p-value
	Freq. (%)	Freq. (%)	Freq		
Province				1104	0.0392
Punjab	94 (19.23)	410 (80.77)	504		
Sindh	84 (28.56)	208 (71.44)	292		
Khyber Pakhtunkhwa	36 (16.51)	182 (83.49)	218		
Balochistan	18 (22.23)	72 (77.77)	90		
Area of residence				1109	0.0713
Urban	82 (17.4)	367 (82.6)			
Rural	150 (23.01)	505 (76.99)			
Wealth Index				1104	0.0001
Poorest	51 (31.66)	117 (68.34)	168		
Poorer	63 (30.02)	157 (69.98)	220		
Middle	46 (21.33)	186 (78.67)	232		
Richer	41 (15.28)	207 (84.72)	248		
Richest	31 (11.49)	205 (88.51)	236		
Household Head				1104	0.7365
Male	217 (21.18)	807 (78.82)	1024		
Female	15 (19.32)	65 (80.68)	80		
Mother's Education				1104	0
No education	162 (27.18)	461 (72.82)			
Primary	37 (20.66)	142 (79.32)			
Secondary	23 (10.1)	190 (89.9)			
Higher	10 (7.4)	79 (92.6)			
Mother's Age				1104	0.4511
15-19	8 (26.73)	32 (73.27)	40		
20-24	71 (26.59)	216 (73.41)	287		
25-29	64 (18.78)	266 (81.22)	330		
30-34	53 (19.49)	204 (80.51)	257		
35-39	25 (16.18)	117 (83.82)	142		
40-44	9 (24.65)	23 (75.35)	32		
45-49	2 (13.09)	14 (86.91)	16		

Table 19 (contd.): Characteristics of children who received and did not receive the third dose of DTP vaccine among children 12 to 23 months of age who received the first dose of DTP vaccine in the Pakistan Demographic and Health Survey (PDHS) 2006

	Did not Receive DTP3	Received DTP3	Total	Sample size	p-value
	Freq. (%)	Freq. (%)	Freq		
Sex of Child				1104	<0.4426
Male	130 (19.9)	483 (80.1)			
Female	102 (22.42)	389 (77.58)			
Health Card				1109	<0.000
No card	47 (55.46)	37 (44.54)	84		
Yes, seen	36 (9.26)	315 (90.74)	351		
Yes, not seen	110 (21.57)	403 (78.43)	513		
No longer has card	39 (26.79)	117 (73.21)	156		
Children <5 years in the household					
Mean number of children		2.56			

Table 20: Characteristics of children 12 to 23 months age who received the Third Dose of DTP vaccine in the Pakistan Demographic and Health Survey (PDHS) 1990

	Proportion	95% Confidence Interval	
Received DTP3			
No	34.02	28.78	39.25
Yes	65.98	60.75	71.22
Area of residence			
Urban	39.56	35.30	43.82
Rural	60.44	56.18	64.70
Household Head			
Male	95.29	92.98	97.59
Female	4.71	2.41	7.02
Province			
Punjab	67.51	63.55	71.47
Sindh	17.65	14.55	20.75
Khyber Pakhtunkhwa	12.75	10.35	15.14
Balochistan	2.09	1.06	3.13
Wealth Index			
Poorest	9.89	5.90	13.90
Poor	21.45	14.50	28.40
Middle	17.55	13.70	21.40
Rich	23.51	17.40	29.70
Richest	27.59	22.80	32.30
Mother's Education			
No Education	68.24	63.22	73.27
Primary	14.08	10.70	17.46
Secondary	16.25	12.82	19.67
Higher	14.3	0.41	2.45
Mother's Age			
15-19	4.05	2.11	5.99
20-24	21.37	17.59	25.15
25-29	33.45	27.38	39.52
30-34	20.08	15.54	24.62
35-39	13.8	9.95	17.65
40-44	5.85	3.18	8.51
45-49	1.4	0.12	2.69

Table 20 (continued): Characteristics of children 12 to 23 months age who received the Third Dose of DTP vaccine in the Pakistan Demographic and Health Survey (PDHS) 1990

	Proportion		95% Confidence Interval	
Sex of Child				
Male	50.11	0.03	44.97	55.26
Female	49.88	0.03	44.74	55.03
Health Card				
No card	37.66	0.01	1.02	6.52
Yes, seen	42.31	0.03	36.32	48.30
Yes, not seen	49.48	0.03	43.27	55.68
No longer has card	4.45	0.01	2.43	6.47
Number of children < 5 years in the household (mean)	2.24	0.06	2.11	2.36

Table 21: Characteristics of children who received and did not receive the third dose of DTP vaccine among children 12 to 23 months of age who received the first dose of DTP vaccine in the Pakistan Demographic and Health Survey (PDHS) 1990

	Did not Receive DTP3	Received DTP3	Total
	Freq. (%)	Freq. (%)	Freq
Province			
Punjab	100 (33.92)	220 (66.08)	320
Sindh	73 (40.02)	103 (59.98)	176
Khyber Pakhtunkhwa	51 (25.72)	152 (74.28)	203
Balochistan	23 (37.32)	48 (62.68)	71
Area of residence			
Urban	141 (35.5)	319 (68.24)	460
Rural	106 (34.02)	204 (64.5)	310
Wealth Index			
Poorest	21 (37.29)	24 (62.71)	45
Poor	38 (45.04)	58 (54.96)	96
Middle	57 (36.62)	89 (63.38)	146
Rich	59 (26.86)	143 (73.14)	202
Richest	72 (28.72)	209 (71.28)	281
Household Head			
Male	241 (35.02)	493 (64.98)	734
Female	6 (13.65)	30 (86.35)	36
Mother's Education			
No education	172 (34.57)	336 (65.43)	508
Primary	33 (38.82)	70 (61.18)	103
Secondary	39 (37.64)	108 (72.84)	147
Higher	3 (34.02)	9 (62.36)	12
Mother's Age			
15-19	13 (53.47)	18 (46.53)	31
20-24	68 (46.47)	112 (53.53)	180
25-29	81 (33.11)	175 (66.89)	256
30-34	50 (29.33)	109 (70.67)	159
35-39	20 (19.06)	75 (80.94)	95
40-44	10 (31.26)	27 (68.74)	37
45-49	5 (30.2)	7 (69.8)	12

Table 21 (contd.): Characteristics of children who received and did not receive the third dose of DTP vaccine among children 12 to 23 months of age who received the first dose of DTP vaccine in the Pakistan Demographic and Health Survey (PDHS) 1990

	Did not Receive DTP3	Received DTP3	Total
Sex of Child			
Male	112 (32.78)	271 (67.22)	383
Female	135 (35.26)	252 (64.74)	387
Health Card			
No card	13 (66.69)	5 (33.31)	18
Yes, seen	45 (15.36)	304 (84.64)	349
Yes, not seen	164 (45.96)	199 (54.04)	363
No longer has card	25 (69.86)	14 (30.14)	39
Number of children< 5 years in the household (mean)	2.18	2.27	

Table 22: Unadjusted odds ratios using logistic regression analysis for individual and contextual characteristics associated with receipt of the third dose of DTP vaccine among children aged 12 to 23 months who received the first dose of DTP vaccine, Pakistan Demographic and Health Survey 2006

	Odds Ratio	p-value	95% CI for OR	
Province				
Punjab	REF.			
Sindh	0.60	0.01	0.40	0.88
Khyber Pakhtunkhwa	1.20	0.49	0.71	2.04
Balochistan	0.83	0.61	0.41	1.68
Area of residence				
Urban	REF.			
Rural	0.70	0.09	0.47	1.06
Wealth Index				
Poorest	REF.			
Poorer	1.08	0.79	0.61	1.91
Middle	1.71	0.07	0.96	3.05
Rich	2.57	0.00	1.36	4.86
Richest	3.57	0.00	1.93	6.59
Household Head				
Male	REF.			
Female	1.12	0.74	0.57	2.20
Mother's Education				
No education	REF.			
Primary	1.43	0.19	0.84	2.45
Secondary	3.32	0.00	1.78	6.22
Higher	4.67	0.00	2.70	8.08
Mother's Age				
15-19	REF.			
20-24	1.01	0.99	0.29	3.54
25-29	1.58	0.49	0.43	5
30-34	1.51	0.56	0.38	5.93
35-39	1.89	0.33	0.52	6.87
40-44	1.12	0.89	0.23	5.39
45-49	2.42	0.51	0.17	34.50
Mean Age of Mother (years)	1.03	0.11	0.99	1.07

Table 22 (contd.): **Unadjusted odds ratios using logistic regression analysis for individual and contextual characteristics associated with receipt of the third dose of DTP vaccine among children aged 12 to 23 months who received the first dose of DTP vaccine, Pakistan Demographic and Health Survey 2006**

	Odds Ratio	P<|t|	95% CI for OR	
Sex of Child				
Male	REF.			
Female	0.86	0.44	0.58	1.27
Health Card				
No card	REF.			
Yes, seen	12.20	0.00	5.41	27.52
Yes, not seen	4.53	0.00	2.29	8.97
No longer has card	3.40	0.00	1.51	7.66
Number of Children <5 years in the Household	1.11	0.14	0.97	1.28
Birth order of child	0.97	0.39	0.89	1.04

Table 23: Unadjusted odds ratios using logistic regression analysis for individual and contextual characteristics associated with receipt of the third dose of DTP vaccine among children aged 12 to 23 months who received the first dose of DTP vaccine, Pakistan Demographic and Health Survey 1990

	Odds Ratio	p-value	95% confidence interval	
Province of residence				
Punjab	REF	-	-	-
Sindh	0.60	0.03	0.37	0.96
Khyber Pukhtunkhwa	1.34	0.43	0.65	2.73
Balochistan	0.92	0.92	0.18	4.68
Area Of residence		-	-	-
Urban	REF			
Rural	1.37	0.30	0.75	2.49
Wealth Index				
Poorest	REF	-	-	-
Poor	0.70	0.40	0.30	1.62
Middle	1.05	0.90	0.47	2.35
Rich	2.03	0.08	0.93	4.46
Richest	2.34	0.06	0.98	5.56
Sex of Household Head				
Male		-	-	-
Female	3.11	0.10	0.80	12.00
Highest Education level				
No Education		-	-	-
Primary	0.82	0.53	0.44	1.53
Secondary	1.12	0.71	0.62	2.02
Higher than secondary	0.76	0.78	0.11	5.41
Sex of Child				
Male		-	-	-
Female	0.84	0.43	0.55	1.29
Birth Order	1.12	0.08	0.99	1.26

Table 23 (contd.) Unadjusted odds ratios using logistic regression analysis for individual and contextual characteristics associated with receipt of the third dose of DTP vaccine among children aged 12 to 23 months who received the first dose of DTP vaccine, Pakistan Demographic and Health Survey 1990

	Odds Ratio	p-value	95% CI
Mother's Education (merged)			
No education	REF		
Primary	0.83	0.538	0.46 - 1.50
Secondary and Higher	1.36	0.205	0.84 - 2.20
Mother's Age			
15-19	REF		
20-24	1.32	0.65	0.6 – 3.1
25-29	2.32	1.77	0.9 – 6.0
30-34	2.77	1.98	1.0 – 7.7
35-39	4.88	2.59	1.5 – 16.4
40-44	2.53	1.59	0.8 – 8.0
45-49	2.66	0.92	0.3 – 21.6
Age categories			
<25	REF		
25-<35	1.95	0.012	1.16 - 3.29
>35	3.01	0.002	1.51 - 6.00
Sex of Child			
Male	REF		
Female	0.9	0.617	0.58 - 1.39
Health Card			
No card			
Yes, seen	11.03	3.3	2.7 – 45.6
Yes, not seen	2.35	1.1	0.5 – 11.8
No longer has card	0.86	-0.2	0.1 – 5.1
Number of Children <5 years in the Household	1.07	0.439	0.90 - 1.27

Table 24: Adjusted odds ratios using logistic regression analysis for individual and contextual characteristics associated with receipt of the third dose of DTP vaccine among children aged 12 to 23 months who received the first dose of DTP vaccine, Pakistan Demographic and Health Survey 2006

Predictors	Odds Ratio	p-value	95% Confidence Interval	
Mother's Education				
No Education/primary	REF			
Secondary	2.74	0.00	1.51	4.97
Higher	3.70	0.00	2.07	6.59
Mother's Age	1.04	0.02	1.01	1.08
Child's Immunization card				
No Card	REF			
Yes, seen	10.62	0.00	4.62	24.39
Yes, not seen	3.88	0.00	1.94	7.74
No longer have card	3.14	0.01	1.36	7.23

Table 25: Adjusted odds ratios using logistic regression analysis for individual and contextual characteristics associated with receipt of the third dose of DTP vaccine among children aged 12 to 23 months who received the first dose of DTP vaccine, Pakistan Demographic and Health Survey 1990

	Odds Ratio	P-value	Lower CI	Upper CI
Wealth Index				
Middle or lower	REF	-	-	-
Rich or Richest	1.82	0.00	1.24	2.68
Sex Of Household Head				
Male	REF	-	-	-
Female	3.26	0.09	0.85	12.50
Mothers' Age				
Less than 25 years	REF	-	-	-
25 - < 35	1.90	0.02	1.13	3.19
>= 35	3.30	0.00	1.63	6.66

Specific aim 3

Assess individual and contextual determinants of Up To Date (UTD) immunization status, among children 52 weeks of age in the 2006-07 PDHS.

Descriptive analysis

A total of 775 children 52 weeks of age were included in the sample after application of the selection criteria for UTD immunization to the 2006 PDHS (see Table 26). More than half of the children in our sample (69.16%) had received BCG vaccine and 64.13 % of the children had received DTP1 vaccine. At 10 weeks of age only half of the children (56%) had received the second dose of DTP2 vaccine and this went down even further for DTP3 to 46.97% by 14 weeks of life. The decline in the proportion of children receiving oral polio vaccine 1-3 was similar to DTP vaccine and was at 82.06 %, 78.97% and 71.48% respectively. The proportion of children who had received Measles vaccine was half that for BCG vaccine and only 37.68% of our sample had received the vaccine by 52 weeks of life (Table 27).

The UTD immunization status of children up to 52 weeks of age who lived in urban and rural areas was not markedly different; the proportion of infants UTD in urban areas was at 36.9% and in rural areas it was 28%. Similarly the UTD immunization status of the proportion of children in the four provinces of Punjab, Sindh, Khyber Pakhtumkhwa and Balochistan are comparable at 34%, 22.4%, 32.3% and 33.4% respectively. This pattern highlights the fact that the families of children who initiate the immunization schedule at the recommended age also complete it regardless of the province of residence (Table 27).

The UTD immunization status of children belonging to the poorest households was alarmingly low at 11% and children belonging to poorer households were at 26.3%. Contrary to the previous observations, the UTD immunization status of the children belonging to households in the middle and rich wealth quintiles was similar at 37.4% and 39.5% respectively. The highest proportion of children who were UTD for their immunizations was from the richest households, which is in

keeping with what is observed globally. However, what is alarming is that even among this subgroup, less than half the children (42.3%) were UTD for their immunizations (Table 27).

UTD immunization status was 25.4% among the children who belonged to mothers with no education and 37% among mothers with up to primary education. It was surprising to note that among children belonging to mothers with secondary education, only 38.2% were UTD which was similar to the children of mothers with up to primary education. The UTD immunization status of children belonging to mothers with higher education was higher at 55%, but still this is very low when compared to WHO requirements. The proportion of boys UTD for immunization was higher at 32.8% compared to girls at 28.4% but the difference is not marked (Table 27).

Unadjusted analysis: Up to Date vaccination

For children living in rural areas the odds (OR 0.67; 95% CI 0.38—1.16) of being UTD were lower compared to children in urban areas but the results were not statistically significant. The odds of being UTD for children in the provinces of Sindh (OR 0.56; 95% CI 0.33—0.95), Khyber Pakhtunkhwa (OR 0.93; 0.51—1.67) and Balochistan (OR 0.97; 95% CI 0.53—1.79) were lower compared to children in the province of Punjab but the results were only significant for the Sindh province (Table 28).

The most highly significant predictor of children being UTD for immunization was having an immunization card. Children for whom the immunization card was seen at the time of the interview had odds of being UTD that were 26 times (OR 26.18; 95% CI 6.33—108.16) higher than children who never had an immunization card. Similarly for children who had a card but it was not seen at the time of interview the odds were 15 times (OR 15.82; 95% CI 3.79 – 66.13) higher and for children who no longer had the card the odds were 9 times (OR 9.32; 95% CI 1.98 – 43.90) higher compared to children with no card (children who were never issued an immunization card) (Table 28).

Children in the richest wealth quintile had 6 times (OR 5.9; 95% CI 2.23-15.57) and children in the richer quintile had 5 times (OR 5.26; 95% CI 2.12—13.07) higher odds to be UTD compared to children in the poorest wealth quintile. Children in the middle quintile (OR 4.81; 95% CI 1.81—12.79) and poorer quintile (OR 2.87; 95% CI 1.19—6.91) also had higher odds compared to poorest children to be UTD (Table 28).

Among individual level factors associated with UTD, maternal education was statistically significant for children whose mothers had secondary education (OR 1.81; 95% CI 1.05—3.11) and higher education (OR 3.55; 95% CI 1.52—8.29) compared to children whose mothers had no education. Sex of the household head, sex of child, number of children less than five years of age in the household and maternal age were associated at a statistically insignificant level with UTD status (Table 28).

Adjusted analysis: Up To Date vaccination

The logistic regression model to assess the association of individual and contextual level variables with UTD immunization was run adjusting for household wealth, maternal education, having a health/immunization card, province of residence and place of residence (urban/rural). The only statistically significant predictor was child having a health/immunization card. The children for whom the card was seen at the time of the interview had 21.63 (OR 21.63; 95% CI 4.92 –94.94) times higher odds to be UTD compared to children who were never issued a health card. We observed that removing the card from the model resulted in a change for the Odds ratios, 95% CI and significance of reminder of variables associated with UTD status of children. Running the model without the card the only statistically significant variables associated with UTD immunization status of the children were household wealth (Ref category: Poorest, Poorer OR 2.8; 95% CI 1.2—6.9, Middle OR 4.7; 95%CI 1.8—12.7, Richer OR 5.3; 95%CI 2.1—13.2, Richest OR 5.5; 95%CI 2.0—14.8) and number of children under-five years of age in the household (continuous variable, OR 0.5; 95%CI 0.3—0.9). (Table 29) The reduced model

including the card was run adjusting for household wealth, maternal education and number of children under-five years of age in the household and still the only significant determinant was child having a health/immunization card (Ref. No Card, Yes, Card seen OR 21.2; 95%CI 4.9—91.8, Yes not seen OR 13.2; 95% CI 3.1—56.9, No longer have card OR 8.0; 95% CI 1.6—39.6) (Table 29)

Table 26 UTD immunization status for individual vaccines among children 36-52 weeks of age, 2006 PDHS

Vaccine Dose (recommended age)	Up To Date (UTD)		
	No	Yes	
	Frequency (%)	Frequency (%)	Missing
BCG (At birth)	160 (20.65)	536 (69.16)	79 (10.19)
Oral Polio Vaccine 1 (6 weeks of age)	67 (8.65)	636 (82.06)	72 (9.29)
DTP 1 (6 weeks of age)	190 (24.52)	497 (64.13)	88 (11.35)
Oral Polio Vaccine 2 (10 weeks of age)	91 (11.74)	612 (78.97)	72 (9.29)
DTP2 (10 weeks of age)	252 (32.52)	434 (56)	89 (11.48)
Oral Polio Vaccine 3 (14 weeks of age)	221 (28.52)	554 (71.48)	N/A
DTP 3 (14 weeks of age)	322 (41.55)	364 (46.97)	89 (11.48)
Measles (36 weeks of age)	411 (53.03)	292 (37.68)	72 (9.29)
Up to Date (52 weeks)	554 (70.19)	231 (29.81)	N/A
Sample size 775			

Table 27 Characteristics of children 36-52 weeks of age and UTD immunization status, 2006, Pakistan DHS

	No		Yes	
	Frequency	**%**	**Frequency**	**%**
Wealth Quintile				
Poorest	141	89	21	11
Poorer	131	73.7	44	26.3
Middle	95	62.6	50	37.4
Richer	98	60.5	57	39.5
Richest	79	57.7	59	42.3
Place of residence				
Urban	179	63.1	97	36.9
Rural	365	72	134	28
Province of residence				
Punjab	218	66	107	34
Sindh	183	77.6	58	22.4
Khyber Pakhtunkhwa	101	67.7	50	32.3
Balochistan	42	66.6	16	33.4
Sex of the Household Head				
Male	510	69.8	209	30.2
Female	34	62.9	22	37.1
Maternal Education				
No education	388	74.6	126	25.4
Primary	70	63.1	43	37
Secondary	63	61.9	38	38.2
Higher	23	0.45	24	0.55

Table 27 (continued) Characteristics of children 36-52 weeks of age and UTD immunization status, 2006, Pakistan DHS

	No		Yes	
	Frequency	**%**	**Frequency**	**%**
Mothers' age				
15-19	24	75.1	8	24.9
20-24	152	73.5	52	26.6
25-29	177	69.3	77	30.8
30-34	109	70.4	50	31.6
35-39	55	65.5	29	34.5
40-44	16	50	12	50.1
45-49	11	74.3	3	25.7
Sex of the Child				
Male	295	67.2	126	32.8
Female	249	71.6	105	28.4
Less than 5 years old children mean (SE)	2.27 (0.08)		2.4 (0.097)	
Sample size 775				

Table 28: Unadjusted analysis using logistic regression of individual and contextual factors associated with Up To Date Immunization among children 36-52 weeks of age in Pakistan (PDHS 2006)

	Odds Ratio	p-value	95% Confidence Interval for OR	
Wealth Quintile				
Poorest	REF			
Poorer	2.87	0.02	1.19	6.91
Middle	4.81	0.00	1.81	12.79
Richer	5.26	0.00	2.12	13.07
Richest	5.90	0.00	2.23	15.57
Place of residence				
Urban	REF			
Rural	0.67	0.15	0.38	1.16
Province of residence				
Punjab	REF			
Sindh	0.56	0.03	0.33	0.95
KPT	0.93	0.80	0.51	1.67
Balochistan	0.97	0.93	0.53	1.79
Sex of the Household Head				
Male	REF			
Female	1.36	0.46	0.60	3.11
Maternal Education				
No education	REF			
Primary	1.72	0.11	0.89	3.33
Secondary	1.81	0.03	1.05	3.11
Higher	3.55	0.00	1.52	8.29

Table 28 (continued): Unadjusted analysis using logistic regression of individual and contextual factors associated with Up To Date Immunization among children 36-52 weeks of age in Pakistan (PDHS 2006)

	Odds Ratio	p-value	95% Confidence Interval for OR	
Sex of the Child				
Male	REF			
Female	0.82	0.40	0.51	1.31
Children less than 5 yrs old	1.08	0.23	0.96	1.21
Age of the mother	1.02	0.18	0.99	1.06
15-19	REF			
20-24	1.09	0.91	0.25	4.66
25-29	1.34	0.68	0.33	5.39
30-34	1.39	0.64	0.34	5.70
35-39	1.58	0.55	0.34	7.30
40-44	3.03	0.24	0.47	19.48
45-49	1.04	0.98	0.08	14.39
No Card	REF			
Yes card seen	26.18	0.000	6.33	108.16
Yes not seen	15.82	0.000	3.79	66.13
No longer has card	9.32	0.005	1.98	43.90

Table 29: Adjusted analysis of individual and contextual factors, excluding immunization card from analysis, association with up to date Immunization in children in Pakistan (PDHS 2006)

	Odds Ratio	p-value	95% CI
Wealth Quintile			
Poorest	REF		
Poorer	2.8	0.021	1.2 - 6.9
Middle	4.7	0.002	1.8 - 12.7
Richer	5.3	0.000	2.1 - 13.2
Richest	5.5	0.001	2.0 - 14.8
Number of Children Died	0.5	0.019	0.3 - 0.9

Table 30: Adjusted analysis of individual and contextual factors, including immunization card, association with up to date Immunization in children in Pakistan (PDHS 2006)

	Odd Ratio	p-value	95% Confidence Interval	
Availability of Immunization card				
No Card				
Yes card seen	21.2	0.000	4.9	91.8
Yes not seen	13.2	0.001	3.1	56.9
No longer has card	8.0	0.011	1.6	39.6
Maternal Education				
No education				
Primary	0.9	0.846	0.4	2.0
Secondary	1.0	0.951	0.4	2.2
Higher	1.6	0.471	0.4	5.9
Children less than 5 yrs old	1.0	0.785	0.9	1.2
Wealth Quintile				
Poorest				
Poorer	1.7	0.347	0.6	5.0
Middle	2.6	0.117	0.8	8.4
Richer	2.8	0.096	0.8	9.1
Richest	2.0	0.324	0.5	7.9

Predictors of immunization card retention

The most significant predictor of vaccination initiation, completion and UTD was child being issued a health/immunization card by the health care system with the odds of the outcome increasing if mothers were able to show the card at the time of the survey. Due to this finding we ran a separate analysis with child's caretaker having an immunization card as an outcome measure and assessing its association with various predictor variables. Children up to five years of age (11-60 months of age) were selected from the Pakistan PDHS 2006 data set. Descriptive analysis was carried out to identify any differences in card being seen at the time of the interview by province, place of residence and individual socio-economic variables. Unadjusted and adjusted analyses were carried out using logistic regression analysis to examine the associations of source of confirmation of immunization status with contextual and individual level variables. The results of the analyses are presented below.

More than a quarter (27%), of the caretakers of children 11 to 60 months of age reported never receiving an immunization card in 2006. Among those who reported having a card during the PDHS 2006, only 19% were able to show it to the survey team at the time of the interview. Among socio-economic variables, province of residence, area of residence, quintiles of wealth and mothers' highest education level showed significant differences for possession of an immunization card (Table 31).

Confirmation of the DPT1 and DPT3 vaccinations was similarly different across the four provinces, urban/rural divide and socio-economic status of the parents. For example, among all children 11 to 60 months of age, 29% in Punjab did not receive any DPT1 vaccine and only 18% were confirmed receiving the vaccine by card and for 53% of the child vaccine status was confirmed by maternal recall (Table 31). The percentage of children for whom DTP1 vaccine status was confirmed in the remaining three provinces was; Sindh 15%, Khyber Pakhtumkhwa 19% and Baluchistan 8%. The same differentials by province, place of residence and socio-

economic status of parents were observed for confirmation of vaccination completion by source. For example, among mothers with no education only 15% were able to confirm the DPT3 immunization status of their children by card and 22% confirmed the completion by personal recall. The DTP3 vaccination status confirmation by card for children in the highest wealth quintile was 24% and only 10% for children in the lowest wealth quintile.

Results of the unadjusted logistic regression analysis (see Table 33) indicate that children living in Khyber Pakhtunkhwa were more likely to be in possession of an immunization card compared to children in the province of Punjab (OR=1.97; 95% CI: 1.51 – 2.57). Whereas the children in the province of Balochistan were less likely to have an immunization card compared to children in the province of Punjab (OR=0.33; 95% CI: 0.2 – 0.53). Children in the province of Sindh were also had lower odds of possessing the immunization card at the time of interview compared to children in Punjab. The odds of possession of an immunization card increased with being in a higher wealth quintile. Households which were in the second wealth quintile had two times higher odds of to be in the possession of an immunization card compared to those in the lowest wealth quintile (OR=2.14; 95% CI: 1.4 – 3.2). A similar trend continued for the remaining wealth quintiles (Table 33).

The mothers' educational level was also associated with the possession of an immunization card for the child in the household. Mothers who had primary education as their highest educational attainment were 18% more likely to have possessed the immunization card for the child compared to those who had no education (OR=1.18; 95% CI: 0.89 – 1.57). Mothers who had secondary and higher education were approximately 50% more likely to be in possession of an immunization card compared to those mothers who did not have any education. We also found that the age of the child was a significant predictor of possession of an immunization card. If the child was older, the caretaker was less likely to have an immunization card. For example, children between the

ages of 25 and 36 months were 50% less likely to have the immunization card compared to children between the ages of 12 and 24 months (OR=0.48; 95% CI: 0.37 – 0.62) (Table 33).

On adjusted analysis, the province of residence, wealth quintile and age of the child were found to be statistically significant factors associated with possession of an immunization card in the PDHS 2006 (Table 34).

Table 31: Selected socio-economic characteristics by possession of an immunization card for children 11-60 months in the Pakistan Demographic Health survey 2006

	No card	Yes, card seen	Yes, Card not seen	No longer has the card	p-value
Province of residence					<0.05
Punjab	27%	19%	47%	7%	
Sindh	42%	15%	39%	3%	
Khyber Pakhtunkhwa	40%	19%	38%	2%	
Balochistan	55%	10%	27%	8%	
Area of residence					<0.05
Urban	18%	22%	54%	6%	
Rural	40%	16%	38%	6%	
Wealth Quintile					<0.05
Poorest	51%	12%	29%	8%	
Poorer	39%	16%	41%	3%	
Middle	36%	18%	40%	6%	
Richer	28%	17%	48%	7%	
Richest	15%	26%	55%	4%	
Age of Mother (respondent)					0.0062
15-19	47%	13%	39%	2%	
20-24	34%	17%	44%	5%	
25-29	32%	20%	41%	6%	
30-34	32%	18%	46%	5%	
35-39	31%	19%	43%	7%	
40-44	35%	13%	47%	4%	
45-49	42%	8%	41%	9%	
Mothers highest education					<0.05
No Education	39%	16%	39%	6%	
Primary	14%	25%	54%	7%	
Secondary	12%	22%	60%	6%	
Higher	1%	22%	78%	0%	
Sex of the child					0.1601
Male	32%	18%	44%	6%	
Female	34%	18%	42%	6%	

Table 32: Confirmation of vaccination initiation (DPT1) by sources by socio-economic factors for children 11-60 months in the DHS in Pakistan 2006

	Didn't receive DPT1	Confirmed by card	Reported by Mother	p-value
Province of residence				<0.05
Punjab	29%	18%	53%	
Sindh	42%	15%	43%	
Khyber Pakhtunkhwa	41%	19%	40%	
Balochistan	57%	8%	35%	
Area of residence				<0.05
Urban	4%	5%	21%	
Rural	20%	8%	42%	
Wealth Quintile				<0.05
Poorest	52%	10%	37%	
Poorer	41%	16%	43%	
Middle	37%	17%	46%	
Richer	29%	17%	55%	
Richest	16%	26%	58%	
Age of Mother (respondent)				0.0049
15-19	50%	13%	37%	
20-24	33%	17%	50%	
25-29	34%	20%	46%	
30-34	33%	17%	50%	
35-39	31%	18%	51%	
40-44	37%	13%	51%	
45-49	47%	8%	45%	
Mothers highest education				<0.05
No Education	41%	16%	44%	
Primary	14%	24%	62%	
Secondary	13%	22%	65%	
Higher	1%	22%	78%	
Sex of the child				
Male	33%	18%	49%	0.1253
Female	35%	17%	47%	

Table 33: Confirmation of vaccination completion (DPT3) by sources and socio-economic factors for children 11-60 months in the DHS in Pakistan 2006

Province of residence	Did not receive DTP3	Confirmed by card	Reported by Mother	p-value
Punjab	53%	18%	29%	<0.05
Sindh	68%	13%	18%	
Khyber Pakhtunkhwa	58%	18%	24%	
Balochistan	77%	5%	17%	
Area of residence				
Urban	48%	21%	31%	<0.05
Rural	63%	14%	23%	
Wealth Quintile				
Poorest	75%	10%	15%	<0.05
Poorer	67%	14%	19%	
Middle	59%	16%	24%	
Richer	49%	16%	35%	
Richest	42%	25%	33%	
Age of Mother (respondent)				
15-19	74%	11%	16%	0.0158
20-24	59%	16%	26%	
25-29	55%	18%	26%	
30-34	58%	17%	25%	
35-39	55%	18%	28%	
40-44	63%	12%	25%	
45-49	68%	9%	23%	
Mothers highest education				<0.05
No Education	63%	15%	22%	
Primary	43%	22%	35%	
Secondary	38%	23%	39%	
Higher	37%	22%	41%	
Sex of the child				
Male	57%	17%	27%	
Female	59%	16%	25%	0.1871

Table 34: Unadjusted odds ratios and 95% confidence intervals from logistic regression for the associations between socio-economic factors and possession of an immunization card for children 11-60 months in the PDHS 2006

	Odds ratio	p-vlaue	95% confidence Interval	
Province of residence				
Punjab	REF	-	-	-
Sindh	0.78	0.053	0.6	1.0
Khyber Pakhtunkhwa	1.97	0.00	1.51	2.57
Balochistan	0.33	0.00	0.2	0.53
Area of residence				
Urban	REF	-	-	-
Rural	0.82	0.12	0.63	1.05
Wealth Quintile				
Poorest	REF	-	-	-
Poorer	2.14	0	1.43	3.21
Middle	2.24	0	1.5	3.33
Richer	2.68	0	1.79	4.03
Richest	2.6	0	1.72	3.94
Age of Respondent				
mean(SE)	0.98	0.015	0.964	0.996
Mothers highest education				
No Education	REF	-	-	-
Primary	1.18	0.246	0.89	1.57
Secondary	1.51	0.008	1.12	2.06
Higher	1.52	0.017	1.08	2.14
Sex of the child				
Male	REF	-	-	-
Female	0.99	0.94	0.84	1.18
Age of Child				
12 - 24 months	REF	-	-	
25 - 36 months	0.48	0	0.37	0.62
37 - 48 months	0.32	0	0.25	0.4
49 - 60 months	0.22	0	0.17	0.3

Table 35: Adjusted odds ratios and 95% confidence intervals from logistic regression analysis for the associations between socio-economic factors and possession of an immunization card for children 11-60 months in the PDHS 2006

	Odds ratio	p-value	95% Confidence Interval	
Province of residence				
Punjab	REF	-	-	-
Sindh	0.83	0.178	0.63	1.09
Khyber Pakhtunkhwa	2.09	0.000	1.59	2.76
Balochistan	0.41	0.001	0.25	0.68
Wealth Quintile				
Poorest	REF	-	-	-
Poorer	1.78	0.008	1.16	2.72
Middle	1.96	0.002	1.30	2.97
Richer	2.38	0.000	1.56	3.63
Richest	2.40	0.000	1.57	3.68
Age of Child				
12 - 24 months	REF	-	-	-
25 - 36 months	0.48	0.000	0.37	0.62
37 - 48 months	0.32	0.000	0.25	0.41
49 - 60 months	0.22	0.000	0.16	0.29

Chapter 5: Discussion

My research hypotheses required assessing whether contextual level variables were more likely than individual level variables to predict vaccination initiation, completion and up to date immunization among children in Pakistan, utilizing the Pakistan Demographic and Health Survey data for 1990 and 2006. Among all variables, possession of a health/immunization card was the strongest predictor and had a statistically significant association with all of the three outcomes. The most significant results from the analyses are summarized and discussed in the following sections.

Vaccination Initiation: The analysis of the 2006 PDHS showed that, unlike possession of a health card, other contextual level variables including place of residence (urban and rural) and province of residence, were not statistically significant predictors of vaccination uptake in the final model. There were, however, significant differences by province in the unadjusted model and marginally significant differences ($p<0.10$) in the full model. In the analysis of the 1990 data, differences by province were significant at the $p<0.05$ level: children in both Sindh and Balochistan were less likely to have received DPT1 vaccinations than children in Punjab. Children in the province of Punjab compared to the other provinces are more likely to initiate vaccination for several reasons: first, the province is densely populated and therefore it is easier for a given basic health unit to reach a larger population. Second, social support services like schools, colleges and roads are available to a larger population, thus improving the education rates and access to services. Last but not least, the population in Punjab has better economic opportunities due to better-irrigated cultivatable land, major industry and centers of commerce.

I also looked at the associations of individual level variables with vaccination related outcomes. Based on my analysis of the PDHS 2006-07, household wealth and maternal education are statistically significantly associated with vaccination initiation for children aged 12 to 23 months in Pakistan, after accounting for contextual level characteristics of province and place of residence (urban or rural). This is in accordance with the trends seen globally (Wiysonge et al.

2012, e37905). The reasons for this trend seen globally and in Pakistan can be explained by the fact that wealthier households are more likely to have better access to health services by virtue of tending to reside in better served areas as well as having financial resources to spend on health (Suarez-Castaneda et al. 2013). These areas are also more likely to have better access to civic services like schools and colleges, thereby increasing the likelihood of communities getting better education.

Maternal education is a strong predictor of vaccination initiation and this can be explained partially by the fact that in Pakistan mothers with higher education are more likely to reside in larger cities, have better economic opportunities and better access to health services. But mothers with higher education even in rural areas act similarly to their counterparts in urban areas when it comes to seeking preventive health services for their children. This pattern suggests the importance of female education in improving the maternal and child health conditions in any society. However it was observed that in Pakistan, mothers with education up through the primary level do not behave differently in terms of initiating vaccination for their children compared to mothers with no education. The difference in behavior due to education is observed only after mothers have completed secondary or higher education. This observation can be explained by two factors: first, mothers who complete secondary and higher education have higher degrees of autonomy of decision making regarding their own health care and that of their children. Second, communities that emphasize the importance of higher education for girls may also be more inclined towards seeking better health services for their children.

But the individual effect of education in improving uptake of preventive health services cannot be over emphasized. As young women acquire more education, their understanding of the scientific basis of disease and prevention is increased which is translated into seeking better preventive health services. It also sheds light on the fact that communities which place value in educating girls and keeping them in school beyond the primary level and have empowered women with

decision making capacity regarding maternal and child health have over all better health and human development indicators. It is unfortunate that the benefits of education have not reached every community in Pakistan, as more than half of the mothers--in the 2006-07 PDHS sample, a total of 63.38%--had no education. Only 15% of mothers had through primary and 15.57% had secondary education. The number of mothers with both secondary and higher education was only 6.01%, indicating the failure of the government to provide education facilities and incentives for young girls to enroll and remain in schools.

The health care providers issue the health/immunization card for a child at the time of the first antenatal visit by the mother or when a child first comes into contact with immunization services/EPI program--ideally at birth--to receive vaccines. Having a health card depends on its being issued by the health care system and the parental attitudes and practices towards vaccines and keeping the card in a safe place. This makes having a card both a contextual as well as an individual level variable/factor. For all my analysis in this thesis I have treated having a card as a contextual level variable for several reasons. First, because the card is issued by the health care system, it indicates the inefficiency of the immunization program in areas where it is never issued. It was observed that a quarter of children (24.88% in our PDHS 2006 sample) were never issued a health card by the vaccination program. In addition, being issued a health card at birth by the health care system may modify the behavior of mothers toward promoting immunization initiation, which further leads to immunization completion. It is important to note that mothers who were not able to produce the card at the time of the interview, or indicated that the child no longer had the card still had children with better performance in completing the DTP3 vaccination compared to children who were never issued a card.

Second, having a health card is treated as a contextual level variable because, as in countries like the United States, it is mandated by the state to complete childhood immunization for entry into the public education system. Thus safeguarding the health/immunization card by the parents is a

behavior incentivized by the public education system. This exemplifies how systems level policy by the department of education may modify parental behavior to safeguard the health/immunization card as well as complete the immunization s schedule of their children before entry to the public school system.

My thesis research findings may also be explained in accordance with the modified Andersen and Aday "Behavior model and access to health care," which was used as the conceptual framework to guide my analysis. The uptake of the immunization services is determined by the contextual level determinants like the increase in number of staff and facilities of the Expanded Program of Immunization reaching a larger proportion of the population. This may explain the increase in the vaccination services uptake between the time periods of 1990 and 2006. The general environment in which the families reside also affects the uptake of health services Thus the current situation in Pakistan which has witnessed an increasing number of violent attacks on vaccination staff may affect population attitudes towards vaccines. However when the PDHS data was collected in 2006 these hostilities were not seen towards immunization programs so we cannot infer that the general socio-political unrest was affecting childhood immunization.

The immunization trends and population behaviors toward vaccines in 1990-91 in Pakistan were not very different from what we observed in the 2006-07 DHS data set. Although in 1990-91 a larger proportion of children, 36.58%, did not initiate the DTP1 vaccine and 34.29% were never issued a health/immunization card, the proportion of mothers who were able to produce a card at the time of the interview (27.43%) was nearly similar to that observed in 2006-07 PDHS (23.74% observed). In the 16 years time the program has not made adequate efforts to issue an immunization/health card to every child presenting for vaccination. Also the program has not been able to change parental attitudes towards safeguarding the immunization records of their children.

The slow pace of development in the country is evident by the female educational attainment rates. In 1990 the proportion of women with no education was 76.83% compared to the 2006-07 proportion of 63.38%; the gap was reduced by only 13.45%. The gap in primary and secondary completion has also not changed much. Although primary school enrollment had increased between 1990-and 2006 a similar increase was not observed for the proportion of young mothers completing both secondary and higher education (In the 1990-91 PDHS it was at 0.89%). There is no doubt that the slow progress in increasing secondary and higher education rates is a compelling finding, requiring the governmental attention for increases in human development initiatives and funding. But this finding also has bigger health implications. The PDHS1990 survey shows that there was no difference between mothers with no education compared to mothers with up through primary education regarding the initiation of the vaccination schedule for their children. This trend is similar to the PDHS 2006-07 findings, again highlighting the neglect of the Expanded Program of Immunization program in targeting young children enrolled in primary schools for health behavior change.

The unadjusted analysis of the PDHS 1990 data shows similar associations of the contextual level determinants with vaccination initiation, as observed in the PDHS 2006 data. The unadjusted analysis of the individual level determinants with vaccination initiation in 1990 was also similar to the pattern observed in the PDHS 2006-7 data.

Vaccination Completion and UTD: Having a health card was most significantly associated with receiving DTP3 after adjusting for individual factors like maternal education and socio-economic status, sex of child, birth order etc. Although vaccination initiation was associated with socio-demographic characteristics like household wealth and maternal education, for vaccination completion these factors were not significant. However, because we selected our sample of children for this analysis of vaccine completion from those who had already initiated the schedule, we are by default already adjusting for the population socio-demographic

characteristics of household wealth and maternal higher education and the population in our sample are those who are aware of the vaccination programs and have better access to vaccines. In the population subgroup,that has already initiated the immunization schedule, the only significant factor associated with completion is having a health/immunization card. The importance of a reminder system like having an immunization card cannot be emphasized enough in facilitating the vaccination completion. In our supplementary analysis we also observed that the date of the vaccine was noted more frequently for mothers with secondary and higher education, indicating that the behavior of the vaccine providers may be influenced by the educational status of their clients.

Parents who initiate the immunization schedule of their children at an early/specified time are more likely to complete it within the recommended age of one year. It is observed that the proportion of children who had UTD immunization was similar in the provinces of Balochistan and Punjab making it, in our analysis, the only comparable indicator between the two provinces. The two provinces have a totally different socio-demographic composition and health system setup in terms of access. This finding emphasizes the fact that parents who are informed of the importance of timely vaccination and initiate the process, behave similarly with follow-up regardless of the differences in vaccine access and socio-demographic differentials. The alarmingly low levels of UTD immunization among children strongly suggests that the EPI should update its program monitoring indicators and not rely solely on BCG, DTP1 and DTP3 coverage among children 12-23 months of age. Using a more stringent criterion of assessing UTD immunization among children 36-52 weeks of age allows for better assessment of the risk of infectious diseases to which Pakistani children are exposed.

Vaccine reminders through mobile phone technology have been in the limelight for several years in several countries and with encouraging results. These reminders have been supplemented with cash incentives to further improve the timeliness of the immunization schedule in Kenya but the

challenges of mobile phone based reminders in developing countries remain. There are technological limitations in integrating the records of each child receiving their scheduled vaccine dose and the automatic generation of the reminders for the next vaccine dose. In developing countries there is also the gender gap of possessing a cell phone even in areas of 100% mobile phone coverage. Women are 20% less likely to possess a mobile phone handset compared to men. The third limitation of mobile phone based reminders is that in the developing countries the pre-paid and non-contracted cell phone service leads to frequent disconnections. Almost 40% of the parents enrolled in a mobile phone vaccine reminder intervention reported service disconnection in the year of enrollment in the program {{371 Wakadha,H. 2013;}}. With these limitations it is important to have an intervention the can give real time reminders to parents, is cost effective and is health systems oriented. The latter characteristic is equally important as such a reminder system would allow for the health care system to control for population level selection biases and provide the service to all members of the community, even the marginalized and those without the means to afford a cell phone.

The recommendation to have a cell phone alternate reminder system that was guided by the findings of this research thesis has been awarded a Gates Foundation Grand Challenges Exploration grant. The grant is funding the development of a time dependent and temperature independent indicator It is an oil-based dye moving on a membrane and coloring it red as it moves along, which reaches specified marks at specified time intervals corresponding to the vaccination schedule to remind parents about the appropriate time to visit the vaccination center for timely and complete immunization of their children. The indicator will be worn by children on their ankles attached to a cloth band secured by a locking device. Each band will have a unique number that will be used to track the timeliness with which children are brought to the center to complete their vaccine dose.

Immunization card retention

Our analysis of the PDHS 2006 shows that geographic location, economic position of the household, and age of the child are significant factors in determining the retention of an immunization card at the household level in Pakistan. Vaccination history as recorded in the form of an immunization card is considered to be a strong predictor of compliance to vaccination in developed and developing countries. There is a lot of emphasis on improving immunization services through novel and innovative mechanisms for areas with low vaccination coverage in developing countries. There is increasing debate regarding having a single digital child health record for major health interventions. Single digital records will provide information on acceptance and coverage of different interventions as well as how participation in various programs improves maternal and child health. The significance of such a system becomes even more valuable in developing countries, where prioritization of health intervention has to be based on impact.

We also analyzed the PDHS 1990 data to see if the factors for immunization card retention have changed over time. We did not conduct logistic regression analysis for the PDHS 1990 due to a difference in the way this variable was recorded between the two surveys However the univariate estimates showed a similar pattern for immunization card possession, indicating little change between the two surveys The overall proportion of households that reported having an immunization card increased from 1990 to 2006, but overall the pattern of retaining/possession of an immunization card showed little change after a gap of more than 16 years.. Our results also show that age of the child is a significant factor in presenting the immunization card at the time of the survey. The older the children were, the less likely their mothers were to present the immunization card to the survey teams. This could be due to the fact that while the children have received the course of the vaccinations, the parents do not keep the vaccination card. This factor has to be taken into account where the government in Pakistan and other countries like to enforce

school entry by immunization record confirmation. If such a policy to is to be implemented to increase immunization coverage, a well-planned communication plan should be implemented for the parents by the health care system. It may be important that the schools are involved at an early stage due to their important role in implementation of immunization card confirmed vaccination for school entry policy implementation.

Our results also highlight the importance of data recording for other interventions, since there is a debate if other health interventions should be implemented while the child visits health centers for immunization. This approach increases the data recording and the records may be required for a longer time by the health system such as with nutrition interventions. It has been found that parents were more likely to keep child health records if they were told at the time of the visit to the health center that they would be needed for follow up visits.

The factors that were found to be statistically significant with possession of an immunization card, in turn indicate underlying issues with the health care system, and population attitudes towards immunization. Province of residence does highlight the importance of provincial health department commitment in undertaking health care delivery. In order to bring change, the government has to look to health system factors that increase awareness among the population regarding the importance of immunization both at the province as well as at the country level. A regular mechanism for immunization assessment beginning from a smallest health administration unit to the provincial level may have a significant effect in addressing the issue of immunization initiation and completion.

We conducted an analysis of the Pakistan Demographic and Health Survey data of 1990 and 2006 to assess predictors/barriers to routine immunization for children 12 to 23 months of age in Pakistan. Our results showed a highly statistical significant association for children who had retained a card to have a timely vaccination as well as vaccination completion. It is however

important, for reasons mentioned above, to understand what are the factors that help families to retain the vaccination cards. Understanding these factors will be helpful in educating the mothers and program managers regarding the importance of the retention of cards and complying with recommended vaccines and health interventions.

Policy implications and recommendations

The validity of our outcome measure, immunization status of children, as confirmed by household held immunization record and maternal recall, is regarded as the gold standard in the absence of provider based health records (Hayford et al. 2013, 1211-2458-13-1211). The literature gives us confidence in the interpretation of our results and in making policy recommendations based on our findings. Our research findings, understanding of the health and education system in Pakistan and critically reviewing the greater literature have guided our policy recommendations. We agree with the conclusion that policies, incentives and communication strategies cannot work in isolation; to reach the WHO recommended 90% coverage and increase timely vaccination completion rates these three approaches have to be addressed at all levels of supply and demand, as well as made into national priorities (Shefer et al. 1999, 96-142).

Policy recommendation 1): Expanded Program of Immunization (EPI) efforts should be directed to reach households in the poorest and poor wealth quintiles: our analysis of the 1990 and 2006 data showed that immunization initiation, completion and UTD status has improved only for children in the middle wealth quintile between the two time periods. In 2006 children belonging to the poorest and poor households still fared worst compared to higher income households and the overall percentages of children in the lower two wealth quintiles completing the third dose of DPT and UTD were still alarmingly low. The EPI program has yet to reach out to the poorest and poor households with better access and incentives for vaccination of their children. This is much needed as disease and under-five mortality is highest among this population. Why households in the middle wealth quintile have made the most improvement in completing the vaccination status of their children can be explained by the fact that as more and more people from rural areas are moving to urban and semi-urban areas for better economic opportunities they are entering the middle wealth quintile group. Although households belonging to the higher wealth quintiles and mothers with higher education are individual level characteristics, they also highlight the fact that

the health care system is more geared to cater to the needs of the population with better access to sources of income and human development. The government should increase its efforts to reach marginal populations with limited financial resources and access to social services like health and education. Once the health care system reaches the populations with easily accessible immunization services then even individual in lower wealth quintiles are more likely to receive the DTP3 vaccine and complete the immunization schedule.

Policy Recommendation 2): Introduce digital immunization records. Our findings show that less than 20% of the mothers were able to show the household held immunization record of the child during both the surveys of 1990 and 2006. Almost half of the mothers were not able to show the paper based immunization record of their children at the time of the interview during the 1990 and 2006 surveys. In light of this finding we recommend that the EPI program should move towards digital/electronic health and immunization records for all children in Pakistan. This system requires initial investment but it is the need of the day. With the increase in technology and its ease of use, this system can be established even in a low-income country like Pakistan. Paper based health records are prone to being easily damaged and lost and one can propose to provide families with easily stored and water/tear resistant cards but there are limitations associated with household held immunization records. A study assessing the validity of household held immunization records using provider health records as the gold standard in the Commonwealth of Northern Mariana Islands, a developing region, has found the household held immunization cards underestimate the true vaccination status of children (Luman, Ryman, and Sablan 2009, 2534-2539). This is due to the fact that often parents taking their children for vaccination may forget to take the immunization card with them, thus vital information is not recorded on the card. The possession of a health card which is seen at the time of interview is a measure of maternal attitudes and understanding towards the importance of immunization completion but during our analysis we found that being issued an immunization card by the EPI

program is also the single most significant factor predicting vaccination completion. In the absence of digital electronic records the EPI program must provide waterproof, tear resistant and easily stored immunization cards to each and every child initiating the vaccination process and if a card is lost to replace it.

In the time period between 1990 and 2006 there has been no significant change in the proportion of mothers who were able to show the card at the time of the interview. The EPI and health care system must direct their efforts to create a social value for mothers/caregivers to save the health card/immunization record card of a child just as much as reinforcing the importance of vaccinating their children in a timely and complete manner. Health care providers must inquire about the immunization status of a child at each encounter they have with their pediatric patients to reinforce in the communities the importance of immunization in a timely and complete manner.

Policy recommendation 3): Introduce innovative systems to remind mothers/caregivers for timely and complete immunization of their children. Analysis of the data showed that household wealth and maternal education were significantly associated with immunization initiation but only maternal education and having an immunization card were significantly associated with completion. Educated mothers may have better understanding of the importance of vaccines but they also have a better understanding of keeping track of time, through newspapers, calendars etc., to which the uneducated mothers have limited access. In the 2006 PDHS sample 63.38% of the mothers had no education, 15% had through the primary level and 15.57% had secondary education. Only 6.01% of the mothers had education above the secondary level and higher. Although we did not assess how well these women kept track of dates, we understand that uneducated women have fewer and less effective means of keeping track of dates. In light of this finding we propose that there is a need to have an innovative system of reminding mothers/caregivers of the vaccine due dates to improve immunization completion, especially

among women who do not have access to electronic reminder systems like cell phones and who also lack education and training to consult calendars.

Policy recommendation 4): Introduce in the primary school curriculum the importance of timely and complete vaccination. Our analysis showed that the beneficial effects of education to improve vaccination status of children are observed only for mothers with secondary and higher education. In our analysis mothers with primary education did not behave differently from mothers with no education. Increasing female literacy is crucial for improving the health of the population, including reducing infant and under-five mortality. The government has improved its efforts to increase female enrollment and keep girls in school beyond the primary level but it also needs to focus on the quality of education provided to these girls. Mothers with primary education do not behave much differently from mothers with no education regarding preventive health seeking behavior; therefore while girls are enrolled in primary school every effort should be made to educate them about health and the benefits of preventive health services. The primary school curriculum needs to be updated to address the significance of completing the immunization schedule and needs to impart this valuable lesson when children are in the most impressionable age. We have not assessed Pakistan's primary school curriculum regarding the content or importance of immunization nor are we able to assess from the data if such education has been imparted to mothers who have secondary level education. Also education may act as a proxy for socio-economic status and place of residence of the family which limits its assumed causal relationship with child health outcomes. But it has been seen that education is significantly associated with immunization even after accounting for individual and contextual level determinants (Desai and Alva 1998, 71-81).

Policy recommendation 5): Conduct in-depth research to understand factors associated with parental compliance to timely immunization and card retention. Retaining the immunization card may predict household behaviors towards immunization and other programs but could be a proxy

for socio-economic and health behavior characteristics. Therefore it is very important for the policy makers and health program implementers to keep in view the factors that predict retention of a health card per se. The success and/or failure of an effort to introduce innovative approaches to retain a card by the household heads (mothers) and in turn reduce vaccination dropout rates would therefore need in-depth understanding of determinants of compliance and retention of a card.

In addition to the policy recommendations guided by our PDHS 1990 and 2006 data analysis we also want to propose redrawing the rural/urban divide in Pakistan by introducing an objective measure of urbanicity; This recommendation is made by our review of the recent literature and is made in light of the current literature on socio-demographic transitions. In our analysis of the PDHS data we were not able to validate the rural or urban status of the primary sampling units in the data set using a composite score for urbanicity or human development. The rural urban divide in Pakistan is based on an outdated arbitrary system set in the sixties; therefore when making inferences regarding population behavior on this variable one has to take into account that areas designated as rural are now growing cities with semi-urban characteristics. Globally and in Pakistan major demographic transitions are taking place as rural villages are transforming into small towns and towns are growing into cities and the rural—urban dichotomy is unable to capture the epidemiological health transitions effectively (Dahly and Adair 2007, 1407-1419).

One way to overcome this limitation is to calculate a validated urbanicity score for rural areas and then assess health outcomes against this score (Colchero and Bishai 2008, 615-623; Allender et al. 2010, 297-304). The 2006-07 Pakistan DHS is representative at the national and provincial levels and the survey collected information on the available civic amenities. This information was collected only in the rural areas from the largest village in the primary sampling unit. However the validated urbanicity score for PSUs and rural districts in Pakistan cannot be calculated using the 2006-07 PDHS for several reasons: 1) There is no way to link the survey data with the district

from which it was collected, therefore it cannot be inferred if the village is representative of the entire district. The PDHS has information on the distance of the village from the district headquarters but as districts cannot be identified this information cannot be used to infer population density nor the population size of the village. Because this information is missing from the PDHS we cannot calculate the urbanicity score of the PSU and know for sure if a given PSU is still rural, in transition or has been transformed into an urban area. The reason DHS and population surveys ensure the district and PSU identifiers are not available in the public domain is to protect the anonymity of the individuals surveyed. An alternate way adopted by major populations surveys is to introduce the replicate weights into the data set which allows for analysis at the district and PSU level but the user is unable to link it to the individual is interviewed in the survey.

Study Limitations and Strengths

1) The demographic and health surveys are primarily descriptive surveys aimed at estimating population totals and means as opposed to analytical surveys which are used to derive coefficients from logit and linear models. Therefore the uses of data from descriptive surveys to arrive at analytical assessment pose challenges that need to be addressed.
2) The predictor variables included in the analysis are only those variables for which information is available in the PDH survey. Significant predictor variables like health care system setup and personnel for delivery of immunizations, population perceptions regarding immunization and program incentives like food/money for immunization completion identified during the literature search in scientific publications are not included for modeling because they are not collected by the PDHS. To address this limitation we can take variables present in the survey and use them as proxy measures for variables of interest. Maternal satisfaction with immunization services is not covered in

the survey but level of satisfaction with health care provider for a sick child visit is measured by the PDHS 2006-07. The latter variable can be used as a proxy measure for the former but this has to be duly acknowledged in the interpretations and presentation of the results.

3) The differences in sample sizes and time frames (a difference of 16 years) and quality of execution of the two surveys, PDHS 2006-07 and 1990-91, pose issues for merging the two data sets. The two data sets were not merged but analyzed separately and the regression results for the two data sets were compared. This is feasible as the sampling methodology and survey tool (questionnaire) for the two surveys provides compatibility that makes comparisons acceptable for the two data sets. However we have to acknowledge this limitation in arriving at inferences.
4) There have been numerous health programs and several policy changes between the time periods of 1990-91 and 2006-07. To assess the impact of each policy on immunization initiation and completion would require collecting data retrospectively which may or may not be present. Health policies are not implemented uniformly across the country, hence the inability to ascertain the effect of each at the implementation (and effect) stage poses a limitation. It is a challenge to find causative associations or direct impacts of the health initiatives and policy changes on childhood routine immunization schedule completion by analyzing published reports only. It is only possible to review the published literature regarding the nature of various policy changes and health initiatives and state what were the vaccination initiation, completion and UTD rates at each point in time without making any causative inferences. The unobserved and unreported influences of various policy changes and health initiatives were not accounted for in the analysis. There are several non-health related policy changes and program initiatives such as increasing primary school enrollment for girls and increasing the number of paved roads in the rural areas that can directly or indirectly affect the health seeking behavior of mothers and the

resulting vaccination completion rates. Communities are dynamic and constantly experience changes in social norms and trends including health-seeking behavior. Our study has not accounted for the myriad of policy and program changes that have taken place in Pakistan between the timeframe of 1990 and 2006 regarding health as this task is not possible through reviewing published literature which comments on the effects of various policy initiatives. The policy recommendations that come out of our study are based on the analysis of the PDHS results and the published systematic literature reviews.

5) The Pakistan Demographic and Health Survey 2006 is the largest nationally representative population survey to date and its results are generalizable to the provincial level. Our analysis has looked at the association of individual and contextual level determinants associated with immunization initiation, completion and up to date status of children in Pakistan. Other published papers have not reported similar research from Pakistan.
6) The sampling methodology and questionnaire design of the PDHS 1990 and 2006 allows for comparison of the two time frames.
7) The validity of our outcome indicators, measured by maternal recall and card, is confirmed by several studies and accepted as the gold standard in the absence of health care provider records. We have made policy recommendations based on our research findings and these are achievable in a limited time frame and possible within the technological and human resources available in Pakistan.

References

The national vaccine advisory committee. "Strategies to sustain success in childhood immunizations". 1999. *JAMA: The Journal of the American Medical Association* 282 (4) (Jul 28): 363-70.

National Institute Of Population Studies (NIPS) [Pakistan] and macro international inc. 2008. Pakistan demographic and health survey 2006-07. Islamabad, Pakistan: National institute of population studies and macro international inc.

Abdul Razzaque Rukanuddin, K. Zaki Hasan. 1992. Maternal and child health in Pakistan demographic and health survey 1990-91, National Institute of Population Studies and IRD/Macro international inc., 97-109. Islamabad, Pakistan and Columbia, Maryland: National institute of population studies and IRD/Macro international Inc.

Ahlers-Schmidt, C. R., A. K. Chesser, T. Nguyen, J. Brannon, T. A. Hart, K. S. Williams, and R. R. Wittler. 2012. Feasibility of a randomized controlled trial to evaluate text reminders for immunization compliance in kids (TRICKs). *Vaccine* 30 (36) (Aug 3): 5305-9.

Akmatov, M. K., M. Kretzschmar, A. Kramer, and R. T. Mikolajczyk. 2008. Timeliness of vaccination and its effects on fraction of vaccinated population. *Vaccine* 26 (31) (Jul 23): 3805-11.

Allender, S., B. Lacey, P. Webster, M. Rayner, M. Deepa, P. Scarborough, C. Arambepola, M. Datta, and V. Mohan. 2010. Level of urbanization and noncommunicable disease risk factors in tamil nadu, india. *Bulletin of the World Health Organization* 88 (4) (Apr): 297-304.

Andersen, R. M. 1995. Revisiting the behavioral model and access to medical care: Does it matter? *Journal of Health and Social Behavior* 36 (1) (Mar): 1-10.

Andersson, N., A. Cockcroft, N. Ansari, K. Omer, J. Losos, R. J. Ledogar, P. Tugwell, and B. Shea. 2005. Household cost-benefit equations and sustainable universal childhood immunisation: A randomised cluster controlled trial in south pakistan [ISRCTN12421731]. *BMC Public Health* 5 (Jun 28): 72.

Antai, D. 2009. Inequitable childhood immunization uptake in nigeria: A multilevel analysis of individual and contextual determinants. *BMC Infectious Diseases* 9 (Nov 20): 181.

Babalola, S. 2009. Determinants of the uptake of the full dose of diphtheria-pertussis-tetanus vaccines (DPT3) in northern nigeria: A multilevel analysis. *Maternal and Child Health Journal* 13 (4) (Jul): 550-8.

Babu, G., J. Olsen, S. Jana, S. Nandy, M. Farid, and SM Sadhana. 2010. *Evaluation of immunization cards and parental recall against gold standard for evaluating immunization coverage*. *He Internet Journal of Epidemiology* 9 (2).

Barham, T., L. Brenzel, and JA Maluccio. 2007. *Beyond 80%: Are there new ways of increasing vaccination coverage? Evaluation of CCT programs in Mexico and Nicaragua.* Washington DC: The International Bank for Reconstruction and Development / The World Bank.

Bishai, D. M. 2008. Global initiatives in universal childhood immunisation. *Lancet* 372 (9655) (Dec 13): 2004-5.

Blau, J., P. C. Faye, K. Senouci, S. N. Dagnan, A. Douba, J. T. Saracino, and B. D. Gessner. 2012. Establishment of a national immunization technical advisory group in Cote d'Ivoire: Process and lessons learned. *Vaccine* 30 (15) (Mar 28): 2588-93.

Bondy, J. N., A. Thind, J. J. Koval, and K. N. Speechley. 2009. Identifying the determinants of childhood immunization in the Philippines. *Vaccine* 27 (1) (Jan 1): 169-75.

Bos, E., and A. Batson. 2000. *Using immunization coverage rates for monitoring health sector performance: Measurement and interpretation issues.* Washington DC: HNP; The World Bank.

Brenzel, L., C. Sanderson, V. Galayda, T. Masud, and I. U. Haq. 2011. *Cost-effectiveness and financial consequences of new vaccine introduction in Pakistan.* Washington DC: The International Bank for Reconstruction and Development / The World Bank, .

Brown, J., Monasch, R., Bicego, G., Burton, A. and Boerma, J. An assessment of the quality of national child immunization coverage estimates in population- based surveys. Measure evaluation. 20022014]. Available from http://www.cpc.unc.edu/measure/publications/wp-02-53.

Chandir, S., A. J. Khan, H. Hussain, H. R. Usman, S. Khowaja, N. A. Halsey, and S. B. Omer. 2010. Effect of food coupon incentives on timely completion of DTP immunization series in children from a low-income area in Karachi, Pakistan: A longitudinal intervention study. *Vaccin*e 28 (19) (Apr 26): 3473-8.

Cho, H. Y. 2012. An overview of the national immunization policy making process: The role of the Korea expert committee on immunization practices. *Korean Journal of Pediatric*s 55 (1) (Jan): 1-5.

Clark, A., and C. Sanderson. 2009. Timing of children's vaccinations in 45 low-income and middle-income countries: An analysis of survey data. *Lance*t 373 (9674) (May 2): 1543-9.

Clark, S. J., A. Butchart, A. Kennedy, and K. J. Dombkowski. 2011. Parents' experiences with and preferences for immunization reminder/recall technologies. *Pediatric*s 128 (5) (Nov): e1100-5.

Cockcroft, A., N. Andersson, K. Omer, N. Ansari, A. Khan, U. U. Chaudhry, and U. Ansari. 2009. One size does not fit all: Local determinants of measles vaccination in four districts of Pakistan. *BMC International Health and Human Right*s 9 (Suppl 1): S4.

Colchero, M. A., and D. Bishai. 2008. Effect of neighborhood exposures on changes in weight among women in Cebu, Philippines (1983-2002). *American Journal of Epidemiolog*y 167 (5) (Mar 1): 615-23.

Cotter, JJ, JD Bramble, VE Bovbjerg, CB Pugh, DK McClish, G. Tipton, and RS Wally. 2002. Timeliness of immunization of children in a medicaid primary care case management managed care program. *Journal of National Medical Associatio*n 94 (9).

Cui, F. Q., and R. Gofin. 2007. Immunization coverage and its determinants in children aged 12-23 months in Gansu, china. *Vaccin*e 25 (4) (Jan 8): 664-71.

Dahly, D. L., and L. S. Adair. 2007. Quantifying the urban environment: A scale measure of urbanicity outperforms the urban-rural dichotomy. *Social Science & Medicine (1982)* 64 (7) (Apr): 1407-19.

Demographic, Pakistan. *Health Survey (PDHS).(2006-07).(National Institute of Population Studies and Macro International Inc.Publication*).

Desai, S., and S. Alva. 1998. Maternal education and child health: Is there a strong causal relationship? *Demography* 35 (1): 71-81.

Diallo, O., M. Schlumberger, C. Sanou, H. Dicko, A. Aplogan, and F. Drabo. 2012. Use of SMS to ask mothers to come to vaccination sessions in bobo-dioulasso. *Bulletin De La Societe De Pathologie Exotique (1990)* 105 (4) (Oct): 291-5.

Dugas, M., E. Dube, B. Kouyate, A. Sanou, and G. Bibeau. 2009. Portrait of a lengthy vaccination trajectory in burkina faso: From cultural acceptance of vaccines to actual immunization. *BMC International Health and Human Rights* 9 Suppl 1 (Oct 14): S9,698X-9-S1-S9.

Fadnes, L. T., D. Jackson, I. M. Engebretsen, W. Zembe, D. Sanders, H. Sommerfelt, T. Tylleskar, and PROMISE-EBF Study Group. 2011. Vaccination coverage and timeliness in three south african areas: A prospective study. *BMC Public Health* 11 (May 27): 404,2458-11-404.

Federal EPI/CDD Cell. 2003. *Expanded Programme on Immnunizatoin: Financial sustainability plan 2003-2012.* Islamabad: National Institute of Health, Pakistan, .

Galpin, R. 2013. Fighting Pakistan's measles epidemic. *BBC*2013.

Glauber, J. H. 2003. The immunization delivery effectiveness assessment score: A better immunization measure? *Pediatrics* 112 (1 Pt 1) (Jul): e39-45.

Gore, P., S. Madhavan, D. Curry, G. McClung, M. Castiglia, S. A. Rosenbluth, and R. A. Smego. 1999. Predictors of childhood immunization completion in a rural population. *Social Science & Medicine (1982)* 48 (8) (Apr): 1011-27.

Government of Pakistan. Population census organization. 2011 [cited 01/13/2011 2011]. Available from http://www.census.gov.pk/index.htm.

Expanded program on immunization. 01, 20112011]. Available from http://202.83.164.26/wps/portal/Moh/!ut/p/c0/04_SB8K8xLLM9MSSzPy8xBz9CP0os3h_Nx9_SzcPIwP_MAsDA6MQL3NXtxBvIwNzA_2CbEdFAOW90ZM!/?WCM_GLOBAL_CONTEXT=/wps/wcm/connect/MohCL/ministry/home/sahomegeneral/sageneralright/a_expanded+program+on+immunization.

Government of Punjab. 20132013]. Available from http://www.punjab.gov.pk/?q=search/node/population%20density.

Groom, A. V., M. L. Washington, P. J. Smith, and R. T. Bryan. 2008. Underimmunization of american indian and alaska native children. *Pediatrics* 121 (5) (May): 938-44.

Haddad, S., A. Bicaba, M. Feletto, E. Taminy, M. Kabore, B. Ouedraogo, G. Contreras, R. Larocque, and P. Fournier. 2009. System-level determinants of immunization coverage

disparities among health districts in burkina faso: A multiple case study. *BMC International Health and Human Right*s 9 Suppl 1 (Oct 14): S15.

Hayford, K. T., M. S. Shomik, H. M. Al-Emran, W. J. Moss, D. Bishai, and O. S. Levine. 2013. Measles vaccination coverage estimates from surveys, clinic records, and immune markers in oral fluid and blood: A population-based cross-sectional study. *BMC Public Healt*h 13 (1) (Dec 20): 1211,2458-13-1211.

Hull, B. P., and P. B. McIntyre. 2006. Timeliness of childhood immunisation in australia. *Vaccin*e 24 (20) (May 15): 4403-8.

Jamil, K., A. Bhuiya, K. Streatfield, and N. Chakrabarty. 1999. The immunization programme in bangladesh: Impressive gains in coverage, but gaps remain. *Health Policy and Planning* 14 (1) (Mar): 49-58.

John, T. J. 2010. India's national technical advisory group on immunisation. *Vaccin*e 28 Suppl 1 (Apr 19): A88-90.

Khan, Adnan, and Ayesha Khan. 2012. *Validating measures of immunization coverage: Lessons from international experience.* USAID's Small Grants Program: Synthesizing Evidence for Policy and Action: Bridging the Gap between Knowledge and Results to Improve Health Outcomes, .

Lagarde, M., A. Haines, and N. Palmer. 2009. The impact of conditional cash transfers on health outcomes and use of health services in low and middle income countries. *Cochrane Database of Systematic Reviews (Online*) (4) (4) (Oct 7): CD008137.

Lim, S. S., D. B. Stein, A. Charrow, and C. J. Murray. 2008. Tracking progress towards universal childhood immunisation and the impact of global initiatives: A systematic analysis of three-dose diphtheria, tetanus, and pertussis immunisation coverage. *Lancet* 372 (9655) (Dec 13): 2031-46.

Liu, L., M. Li, L. Yang, L. Ju, and B. et al Tan. 2013. Measuring coverage in MNCH: A validation study linking population survey derived coverage to maternal, Newborn, and child health care records in rural china. *PloS One*.

Luman, E. T., L. E. Barker, M. M. McCauley, and C. Drews-Botsch. 2005. Timeliness of childhood immunizations: A state-specific analysis. *American Journal of Public Health* 95 (8) (Aug): 1367-74.

Luman, E. T., L. E. Barker, K. M. Shaw, M. M. McCauley, J. W. Buehler, and L. K. Pickering. 2005. Timeliness of childhood vaccinations in the United States: Days undervaccinated and number of vaccines delayed. *JAMA : The Journal of the American Medical Association* 293 (10) (Mar 9): 1204-11.

Luman, E. T., M. M. McCauley, S. Stokley, S. Y. Chu, and L. K. Pickering. 2002. Timeliness of childhood immunizations. *Pediatrics* 110 (5) (Nov): 935-9.

Luman, E. T., T. K. Ryman, and M. Sablan. 2009. Estimating vaccination coverage: Validity of household-retained vaccination cards and parental recall. *Vaccine* 27 (19) (Apr 28): 2534-9.

Masoud, H. 2011. Health policy: What does it mean in Pakistan? Policy actors' perspective. Masters thesis, Umea University Sweden.

Measure DHS. Data processing. 2013 [cited 05/29 2013]. Available from http://www.measuredhs.com/data/Data-Processing.cfm.

Miles, M., T. K. Ryman, V. Dietz, E. Zell, and E. T. Luman. 2013. Validity of vaccination cards and parental recall to estimate vaccination coverage: A systematic review of the literature. *Vaccin*e 31 (12) (Mar 15): 1560-8.

Minh Thang, N., I. Bhushan, E. Bloom, and S. Bonu. 2007. Child immunization in Vietnam: Situation and barriers to coverage. *Journal of Biosocial Scienc*e 39 (1) (Jan): 41-58.

Mitchell, S., N. Andersson, N. M. Ansari, K. Omer, J. L. Soberanis, and A. Cockcroft. 2009. Equity and vaccine uptake: A cross-sectional study of measles vaccination in lasbela district, Pakistan. *BMC International Health and Human Right*s 9 Suppl 1 (Oct 14): S7.

Mosley, W. H., and L. C. Chen. 2003. An analytical framework for the study of child survival in developing countries. 1984. *Bulletin of the World Health Organizatio*n 81 (2): 140-5.

Murray, C. J., B. Shengelia, N. Gupta, S. Moussavi, A. Tandon, and M. Thieren. 2003. Validity of reported vaccination coverage in 45 countries. *Lance*t 362 (9389) (Sep 27): 1022-7.

Nuri, M., M. Hanif, and M. Khan, eds. 2011. *Eighteenth amendment revisite*d. 1st ed. Islamabad, Pakistan: Islamabad Policy Research Institute (IPRI), Hanns SeidelFoundation (HSF) Islamaba.

Ouédraogo, N., M. Kagoné, A. Sié, H. Becher, and O. Müller. 2013. Timeliness and out-of-sequence vaccination among young children in Burkina Faso- analysis of health and demographic surveillance system (HDSS) data. *International Journal of Tropical Disease & Healt*h 3 (1): 45-56.

Oyo-Ita, A., C. E. Nwachukwu, C. Oringanje, and M. M. Meremikwu. 2011. Interventions for improving coverage of child immunization in low- and middle-income countries. *Cochrane Database of Systematic Reviews (Online*) (7):CD008145. doi (7) (Jul 6): CD008145.

Pakistan Ministry of Information and Broadcasting. 20062013]. Available from http://www.infopak.gov.pk/districtpk.aspx.

Pande, R. P., and A. S. Yazbeck. 2003. What's in a country average? Wealth, gender, and regional inequalities in immunization in India. *Social Science & Medicine (1982*) 57 (11) (Dec): 2075-88.

Pang, T., R. Sadana, S. Hanney, Z. A. Bhutta, A. A. Hyder, and J. Simon. 2003. Knowledge for better health: A conceptual framework and foundation for health research systems. *Bulletin of the World Health Organizatio*n 81 : 815-20.

Phukan, R. K., M. P. Barman, and J. Mahanta. 2009. Factors associated with immunization coverage of children in Assam, India: Over the first year of life. *Journal of Tropical Pediatric*s 55 (4) (Aug): 249-52.

Planning Commission: Government of Pakistan. 2012. *Health, nutrition and population: Annual plan 2012-13.* Islamabad, Pakistan: Planning and Development Sector: Planning Commission, Government of Pakistan, .

Rainey, J. J., M. Watkins, T. K. Ryman, P. Sandhu, A. Bo, and K. Banerjee. 2011. Reasons related to non-vaccination and under-vaccination of children in low and middle income

countries: Findings from a systematic review of the published literature, 1999-2009. *Vaccin*e 29 (46) (Oct 26): 8215-21.

Rosenthal, J., L. Rodewald, M. McCauley, S. Berman, M. Irigoyen, M. Sawyer, H. Yusuf, R. Davis, and G. Kalton. 2004. Immunization coverage levels among 19- to 35-month-old children in 4 diverse, medically underserved areas of the United States. *Pediatric*s 113 (4) (Apr): e296-302.

Ryman, TK, V. Diet, and KL Cairns. 2008. Too little but not too late: Results of a literature review to improve routine immunization programs in developing countries. *Health Services Researc*h 8 (134).

Salmon, D. A., M. J. Sotir, W. K. Pan, J. L. Berg, S. B. Omer, S. Stokley, D. J. Hopfensperger, J. P. Davis, and N. A. Halsey. 2009. Parental vaccine refusal in Wisconsin: A case-control study. *WMJ : Official Publication of the State Medical Society of Wisconsi*n 108 (1) (Feb): 17-23.

Sanou, A., S. Simboro, B. Kouyate, M. Dugas, J. Graham, and G. Bibeau. 2009. Assessment of factors associated with complete immunization coverage in children aged 12-23 months: A cross-sectional study in nouna district, burkina faso. *BMC International Health and Human Right*s 9 Suppl 1 (Oct 14): S10.

Shaikh, S., T. M. Taj, A. Kazi, J. Ahmed, and Z. Fatmi. 2010. Coverage and predictors of vaccination among children of 1-4 years of age in a rural sub-district of Sindh. *Journal of the College of Physicians and Surgeons--Pakistan: JCPS*P 20 (12) (Dec): 806-10.

Shefer, A., P. Briss, L. Rodewald, R. Bernier, R. Strikas, H. Yusuf, S. Ndiaye, S. Wiliams, M. Pappaioanou, and A. R. Hinman. 1999. Improving immunization coverage rates: An evidence-based review of the literature. *Epidemiologic Review*s 21 (1): 96-142.

Sherazi, ZS. 2013. Taliban militants announce "conditional support" for anti-polio drive. *Daw*n, 04/12/13, 2013.

Short Fabic, M., Y. Choi, and S. Bird. 2012. A systematic review of demographic and health surveys: Data availability and utilization for research. *Bulletin of the World Health Organizatio*n 90 (8) (Aug 1): 604-12.

Sia, D., P. Fournier, J. F. Kobiane, and B. K. Sondo. 2009. Rates of coverage and determinants of complete vaccination of children in rural areas of burkina faso (1998-2003). *BMC Public Healt*h 9 (Nov 17): 416.

Sia, D., J. F. Kobiane, B. K. Sondo, and P. Fournier. 2007. Individual and environmental characteristics associated with immunization of children in rural areas in burkina faso: A multi-level analysis. *Sante (Montrouge, France*) 17 (4) (Oct-Dec): 201-6.

Solar, O., and A. Irwin. 2007. *A conceptual framework for action on the social determinants of health.*

Som, S., M. Pal, S. Chakrabarty, and P. Bharati. 2010. Socioeconomic impact on child immunisation in the districts of west bengal, india. *Singapore Medical Journa*l 51 (5) (May): 406-12.

Suarez-Castaneda, E., L. Pezzoli, M. Elas, R. Baltrons, E. O. Crespin-Elias, O. A. Pleitez, M. I. de Campos, and M. C. Danovaro-Holliday. 2013. Routine childhood vaccination programme coverage, el salvador, 2011-in search of timeliness. *Vaccin*e (Dec 4).

Sullivan, M. C., A. Tegegn, F. Tessema, S. Galea, and C. Hadley. 2010. Minding the immunization gap: Family characteristics associated with completion rates in rural ethiopia. *Journal of Community Healt*h 35 (1) (Feb): 53-9.

The World Bank. Pakistan | data. 01, 2011 [cited 01/27 2011]. Available from http://data.worldbank.org/country/pakistan.

Torun, S. D., and N. Bakirci. 2006. Vaccination coverage and reasons for non-vaccination in a district of istanbul. *BMC Public Healt*h 6 (May 5): 125.

United Nations Statistics Division. Indicators on income and economic activity. 12, 2010 [cited 01/27 2011]. Available from http://unstats.un.org/unsd/demographic/products/socind/inc-eco.htm.

Usman, H. R., S. Kristensen, M. H. Rahbar, S. H. Vermund, F. Habib, and E. Chamot. 2010. Determinants of third dose of diphtheria-tetanus-pertussis (DTP) completion among children who received DTP1 at rural immunization centres in pakistan: A cohort study. *Tropical Medicine & International Health : TM & I*H 15 (1) (Jan): 140-7.

Usman, H. R., M. H. Rahbar, S. Kristensen, S. H. Vermund, R. S. Kirby, F. Habib, and E. Chamot. 2010. Randomized controlled trial to improve childhood immunization adherence in rural pakistan: Redesigned immunization card and maternal education. *Tropical Medicine & International Health : TM & I*H (Dec 15).

Valadez J, Joseph, and Leisa Weld H. 1992. Maternal recall error of child vaccination status in a developing nation . *American Journal of Public Healt*h 82 : 120-2.

Van den Broeck, J., S. A. Cunningham, R. Eeckels, and K. Herbst. 2005. Data cleaning: Detecting, diagnosing, and editing data abnormalities. *PLoS Medicin*e 2 (10) (Oct): e267.

Vance Dietz, "Epidemiology of the Unvaccinated Child: Systematic Review of the Peer-Reviewed Literature" 2009) (accessed 2011).

Wakadha, H., S. Chandir, E. V. Were, A. Rubin, D. Obor, O. S. Levine, D. G. Gibson, F. Odhiambo, K. F. Laserson, and D. R. Feikin. 2013. The feasibility of using mobile-phone based SMS reminders and conditional cash transfers to improve timely immunization in rural kenya. *Vaccin*e 31 (6) (Jan 30): 987-93.

Waters, H. R., L. Dougherty, S. P. Tegang, N. Tran, C. S. Wiysonge, K. Long, N. D. Wolfe, and D. S. Burke. 2004. Coverage and costs of childhood immunizations in cameroon. *Bulletin of the World Health Organizatio*n 82 (9) (Sep): 668-75.

WHO Department of Immunization, Vaccines and Biologicals. 2010. *Global immunization data.* , http://www.who.int/immunization_monitoring/Global_Immunization_Data.pdf.

WHO Department of Immunization, Vaccines and Biologicals, UNICEF Programme Division, Health Section. 2005. *Global immunization vision and strategy 2006 - 2015.* , http://www.who.int/vaccines-documents/DocsPDF05/GIVS_Final_EN.pdf.

WHO EMRO. Expanded program on immunization: Pakistan. 2013 [cited 05/29 2013]. Available from http://www.emro.who.int/pak/programmes/expanded-programme-on-immunization.html.

WHO Immunization Service Delivery. Expanded program on immunization. 2013 [cited 06/04 2013]. Available from http://www.who.int/immunization_delivery/en/.

Williams, I. T., J. D. Milton, J. B. Farrell, and N. M. Graham. 1995. Interaction of socioeconomic status and provider practices as predictors of immunization coverage in virginia children. *Pediatric*s 96 (3 Pt 1) (Sep): 439-46.

Wiysonge, Charles S., Olalekan A. Uthman, Peter M. Ndumbe, and Gregory D. Hussey. 2012. Individual and contextual factors associated with low childhood immunization coverage in sub-saharan africa: A multilevel analysis. *PloS On*e 7 (5): e37905.

World Health Organization. Immunization profile - Pakistan. December, 2010 [cited 01/26 2011]. Available from http://apps.who.int/immunization_monitoring/en/globalsummary/countryprofileresult.cfm?C='pak'.

ADDITIONAL TABLES

Table 36 Adjusted odds ratios for individual and contextual characteristics of population with the receipt of third dose of DTP vaccine having received first dose of DTP vaccine in children aged 12 to 23months old using logistic regression analysis, Pakistan Demographic and Health Survey 2006 (Full model)

Predictors	Odds Ratio	p-value	95% Confidence Interval	
Province of residence				
Punjab	REF.			
Sindh	0.72	0.19	0.44	1.18
Khyber Pakhtunkhwa	1.03	0.92	0.56	1.92
Balochistan	1.16	0.72	0.51	2.64
Area of residence				
Urban	REF.			
Rural	1.05	0.85	0.61	1.81
Wealth Index				
Poorest and Poorer	REF.			
Middle, richer, richest	1.42	0.23	0.80	2.52
Household Head				
Male	REF.			
Female	1.08	0.83	0.53	2.22
Mother's Education				
No Education/primary				
_Secondary	2.42	0.01	1.30	4.50
Higher	3.26	0.00	1.76	6.02
Mother's Mean age	1.04	0.04	1.00	1.07
Sex of child				
Male	REF			
Female	0.85	0.43	0.56	1.28
Child's Immunization card				
No Card	REF.			
Yes, seen	9.13	0.00	4.01	####
Yes, not seen	3.35	0.00	1.67	6.70
No longer have card	2.81	0.02	1.19	6.67

Table 37 Adjusted odds ratios for individual and contextual characteristics of population with the receipt of third dose of DTP vaccine having received first dose of DTP vaccine in children aged 12 to 23months old using logistic regression analysis, Pakistan Demographic and Health Survey 2006 (reduced model)

Predictors	Odds Ratio	p-value	95% Confidence Interval	
Province of residence				
Punjab	REF			
Sindh	0.71	0.15	0.44	1.14
Khyber Pakhtunkhwa	1.05	0.89	0.57	1.93
Balochistan	1.16	0.71	0.52	2.59
Wealth Index				
Poorest and Poorer	REF			
Middle, richer, richest	1.40	0.21	0.83	2.37
Mother's Education				
No Education/primary	REF			
Secondary	2.40	0.01	1.29	4.44
Higher	3.26	0.00	1.77	6.01
Mother's Age				
Mean age	1.04	0.04	1.00	1.07
Child's Immunization card				
No Card	REF			
Yes, seen	8.99	0.00	3.86	9.88
Yes, not seen	3.30	0.00	1.63	6.67
No longer have card	2.79	0.02	1.18	6.59

Table 38: Adjusted association of individual and contextual level factors with possession of a vaccination (health) card as a record of vaccination history in children in Pakistan Demographic Health Survey, 2006-07

	Odds ratio	t	p-value	95% Confidence limits
Immunization card				
No Card	REF			
Yes card seen	26.2	4.56	0.000	6.3 – 108.2
Yes not seen	15.8	3.82	0.000	3.8 – 66.1
No longer has card	9.3	2.85	0.005	2.0 – 43.9

Appendix 1: Urbanicity scale components and variables with their corresponding scores

Scale Components	Urbanicity Variables	Score
Population size		
	1 – 500	1
	501 – 1000	2
	1001 – 2000	3
	2001 – 4000	4
	4001 – 6000	5
	6001 – 8000	6
	8001 – 10000	7
	10001 – 15000	8
	15001 – 20000	9
	≥ 20000	10
	Maximum possible score	10
Population density (person per km^2)		
	1 – 500	1
	501 – 1000	2
	1001 – 2500	3
	2501 – 5000	4
	5001 – 7500	5
	7501 – 10000	6
	10001 – 15000	7
	15001 – 30000	8
	30001 – 50000	9
	≥ 50000	10
	Total maximum score	10
Communications	Cable television coverage	1
	Television service	1
	Any landline telephone service	3
	Mobile telephone coverage	1
	Public call office (PCO)	1
	Post office	2
	Total possible score	9
Transportation	Motorized public transport	2
	Non-motorized public transport	1
	Total possible score	3
Education Facilities	Primary school for boys	2

	Primary school for girls	2
	Secondary school for boys	2
	Secondary school for girls	2
	Total possible score	8
Health Services		
	Functioning basic health unit (BHU)	1
	Rural health center (RHC)	2
	Government dispensary	1
	Functioning maternal and child health (MCH) center	1
	Private doctor	2
	Dispenser or compounder	
	Family welfare center/source of family planning	1
	Hospital	3
	Total possible score	11
Markets	General store or shop	2
	Medical store	1
	Bank	5
	Total possible score	8

Curriculum Vitae

NOOR SABAH RAKHSHANI

Johns Hopkins University
Bloomberg School of Public Health
Department of Health Policy and Management
615 N. Wolfe Street
Baltimore, MD 21205, USA

3163 Pine Orchard Ln, Apt. 201
Ellicott City, MD 21042, USA
Cell: +1 443 248 2921
E-mail: nrakshan@jhsph.edu
noor.rakshani@gmail.com

EDUCATION

- DrPh — November 2013
  Health Care Management and Leadership
  Johns Hopkins University
- Masters in Public Health — May 2008
  Johns Hopkins University, USA
- MBBS — December 1998
  Graduate, Medicine and Surgery
  Balochistan University, Pakistan

WORK EXPERIENCE

- Community Medicine Resident — December 2004 – September 2006
  Aga Khan University, Pakistan
- HIV/AIDS and STI Prevention Officer — October – November 2004
  Central Female Prison, Karachi
- Medical Officer (In-Charge) Health Center — December 2001—January 2003
  Taraqee Trust, Quetta – Pakistan
- Medical Officer — April 2001 – November 2001
  Quetta Hospital, Pakistan
- Medical Officer — March 1999 – March 2000
  Sandemen Provincial Hospital, Pakistan

RESEARCH GRANTS

Principal Investigator

- Project title: Time-dependent color changing vaccine reminder ankle bands
  Grantee: Gates Foundation Grand Challenge Exploration Round 9, Phase I grant
  Project duration: November 2012-July 2014
  Grant amount: **USD 100,000**
- Project title: Empowering Clients and Sensitizing Providers to Increase Uptake of Maternal and Neonatal Health Care Services: Design of a Social Accountability Model for Implementation in Balochistan, Pakistan
  Grantee: Research and Advocacy Fund Pakistan
  Project duration: June 2012- August 2013
  Grant amount: **GBP 271,290.40**

RESEARCH EXPERINENCE

- World Bank Institute
  Concept note, Unnecessary Elective Surgeries and the Movement towards Universal Health Coverage in Middle Income Countries
- Designed Monitoring and Evaluation of Water and Sanitation Program and Survey Analysis for Save the Children (UK) DPR Korea.
- Survey of health care system to assess preparedness for HIV/AIDS in Karachi, Pakistan 2006.

OTHER EXPERIENCE

- Consultant: World Bank Institute, Washington DC, USA, September 2011-June 2012
- Health Consultant: Save the Children (UK), DPR Korea, January 2007—April 2007.
- Health Officer: Short Term Contract, UNDP, DPR Korea, November 2006 —December 2006.

RESERCH PAPERS

- Factors associated with Up to Date (UTD) Immunization among children in Pakistan. Paper accepted for poster presentation at The 8th Conference on Global Health and Vaccination Research, Bergen Norway
- Contextual and individual determinants of DPT3 vaccination completion among children 12-23 months in Pakistan. Paper accepted for poster presentation at Academy Health 2012 Annual Research Meeting, Orlando, FL, USA.
- Factors associated with immunization initiation among children in Pakistan. Paper accepted for poster presentation at Academy Health 2012 Annual Research Meeting, Orlando, FL, USA
- A review of social accountability model use in health: the implications for Pakistan *(manuscript in preparation)*
- Assessment of utilization and domains of quality in health care in Balochistan: analysis of Demographic health survey Pakistan *(manuscript in preparation)*
- Elective Surgeries in the Movement towards Universal Health Coverage - a Case Study of the Cesarean Delivery *(manuscript submitted for publication)*
- MPH Capstone
  Evaluation of Pakistan health care system preparedness to address the future challenges
- DrPH Thesis
  Immunization coverage in Pakistan: A comparative analysis of Pakistan demographic health surveys (2006 and 1990) and policy recommendations for future

FELLOWSHIPS AND AWARDS

- Policy Communication Fellow, Population Reference Bureau, Washington D.C, USA, 2011.
- Higher Education Commission, Pakistan/ Fulbright Scholarship, 2008—present.
- Fulbright Scholar 2007—08.

RESEARCH AND TEACHING INTERESTS

- Research: Strengthening supply and creating demand in health, health equity and leadership.
- Teaching: Evidence based decision making by health policy makers.

- Frequent contributor to the Population Reference Bureau (PRB) Washington D.C., USA Researcher's Blog

TEACHING

- Courses supported as teaching assistant at JHU
- *Quality in Medical Care, 1st terms 2010 and 2011.*
- Courses supported as teaching assistant at AKU
- *Epidemiology, WHO Primary Health Care Modules, First and second year medical students.*

MISCELLANEOUS INFORMATION

- Programing Proficiency: Stata and TreeAge, MS Office
- Languages: Urdu, Farsi (Native) English (Fluent)
- Citizenship: Pakistan

REFERENCES

- Professor Laura Morlock (Academic Advisor)
  Department of Health Policy and Management,
  Johns Hopkins University
  Email: lmorlock@jhsph.edu
  Phone: 410-955-5315

- Professor Orin Levine
  Director Vaccine Delivery, Gates Foundation, Seattle, WA
  Email: Orin.Levine@gatesfoundation.org
  Phone: 206-709-3112

- Associate Professor Saifuddin Ahmed
  Department of Population, Family and Reproductive Health,
  Johns Hopkins University
  Email: sahmed@jhsph.edu
  Phone 410-614-4952